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Eftihia G. Nathanail
Ioannis D. Karakikes *Editors*

Data Analytics: Paving the Way to Sustainable Urban Mobility

Proceedings of 4th Conference on Sustainable Urban Mobility (CSUM2018), 24–25 May, Skiathos Island, Greece

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Editors

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Preface

This issue contains papers presented at the 4th Conference on Sustainable Urban Mobility (CSUM2018), which was held on May 24–25, 2018, in Skiathos Island, Greece. The conference focused on **Data Analytics: Paving the Way to Sustainable Urban Mobility**, as a sequence on the themes of the previous three events on green modes of transport, the impact of ITS in transit services and behavior, and the anthropocentric approach in urban mobility planning. The increasing and demanding needs for transport services, alleviating at the same time the consequences on the sustainability of the urban agglomeration and environment, place the emerging technologies as the top priority of the involved stakeholders. In the era of big data and digitization, the interest is set to meet the challenge of providing high-level mobility services by exploring the new capabilities opened to the domain. Data mining, data analytics, and machine learning techniques are in play. GPS and smart personal appliances, point detectors, and social media are indicative sources providing ample information, which when handled properly are transformed to vital knowledge for better planning and achieving sustainable mobility.

The above topics and many more were the content of CSUM2018. Delegates from 28 countries shared their interests, findings, and experience. Following at least a three-round open review process, 103 papers of 268 authors were selected out of the 168 submitted and were presented at the conference, with the addition of three keynotes and two stakeholders' presentations.

The geospatial perspective of big data is discussed in some researchers' work, which focuses on social networking and the usage of crowdsourcing in affecting mobility planning and travelers' behavior. Urban space plays an important role in the livable city and its preservation is associated with eco-friendly travel activities and transportation infrastructure design, and some conference papers demonstrate that. Controlling CO2 emissions is the main concern of policymakers, who promote and favor mobility as a service and collaborative and cooperative transportation systems. Relevant topics are covered by researchers, in various applications. Incident detection, demand and traffic management, trip planning, shared infrastructure, shared, connected and autonomous vehicles constitute some of the areas of research involving big data, depicted in another group of papers. Their applicability raises cybersecurity issues, and the associated legal aspects, which are still under investigation, are addressed.

We believe that this book will provide the reader with an up-to-date review of the most representative research on data management techniques for enabling sustainable urban mobility. We also hope that the presented work will trigger a dialog for more efficient and effective ways of exploiting emerging technologies and facilitate the development and operation of collaborative schemes, which are considered crucial for achieving sustainable mobility. Special thanks to the presenters, authors, and reviewers who contributed to the high quality of the contents, and we wish you a pleasant reading.

July 2018

Eftihia G. Nathanail
Ioannis D. Karakikes
Guest Editors

The original version of the book was revised: For detailed information please see Correction. The correction to the book is available at https://doi.org/10.1007/978-3-030-02305-8_104

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Contents

Data-Driven Infrastructure Management

Have Information Technologies Forgotten Pedestrians? To What Extent Can It/Its Improve Pedestrian's Mobility and Safety

Hector Monterde-i-Bort[1], Socrates Basbas[2(✉)], Charlotta Johansson[3], Lars Leden[3,4], and Per Gårder[5]

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Abstract. Worldwide, pedestrians make up close to half of all motor-vehicle related fatalities but disproportionally little of the research in Information Technologies (IT) in general and Intelligent Transportation Systems (ITS) in particular has aimed at pedestrian safety improvements. This paper analyses and compiles three different ways so that IT and ITS can be used in order to improve mobility and safety of pedestrians in urban spaces: (a) for contacting and/or being localized, (b) for guidance (leading/navigating), (c) for alerting or informing of a danger.

The aim is to categorize recent experiences where ITS can improve pedestrians' mobility and safety so that new ideas based on ITS will be developed. These new ideas will better meet pedestrians' functional quality needs today as well as in the future in a society with an aging population and aging infrastructure. This is very important for a society where people will not accept high fatality risks. The most important developments are described with links to websites in which one can gather more information.

Target groups of this paper are professionals working in the field of traffic planning; practitioners, planners and researchers.

Keywords: Information technologies · Intelligent Transportation Systems Pedestrians · Traffic safety · eSafety

1 Introduction

The consequences of inadequate traffic planning regarding pedestrians' needs leads to an unfriendly "walking environment" and people often feel unsafe when walking; and frequently they are unsafe as well. This can go as far as creating a real fear of walking and may result into excluding some vulnerable road users from important social

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activities. The reduction in walking has economic implications for both the society (i.e. less shopping) and specific individuals. In order to improve the situation of the walking environment, to help current pedestrians and attract new ones, the walking environment should be improved. These improvements should be done with respect to real safety as well as the feeling on safety, security, aesthetics, traffic noise, emissions, severance (barrier) effects and infrastructure which is provided for the facilitation of pedestrian trips.

Worldwide, pedestrians account for roughly half of all motor-vehicle related fatalities. Although this percentage is lower in developed countries, there is still need to accommodate pedestrians in a safe way. Responsible authorities should provide sufficiently wide areas for pedestrian movements, segregated paths and safe environment of paths; besides, they should "design and maintain paths to a high enough standard to attract the vulnerable road users away from the smooth road surface open to motor-vehicle traffic, ideally by providing a sealed surface". Finally, they should provide signs and information systems for the safest and most accessible walking trips [1]. In addition, a series of measures should be taken into account in order to improve pedestrians' safety and accessibility and change their daily habits and movements [2]. Therefore, the quality of mobility and safety of pedestrians, whether they walk for pleasure or to access services and facilities – for example, to use public transport, or walk to and from a parking lot - must be a major focus of any road safety strategy or policy.

In this context the information technologies play a key role. Disproportionally little of Intelligent Transportation Systems (ITS) research has been dedicated towards pedestrian safety so far. Information technology (IT) was defined by the Information Technology Association of America (ITAA) as: "the study, design, development, implementation, support or management of computer-based information systems, particularly software applications and computer hard-ware." IT deals with the use of electronic computers and computer software to convert, store, protect, process, transmit, and securely retrieve information.

The consideration of IT in the transportation sector originates in the development of what is called "Intelligent Transportation Systems" (ITS); it is an expression that refers to the application of information and communication technologies to the transport infrastructure, vehicles and drivers, in order to improve their efficiency and safety. Especially in the context of this paper, ITS are considered in relation to pedestrians' quality needs. ITS applications can play an important role towards satisfying pedestrian and drivers' quality needs. Intelligent signal-controlled crossings for pedestrians should automatically detect pedestrians, as well as prioritizing and adapting green phases. Especially child pedestrians need such features. Probably, ITS connected to motor vehicles is the most efficient measure to secure a safe and flexible movement for pedestrians. This includes controlling speeds whenever pedestrians are nearby; see e.g. [3]. However, if a pedestrian or bicyclist is hit by a truck or bus, the fatality risk is high at any vehicle speed. Therefore, ITS measures like Advanced Driver Assistance Systems (ADAS), are needed in order to provide a safe environment to the pedestrians. Pedestrian detection method based on machine vision was developed by combining AdaBoost algorithm and the support vector machine [4]. A vision based pedestrian detection approach is presented in another study which was carried out by Gaikwada and Lokhande [5]. ITS systems should also give priority to the needs of the elderly people because of the difficulties these citizens face in the road environment [6]. A selection of ITS measures aiming at the improvement of safety level for the pedestrians is presented in a study concerning signalized intersections in Greater Beirut Area [7]. In addition, the creation of cooperative ITS will enhance safety for all the users of the road transport system with emphasis on pedestrians and cyclists [8].

This paper is based on a literature review. The most important developments are described with links to their websites in which one can gather more information. The originally studied ITS systems are related to the following eleven functional pedestrians' needs (and in some cases the vehicle drivers' need to interact with pedestrians). It must be mentioned at this point that the paper focuses on the first three functional needs:

1. For getting contact with and/or being localized
2. For guidance (leading or navigating)
3. For alerting or informing of a danger
4. For adapting the environment to pedestrian conditions
5. For promoting confidence and/or security (avoiding victimization)
6. For counting and controlling flows
7. For simulating (flows, accidents, evaluating consequences etc.)
8. For compensating people with special needs and/or handicaps
9. For redesigning (vehicles, urban spaces, street furniture, etc.) to reduce the injuries from an accident
10. For checking and measuring the efficacy of developed solutions
11. For encouraging leaving home and walking

2 Overview

2.1 For Getting Contact with and/or Being Localized

This section refers to the developments which allow pedestrians to establish contact with their families and friends wherever they are. It also includes developments which enable the respective authorities to locate vulnerable road users, such as elderly people with dementia. These developments include the category "emergency call systems", type "eCall system" [9], or refer to the use of an ordinary mobile phone [10] in combination with special numbers pre-set and, in some cases, associated to specific key numbers (like emergency numbers and "call centers"), or special radiophones which people with special needs or elderly can carry (e.g.: hanging from a necklace). Other projects such as the LOCOMOTION project would also fit here to provide wireless care for elderly and disabled people. Thanks to the combined use of GPS and standard mobile phones, this system allows contact between the elderly or disabled with their caretakers. At the same time, caretakers can locate the users of this service at any moment.

In addition, new advantages of recent appliances are being discovered. For example, within the frame of project SIZE, "Life quality of senior citizens in relation to mobility conditions" (EU's Fifth Framework Programme, 2003–2006), the importance of the ordinary mobile phone was shown to be a promoting factor in the mobility of older people [11, 12].

This importance of the ordinary mobile phone, as a factor which favors mobility, was studied in greater depth in a research which utilized the data collected in the project SIZE [13]; the statistical analysis revealed that carrying a mobile phone was a determining factor for elderly people to decide to leave their house for a walk around. The importance of this new telematics device lies in the fact that it gives them a feeling of autonomy and security because they can contact their families, health centers or help services. Security and anxiety in relation to their decision to walk has already been highlighted in various studies [14].

It must be mentioned at this point that there are studies which analyze the "new functions" of mobile phone and go beyond the simple idea that these devices are "something you can easily carry with you". The above mentioned conclusions are applicable to the general population and not necessarily only to the elderly people [15, 16]. Consequently, the "ordinary" mobile telephone has to be included within the group of telematics devices used to ensure safe walking.

2.2 For Guidance (Leading or Navigating)

This section includes the denominated systems of navigation developed specifically for walking. Taking into account this function, we can distinguish two main groups of devices: those based on GPS and those based on other technologies. The latter are normally used to complement the first in order to improve their accuracy.

(a) Within the first group (GPS-based systems) we can find systems like:

- The "Easy Walk", developed by Vodafone. It is an innovative system of navigation based on the GPS system and in Symbian mobile phone technology. It offers blind or visually impaired people information of their actual position (localization), and also offers them access to assistance and useful information in order to move in an extremely easy and independent way. The use of this technology can also be extended to non-handicapped people.
- The Telmap Navigator. This instrument combines the GPS and the mobile phone. Through the use of a specific software it is supposedly capable of guiding the pedestrian to use the best route possible using pedestrian footpaths with detailed maps. These maps show places including private businesses and also labels and references in streets. Telmap Navigator provides maps with zoom. Once in the desired zone, one can easily find the places and businesses on the map, and detailed information like the address and phone number – one can even call directly from the Telmap Navigator.
- The Nokia mobile phones with navigation service. Nokia has been pioneering personal navigation mobile phones, by including three basic functions in some phone models: navigation, position and travel distance; with options specially for walking.
- The Mobile Navigator 7, a software developed by NAVIGON for PDA's and mobile phones working under Symbian operative system. This version

incorporates the specific needs of pedestrians. It includes a compass that indicates the direction to your destination, plus your exact distance from it. In addition, the software will actively prioritize the use of small alleyways, narrow paths and pedestrian-only routes as long as they provide adequate security which can be programmed into the device.

– Tele-Atlas pedestrian maps. This company specializes in developing maps for GPS devices, and has developed versions of maps specific for pedestrians. Tele Atlas combines its traditional Multinet cartographic database with a series of special attributes for citizens “afoot”, which eases the outline of specific routes and provides data which will enable pedestrians to orient themselves in unknown areas. Moreover, these maps identify the place in which a pedestrian is situated at any moment. The new digital cartography that contains detailed information about tunnels, foot-bridges or pedestrian paths, will provide security and comfort to citizens walking around, improving walking in the various streets and facilitating the traveler to take the shortest path to his/her hotel or to the closest metro station. Likewise, this database is valid for users of portable navigation devices and mobile phones and offers pedestrians with valuable information on a range of points of interest such as the location of restaurants, businesses, or ATMs, avoiding unnecessary paths and giving them the opportunity to save time while trying to reach their destination.

(b) Within the second group (non-GPS based systems) we can distinguish two subtypes: systems based on the use of radio-beacons, and systems based on algorithms which estimate the movement of a person by using data supplied from their own movement.

It must also be mentioned that there are some resources which are not physical devices, but are resources for guidance which either belong to the ITS field or can improve the existing ITS devices or even be a component of them. We select two as representative examples: the service “get directions: to there from here”, with “by walking” option, offered by Google-Maps through Internet, and the attempts for developing urban routes based on “Landmarks” (Landmarks-based Pedestrian Navigation Systems) [17].

2.3 For Alerting or Informing of a Danger

The systems presented in this section refer to systems that can either warn drivers about the pedestrians’ presence or warn pedestrians about approaching vehicles or both.

The developments in this field are principally directed towards avoiding automobile-pedestrian and automobile-cyclist collisions (accidents).

Concerning the devices used both to detect as to alert, we can mention the following: microwave, ultrasonic and infrared detectors (to detect presence), count-down signals (to inform pedestrians about time remaining) [18], in-pavement lights (to alert drivers in pedestrian crossings), illuminated pushbuttons (immediate feedback to pedestrians about ordering reception), animated eyes display (to alert pedestrians to look for their direction), signal-mounted speakers, and the group of subsystems under the expression “Accessible Pedestrian Signals” (APS), which include several systems to provide “walk/don’t walk” information [19] using one or any combination of the following ways: tones, speech messages, vibrating surfaces and/or messages to receiver hardware (pedestrian-head-mounted, pushbutton-integrated, vibrotactile-only and receiver-based). In addition, there are gadgets mounted in the same vehicle, as the fisheye cameras, to detect and inform the driver about the close presence of pedestrians, specially proved to be useful, e.g., in parking areas of commercial centers, where customers should walk among the cars.

An inventory of most of these solutions and their application tests is PedSmart [20–22], a website (www.walkinginfo.org/pedsmart) developed by the University of North Carolina Highway Safety Research Center for the USA Federal Highway Administration, with the objective of describing the technologies in use and providing links to manufacturers and other resources.

The main research lines in this field are “Automatic pedestrian detection at Intersections”, “Variable (or Changeable or Dynamic) Message Signs (VMS/CMS/DMS)”, and methods for identifying human figures in target settings (pedestrian detection) under different and variable stimulus conditions (sunny/shadowy, day/night etc.).

3 Conclusions

The consequences of inadequate traffic planning regarding pedestrians’ needs leads to an unfriendly “walking environment” where people often feel unsafe when walking. This can result into preventing some vulnerable road users from doing some important activities. In order to help current pedestrians move easily and safely the walking environment should be improved.

Several Intelligent Technologies (IT) which improve the quality of pedestrian trips have been discussed above. These technologies hopefully assist various ministries (e.g., ministry of environment, physical planning and public works, ministry of transport and communications, ministry of public health and social welfare and ministry of public order) to better promote non-motorized travel and to offer an acceptable level of convenience, efficiency, comfort, safety and security to pedestrians.

Finally, another most important conclusion is that the research and development of IT/ITS, specifically designed for pedestrians, should be promoted. New devices and applications should also be developed so as the mobility and safety level of pedestrians will be improved.

The requirements of ITS operation are:

1. Involvement of the public into the decision process - Public acceptance
2. Adequate funding
3. Availability of technology & infrastructure
4. Know-how & past experience (if any)
5. Support from legislation

The final objective is an improvement of the walking environment by means of ITS in order to increase the possibility for pedestrians to walk in a safe and secure manner.

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Trip Generation Rates for a University Campus: The Case of the Aristotle University of Thessaloniki, Greece

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Abstract. Trip generation rates provide essential information in the transport planning process and especially in the land-use transport interaction models. Among the general population, university students form a specific group of people which is characterized by increased mobility rates. In the framework of this paper, the results from a survey concerning the trip generation rates of the students of the Aristotle University of Thessaloniki (AUTh), Greece are presented and discussed. The main university campus which is located in the city center, covers an area of around 430000 m^2 and serves thousands of students on a daily basis. AUTh is actually the largest university in the country. A face-to-face questionnaire-based survey took place during spring 2015 and a number of 595 questionnaires from the students of AUTh was collected. A sample of 1% of the population of students from each one of the nine (9) Faculties of AUTh, which were examined in the research, was collected during the questionnaire-based survey. A total number of nine (9) questions were included in the questionnaires, aiming at the determination of the trip generation rates in the University campus. Linear regression analysis was used in order to construct a trip generation model. This model shows that trip generation rate almost equals to two daily trips per student. Four (4) models with dummy predictors were also constructed, using linear regression analysis, to describe the percentage distribution of the sampled population that made the trips throughout the day. Furthermore, data concerning the mobility characteristics of the university students are also presented in the framework of the paper. The results are expected to add some knowledge to the scientists involved in the design and implementation of a sustainable transport plan in the wider area of a University campus.

Keywords: Trip generation rates · Travel behavior
University students' mobility · University campus travel plans

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1 Introduction

Land-uses generate different kinds of activities in an area, such as work, entertainment, shopping, education etc. These activities attract and produce trips, forming the travel demand to and from those land-uses, and at a second stage this affects the transportation infrastructure. Trip generation models are often used to forecast future travel demand given population characteristics such as income, car ownership etc., contributing, in this way, to the land use - transport interaction [1, 2].

Trip generation models are constructed in the first stage of the traditional four-step transport prediction process. Trip generation rates indicate the number of trips made by a household or an individual daily in the models, based on a characteristic, designating the demand a land use generates [3]. A study resulted in trip generation rates, in the city center banks of the Thessaloniki Greater Area, equal to almost 2 daily trips per employee in respect to the number of the banks' employees and 0.09 daily trips per employee in respect to the floor space of the banks [3]. Another study, in which multiple liner regression analysis was used and considering the spatial autocorrelation between the values of the response variables, resulted to 4.529 home-based daily trips generated and attracted in Santander's, Spain zones in respect to their residential density [4]. In a recent study, trip generation and attraction models were constructed for two traffic segments, settlements towards Budapest and the reversal, for different trip purposes. The study, referring to home-work trips, resulted in 0.205 daily trips generated in the settlements closer than 30 km to Budapest in respect to their population and 572.649 daily trips attracted by Budapest with respect to the number of enterprises with more than 500 employees [5].

Concerning education, a study resulted in a trip generation rate, of the main AUTh campus, equal to almost 2 daily trips in respect to its number of students, administration and academic staff [6]. This paper's main objective is the estimation of the trip generation rate of the nine (9) Faculties' student populations facilitated in the main AUTh campus by examining the relationship between each Faculty's student population and the trips it made, through the trip generation model, using simple linear regression analysis also by exploring the method's assumptions. Complementary, in the paper, four (4) percentage distribution models of the trips made throughout the day are constructed. Both methodologies of linear regression analysis serve the same overall objective, which is the development of the trip generation model. Finally, the mode split and some trip characteristics of the students are described as well. The exploitation of the results can add some knowledge in larger scale transport planning projects such as a Sustainable Urban Mobility Plan for a University.

2 Data Collection and Sampling

The data of this research were collected through a face-to-face questionnaire-based survey, taken place in AUTh main campus' facilities during May 2015. A total number of 595 questionnaires were distributed, addressing only to the student population of the nine (9) Faculties of which the courses were taking place in the campus (from now and on "Faculties"). The 595 questionnaires comprise a sample of 1% of around 60000 students, stated from an AUTh Informatics School's report published in 2012 [7].

The questionnaire included nine (9) questions.

A stratified random sample was taken in each one of the nine (9) Faculties' (strata) student populations. Every student in the sampling population had the same inclusion probability since the sample of the total student population was taken as a proportion and not as an absolute value. Before the survey was conducted, each of the nine (9) samples had been checked if it was representative to the respective student population, by accepting a margin of error (e) at the scale of 0.3 daily trips per student and a 90% confidence interval (1- a). The nine (9) samples were determined representative by using Formula 1 for each sample [8].

$$n_0 = \left(\frac{z_{a/2} * S}{e}\right)^2 \tag{1}$$

n_0 = the smallest possible sample size determined as representative
S = standard deviation of each School's sample
e = margin of error
$z_{a/2}$ = the value of the normally distributed transformed variable X, $z = (\frac{\bar{X}-\mu}{\sigma})$

3 Construction of the Trip Generation Model

Simple linear regression analysis, used for the construction of the trip generation model, explores the impact of one independent variable X (or predictor) on a dependent (or response) variable Y expressed by the values of the partial regression coefficients a and b, according to Formula 2 [9]. In this case, X stands as the size of each of the nine (9) Faculties sampled population and Y stands as the total trips made by each one of them.

$$Y = a + b * X \tag{2}$$

The implementation of simple linear regression requires a set of assumptions to be made for the approval of the results' validity and reliability. These assumptions include: (1) the independence of the observations' disturbance factors (or residuals), (2) the disturbance factor of each observation to be normally distributed with mean 0, (3) constant variance of the dependent variable (Homoscedasticity), (4) the relationship to be assumed linear [9]. For the construction of the trip generation model, the homoscedasticity was examined applying the statistical Levene test and the normality of the disturbance factors considering the skewness and kurtosis indicators of each one of the nine (9) samples' distributions. The first and last assumptions were presumed to hold.

After the model was constructed, its validity and quality were checked which are declared with a series of indicators.

Firstly, the normality of the residuals for each of the nine (9) sampled populations was tested. As shown in Table 1, the residuals for all samples are normally distributed with mean close to 0 considering the skewness and kurtosis indicators, which rigorously imply normality for values −1 to 1 [10, 11].

Table 1. Results on normality of residuals for the trip generation model.

Faculty	Residuals			
	Mean	Std. error of mean	Skewness	Kurtosis
Faculty of Philosophy	−0.1098	0.10647	0.042	0.013
Faculty of Theology	−0.1422	0.14611	−0.003	0.416
Faculty of Economic & Political Sciences	−0.0864	0.16338	−0.045	−0.237
Faculty of Law	0.2150	0.15712	0.052	−0.236
Faculty of Agriculture, Forestry and Natural Environment	−0.3176	0.17669	−0.023	0.750
Faculty of Sciences	0.1712	0.11673	−0.02	−0.231
Faculty of Education	0.1674	0.2071	−0.192	−0.484
Faculty of Health Sciences	−0.0507	0.13171	0.258	1.082
Faculty of Engineering	0.0647	0.12211	−0.029	−0.182

Next, the homogeneity of the nine (9) samples' variances was tested applying the Levene test for a 5% level of significance. The Levene test resulted in $p = 0.124 > 0.05$ suggesting that the null hypothesis of equal variances is not rejected, thus the values of Y, correspondingly the respective values of residuals, have a constant variance along the line regression.

After the assumptions were checked and the derivation of non-significance of the constant in the model, the trip generation model in Formula 3 was constructed

$$Y = 2.265 * X \tag{3}$$

X: the size of each Faculty's sampled population
Y: the total trips made by each Faculty's sampled population
$\mathbf{R^2} = 0.996$, $\mathbf{R} = 0.998$

The trip generation rate equals to 2.265 trips (departure and arrival) per student per day and a standard error at the scale of 0.048. Furthermore, the standard error of estimate **s** equals to 10.324 implying there is not a big difference between the observed values and the respective ones produced by the model. Lastly, t-statistic equals to 46.745, which is greater than 2.365 (value of t-statistic for a 5% significance in t-student distribution), implying the relationship between the trips made and the size of the sampled population cannot be random.

4 The Percentage Distribution Models of the Sampled Population Throughout the Day

The percentage distribution models describe the percentages of the sampled population that made a trip, arrival or departure in main AUTh campus, at a specific time-period in the morning or afternoon using dummy variables as predictors. For clarification, the percentage refers to the student population who either made a trip or not. Four (4) models were constructed; the morning-arrival, the morning-departure, the afternoon-arrival and the afternoon-departure model exploring only the normality of the residuals accepting a wider interval (−3, 3) for the skewness and kurtosis indicators. Except for the normality exploration, the other assumptions were not examined and were presumed to hold.

Dummy variables are dichotomous and take the values of 0 and 1 as a numeric stand-in for a qualitative fact or a logical proposition [12]. When a qualitative predictor has many levels, for example the time-period a student arrived at AUTh campus, then the dummy variables formed are as many as the levels of the time-period minus the levels which are not significantly different. The latter levels form the reference category, which is the constant in the model [12].

4.1 Morning-Arrival Model

The morning-arrival model (Formula 4) estimates the percentage of the sampled population that arrived in AUTh campus at seven possible time-periods in the morning. The possible time-periods are 8-9, 9-10, 10-11, 11-12 a.m. and 12-1, 1-2, 2-3 p.m. and each one is represented in the model by a dummy variable. Dummy0, dummy1, dummy2, and dummy3 illustrate 8-9, 9-10, 10-11, and 11-12 a.m. respectively.

$$Y = 4.434 + 11.410 * dummy0 + 16.793 * dummy1 + 16.546 * dummy2 + 9.279 * dummy3 \tag{4}$$

Y = the percentage of the sampled population that arrived in AUTh campus in a possible time-period in the morning

Since there are no dummies for 12-1, 1-2, 2-3 periods, it means that these time-periods showed no significant difference between them. The constant 4.434 mirrors the mean percentage of the mean percentages produced for 12-1, 1-2, 2-3 p.m. For the estimation of the percentage of the sampled population arrived at 8-9 a.m., dummy0 equals to 1 and all other dummies equal to zero 0 making the output percentage equal to 15.844, which is almost the mean percentage at 8-9 a.m. The same holds for the other time-periods. The highest rates of arrivals, around 20%, were made at 9-10 or 10-11 a.m. $\mathbf{R^2}$ and **R** equal to 0.615 and 0.784 respectively. Moreover, the standard error of estimate is 5.86775 and the null hypothesis of the partial coefficients being equal to 0 is rejected for 5% level since $p < 0.05$, indicating the model is statistically significant.

The mean of residuals and its standard error equal to 0 and 0.715 respectively. The skewness and kurtosis indicators are 0.658 and 1.926 respectively.

4.2 Morning-Departure Model

The possible time-periods for the morning-departure model (Formula 5) are 9-10, 10-11, 11-12 a.m. and 12-1, 1-2, 2-3, 3-4 p.m.

$$Y = 18.216 - 17.876 * dummy0 - 15.910 * dummy1 - 13.653 * dummy2 - 11.326 * dummy3 \quad (5)$$

The percentages at 9-10, 10-11, 11-12 a.m. and 12-1 p.m. corresponding to dummy0, dummy1, dummy2, dummy3 respectively are significantly different from those at 1-2, 2-3, 3-4 p.m.; the latter form the reference category. The lowest rates of departure were noticed at 9-10 and 10-11 and the highest ones at 1-2, 2-3, 3-4. $\mathbf{R^2}$ and $\mathbf{R}$ equal to 0.732 and 0.856 respectively, the standard error of estimate is 4.73199 and the null hypothesis of the partial coefficients being equal to 0 is rejected for 5% level, since $p < 0.05$.

The mean of residuals equals to 0 with standard error equal to 0.576 and the skewness and kurtosis indicators being −0.380 and 1.335 respectively.

4.3 Afternoon-Arrival Model

The possible time-periods for the afternoon-arrival model (Formula 6) are 3-4, 4-5, 5-6, 6-7 and 7-8 p.m.

$$Y = 6.055 - 3.617 * dummy0 \quad (6)$$

The percentage at 3-4 a.m. corresponding to dummy0 proved to be significantly different from the ones at 4-5, 5-6, 6-7 and 7-8 p.m., which form the reference category. $\mathbf{R^2}$ and $\mathbf{R}$ equal to 0.182 and 0.424 respectively. The standard error of estimate is 3.160 and the null hypothesis of the partial coefficient being equal to 0 is rejected for 5% level, since $p < 0.05$. Regarding the normality of residuals, the results show a mean equal to 0 with standard error equal to 0.465 and the skewness and kurtosis indicators being 0.614 and 0.154 respectively.

4.4 Afternoon-Departure Model

The possible time-periods for the afternoon-departure model (Formula 7) are 4-5, 5-6, 6-7, 7-8 and 8-9 p.m.

$$Y = 4.306 + 5.176 * dummy3 + 16.652 * dummy4 \quad (7)$$

The percentages at 7-8 and 8-9 p.m. corresponding to dummy3 and dummy4 respectively appeared to be significantly different from the ones at 4-5, 5-6, 6-7 p.m. $\mathbf{R^2}$

and **R** equal to 0.594 and 0.771 respectively. The standard error of estimate is 5.528 and the null hypothesis of the partial coefficients being equal to 0 is rejected for 5% level, since $p < 0.05$. The residuals show a mean equal to 0 with standard error 0.805.

5 Mobility Characteristics

The data processing led to valuable results concerning the mobility characteristics of the university students.

Concerning the car usage, 9.41% of the university students has access to a car, something which can be explained by the age of the students, and 45.61% of them avoid using it because of lack of parking space. Moreover, only 1.81% travels to the campus as passengers. The 0.90% on taxi service usage indicates that students prefer taxis only in urgent cases considering the cost of taxi service.

The low rates of cycling (0.60%) is no surprise considering the existing rather poor cycle network and the perceived low safety level because of the coexistence of cycles and cars in the same infrastructure. Furthermore, the 1.58% of motorbike usage arises by university students usually living not at a reasonable distance from the campus, who prefer flexibility and comfort, but cannot afford the cost of a car.

The bus appears to be the dominant mode of transport to and from AUTh campus for students. The 47.86% probably arises from the fact that the bus is the only Public Transport mode for students living in a long-distance and the campus is highly accessible. Moreover, the cost of a bus ticket for students is half the cost of a regular one, which is an extra motivation for them.

The 39.8% prefer to walk due to two main reasons. Firstly, a significant part of the students coming from different cities live in apartments which are located at a reasonable walking distance from the campus. Secondly, students living in greater distances may leave the campus on foot in the morning, towards the city center for entertainment and then head back to the campus, again on foot, for education, which explains the 45.30% and 41.51% percentages of morning-departures and afternoon-arrivals on foot, respectively. A possible extra reason is that the survey was conducted in May, when the weather conditions might had encouraged the students to make the trips on foot.

The accessibility of a land-use usually depends on many aspects. In this case, only the number of buses used by a student to reach the campus area was considered. The data showed that 333 students use one bus to reach the main campus, the majority living in the urban area of the Thessaloniki Greater Area; 97 students use two buses and the majority live in the suburban areas of the Thessaloniki Greater Area.

In the last question of the questionnaire, students were asked to fill their address and to estimate the distance between their residence and the main AUTh campus, aiming at the estimation of the perceived distance of the students. Then, the actual distances were measured, using Google Earth. The mean and standard deviation of the actual-perceived distance differences computed, were 1268.5 m and 1907.37 m respectively. The value of the standard deviation implies that the majority of the students cannot accurately estimate the distance between their residences and the campus, something which may affect transport mode selection.

6 Discussion

This study estimated a trip generation rate of 2.265 daily trips per student for the student population of AUTh main campus. Moreover, the trip generation model proves to be reliable considering the resulted validity indicators and that the assumptions hold [6].

The majority of the morning arrivals were made at 9-10 and 10-11 a.m. and a small number was noticed at 12-1, 1-2, 2-3 p.m. Furthermore, most of the students who left the campus in the morning, made that trip at 1-2, 2-3 or 3-4 p.m., while a small number attended at 9-10 or 10-11 a.m. The afternoon-arrival model showed that the percentage of the sampled population that arrived at 3-4 p.m. in the campus is significantly less than the ones arrived at 4-5, 5-6, 6-7 or 7-8 p.m. Lastly, most of the afternoon departures are attended at 8-9 p.m. and the percentages left the campus at 8-9 or 7-8 p.m. are significantly different from the ones estimated at 4-5, 5-6 or 6-7 p.m.

Importantly, the dominant means of transport to and from the AUTh campus for students are bus and walking. Car accessibility for students is low but when it occurs, half of them avoid using it because of lack of parking in the wider area of the campus.

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An Analysis on Drivers' Self-reported Questionnaire Responses, Regarding Aggressive Driving, Attitude Toward Cyclists and Personal Values

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Abstract. Driving behavior plays an important role in road safety and it is under investigation by researchers worldwide. In the framework of this paper an attempt is made to gain insight into safe driving behavior with the use of a questionnaire-based survey. One hundred and forty car drivers participated in the questionnaire-based survey that was conducted during 2015 in the city of Thessaloniki. The questionnaire consisted of thirty two questions grouped into four sections. The sections addressed different issues in the scope of Road Safety, Sustainable Mobility and Traffic Psychology such as aggressive driving toward other car drivers, cyclists and pedestrians, attitude toward the use of the bicycle and of the cyclists in general and drivers' personal values that potentially influence their driving behavior. The questionnaire also included a section about drivers' Road Safety awareness and information, driving experience as well as their socioeconomic characteristics. In this paper, the variables derived from the survey are presented with the use of descriptive and inferential statistics.

Keywords: Driving behavior · Aggressive driving · Driver · Cyclist Road safety · Questionnaire survey · Personal attitudes and values

1 Introduction

Aggressive driving is considered to be associated with road accidents and it is therefore actively studied in the scope of traffic safety [1]. It manifests as a behavior and as such is related to the inner or psychological state of the driver [2]. There are multiple definitions of aggressive driving. Some focus on whether the aggressive behavior is deliberate [3] or on the driver's negative feelings [4] or motives. In most cases, behaviors involved in aggressive driving constitute traffic violations such as speeding and tailgating. The consequence of such behaviors may be endured by any road user including other car drivers, pedestrians and cyclists.

Cycling in particular is a desirable means of urban transport because it promotes sustainable mobility. Still, cycling and cyclists remain largely marginalized [5].

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A number of motorists do not seem to accept or tolerate the increasing number of cyclists on the road and tend to hold a negative attitude toward them. Cyclists have an equal right to use the road while at the same time constitute a special group of road users with different characteristics and needs [6]. As previously mentioned, aggressive driving is related to the psychological state of the driver. In this context, certain values drivers hold and their attitude toward other road users become relevant. For example, one could expect that a motorist who values equality in general, would likely consider a cyclist's equal right to use the road.

It must be mentioned at this point that research on the above mentioned topics has been conducted in the School of Civil Engineering and in the School of Rural and Surveying Engineering of the Aristotle University of Thessaloniki during the last years [7–13]. Specifically, the interaction between drivers, cyclists and pedestrians has been investigated in the road environment of Thessaloniki in order to identify and better understand road users' behavior. Within the framework of this paper the focus was set on aggressive driving, driver attitude towards cyclists and driver personal values.

2 Methodology

Car drivers participated in a supervised self-completion questionnaire survey that was conducted in 2015 in Thessaloniki [13]. The average completion time was 6 min and a total of 140 questionnaires were completed. The questionnaire consisted of 32 items grouped into four sections: (a) aggressive driving toward other road users, (b) driver personal values and attitude toward cyclists, (c) questions related to cycling in general and (d) general scope and socioeconomic characteristics. The collected data were screened for incomplete cases, outliers and unengaged responses and were analyzed using IBM SPSS 19 software.

In Table 1, every different type of aggressive driving behavior constitutes a traffic violation according to the Greek Highway Code. This is true even for behaviors that might be considered "not so serious" and the respective rule is hardly ever enforced, such as honking the horn immediately at a green light signal or blocking the pedestrian crossing during a red light signal. A short description of each variable along with their binary values is presented. Following in Table 1, description and values of the variables related to driver attitude toward cyclists and driver personal values are presented. The first two items relating to driver attitude toward cyclists were intentionally formulated as faulty generalizations and express a prejudiced opinion. Obviously, not all cyclists behave this way. Items relating to driver personal values originated from the supplementary questionnaire of European Social Survey, a 21-item measure of human values [14]. Also in Table 1, description and values of the variables related to cycling in general are presented. Variables DMCycl and AccCar derived from conditional items of the questionnaire and were filled in by car drivers who stated they also cycle or had been cycling.

Finally, description and values of general scope variables are presented in Table 2. Items in this section of the questionnaire included driver's road safety awareness and information, driving experience as well as socioeconomic items. Household income was presented as an optional question to the participants.

Table 1. Description and values of variables denoting aggressive driving, attitude towards cyclists, driver personal values and items related to cycling.

Variable	Description	Values
AggrDriv1	Speeding	0: No, 1: Yes
AggrDriv2	Tailgating	
AggrDriv3	Immediately honking the horn at green lights	
AggrPdstr1	Not giving way at pedestrian crossings	
AggrPdstr2	Blocking pedestrian crossings	
AggrCycl1	Parking in cycle lanes	
AggrCycl2	Overtaking cyclists too closely	
AggrCycl3	Honking the horn at cyclists to move over	
Attitude1	Cyclists do no respect traffic rules	1: Fully agree, 2: Agree, 3: Neutral, 4: Disagree, 5: Fully Disagree
Attitude2	Cyclists drive dangerously	
Attitude3	Cyclists should not be on the road	
Attitude4	Cycle lanes take up car space	
ValSafety	A person who values safety is:	1: Much like me, 2: Like me, 3: Somewhat like me, 4: Little like me, 5: Not like me, 6: Not like me at all
ValEqual	A person who values equality is:	
ValDiffer	A person who values different view is:	
ValRisk	A person who likes to take risks is:	
OwnBic	Own a bike	0: No, 1: Yes
CyclHndcp	Personal reason to refrain from cycling	
ConsdCycl	Do you consider cycling?	1: No thoughts, 2: Some thought, 3: Serious thought, 4: Already cycling
DMCycl	Average days/month cycling (c)	Open type
AccBike	As a driver I had an accident with a cyclist	1: I had an accident, 2: Almost had an accident, 3: No accident
AccCar	As a cyclist I had an accident with a car (c)	

3 Descriptive and Inferential Statistics

3.1 Summary Statistics

For the binary variables of the survey the proportion of the drivers who responded "yes" is presented in Table 3. Despite the fact that 77% of the drivers reported to be aware of the increased road accidents in Greece, percentages for the various types of aggressive driving were considerable. It is worth noting that only 59% were aware of the default urban speed limit (50 km/h); a supposedly well-known piece of traffic rules information.

In regard to driver attitude towards cyclists, considerable percentages that indicate a negative attitude were found and they are presented in Table 4. Especially, in

Table 2. Description and values of the general variables.

Variable	Description	Values
GenderFem	Female gender	0: No, 1: Yes
DrivYears	Years driving a car	Open type
KmYear	Kilometers driven last year	
Age	Age	
Income	Household income (optional question)	
Education	Education level	1: Elementary, 2: High school graduate, 3: University/Technological Educational Institutions student, 4: Technological Educational Institutions graduate, 5: University graduate, 6: Master degree, 7: Doctoral degree
SpeedLimit	Aware of default urban speed limit	0: No, 1: Yes
TrafficTicket	Received a traffic ticket during the last 3 years	
AccidentsGr	Aware of increased road accidents in Greece	
RoadSafetyAd	Watched a road safety campaign	1: A month ago, 2: Six months ago, 3: A year ago, 4: Never

Table 3. Summary statistics of binary variables.

Variable	N	Min	Max	Proportion
AggrDriv1	140	0	1	55.7
AggrDriv2	140	0	1	67.9
AggrDriv3	140	0	1	37.9
AggrPdstr1	140	0	1	27.1
AggrPdstr2	140	0	1	41.4
AggrCycl1	140	0	1	23.6
AggrCycl2	140	0	1	45.7
AggrCycl3	140	0	1	56.4
SpeedLimit	140	0	1	58.6
TrafficTicket	140	0	1	12.9
AccidentsGr	140	0	1	77.1
OwnBic	140	0	1	50.7
CyclHndcp	140	0	1	10.7
GenderFem	140	0	1	47.1

Attitude3: "Cyclists should not be on the road", a combined 66% of the participants responded either "Fully agree" or "Agree". On the contrary, drivers responded mostly in favor of the presence of cycle lanes. Attitude4: "Cycle lanes take up car space", received a combined 73% of either "Disagree" or "Fully Disagree".

Table 4. Percent frequencies of Education.

Variable	N	1	2	3	4	5	6	7	Mean
Attitude1	140	22.1	33.6	8.6	35.0	.7			2.59
Attitude2	140	13.6	33.6	7.9	43.6	1.4			2.86
Attitude3	140	45.0	21.4	1.4	24.3	7.9			2.29
Attitude4	140	12.1	9.3	5.7	47.1	25.7			3.65
ValSafe	140	25.7	25.0	34.3	7.1	5.7	2.1		2.49
ValEqual	140	47.1	32.9	16.4	1.4	.7	1.4		1.80
ValDiffer	140	39.3	37.1	15.7	5.7	1.4	.7		1.95
ValRisk	140	6.4	22.9	30.0	21.4	13.6	5.7		3.30
AccBike	140	.7	5.7	93.6					2.93
AccCar	70	1.4	7.2	91.3					2.90
ConsdCycl	140	21.4	35.7	9.3	33.6				2.55
RoadSafetyAd	140	49.3	23.6	14.3	12.9				1.91
Education	140	10.7	19.3	18.6	16.4	27.9	6.4	.7	2.55

In regard to drivers' personal values (see Table 4), percent frequencies show that drivers mostly identified as persons who value safety, equality and tolerance. However, percent frequencies for those who like to take risks are also sizeable.

Half the drivers (N = 70) reported they also cycle or had been cycling. The majority of the participants hadn't had an accident either as car drivers with a cyclist or as cyclists with a car (see Table 4). About one fifth (21%) of the drivers do not consider cycling as a possibility at all (see Table 4). Also, almost half the drivers (49%) reported they had watched a road safety campaign during the previous month.

Summary statistics for the rest of the variables of the survey that are continuous are presented in Table 5.

Table 5. Summary statistics of continuous variables.

Variable	N	Min	Max	Mean	SD	Skewness	Kurtosis
Age	140	19	75	38.55	13.15	.404	−.658
Income	77	1000	75000	16118.70	11304.07	2.429	9.506
DrivYears	140	1	50	16.45	11.63	.536	−.524
KmYear	140	100	150000	12723.21	19972.55	5.406	32.473
DMCycl	70	0	30	7.69	6.93	.788	.679

3.2 Bivariate Associations

Associations between variables from the sections of aggressive driving, driver attitude toward cyclists and driver personal values are presented in Table 6. Only significant associations at the .05 level are presented. Since the variables were measured at different levels, phi coefficient was utilized for associations between two binary variables, rank biserial coefficient between a binary and an ordinal variable and Spearman's rho correlation coefficient between two ordinal variables.

Table 6. Statistically significant bivariate associations between variables denoting aggressive driving, driver attitude towards cyclists and driver personal values.

Variable 1	Variable 2	Association/correlation coefficient	Approx. Sig.	Coefficient used
AggrDriv1	AggrPdstr1	.253**	.003	Phi
AggrDriv2	AggrPdstr1	.248**	.003	Phi
AggrDriv2	Attitude4	−.175*	.038	Rank-Biserial
AggrDriv2	ValDiffer	.330**	.000	Rank-Biserial
AggrDriv2	ValRisk	−.267**	.001	Rank-Biserial
AggrDriv3	AggrCycl3	.359**	.000	Phi
AggrDriv3	Attitude4	−.280**	.001	Rank-Biserial
AggrDriv3	ValDiffer	−.170*	.045	Rank-Biserial
AggrPdstr1	ValRisk	−.241**	.004	Rank-Biserial
AggrPdstr2	AggrCycl3	.359**	.000	Phi
AggrPdstr2	Attitude1	−.218*	.010	Rank-Biserial
AggrPdstr2	Attitude4	−.199*	.018	Rank-Biserial
AggrCycl1	AggrCycl2	.200*	.018	Phi
AggrCycl1	AggrCycl3	.250**	.003	Phi
AggrCycl1	Attitude4	−.228*	.007	Rank-Biserial
AggrCycl1	ValDiffer	.178*	.036	Rank-Biserial
AggrCycl3	Attitude4	−.205*	.015	Rank-Biserial
Attitude1	Attitude2	.582**	.000	Spearman's rho
Attitude1	Attitude4	.195*	.021	Spearman's rho
Attitude3	Attitude4	.244**	.004	Spearman's rho
Attitude3	ValSafe	.187*	.027	Spearman's rho
Attitude4	ValDiffer	−.166*	.050	Spearman's rho
ValSafe	ValEqual	.398**	.000	Spearman's rho
ValSafe	ValDiffer	.350**	.000	Spearman's rho
ValEqual	ValDiffer	.650**	.000	Spearman's rho

Note. * $p < .05$, ** $p < .01$.

4 Conclusions

A considerable proportion of the drivers that participated in the questionnaire-based survey stated that they drive aggressively. The most common behaviors were speeding (56%) and tailgating (68%). In comparison to the literature, a report on aggressive driving in Canada [15] found that roughly 60% of the drivers were driving in excess of the posted speed limit.

The participants of the study claimed that cyclists are dangerous drivers (56%) with no respect for the traffic rules (47%) and should not be allowed to use the road space (66%). These results are in accordance with a previous study that argues cycling remains marginalized [5]. Most drivers (73%) didn't regard cycle lanes as facilities that take up car space. Concerning personal values, drivers tended to value safety (85%), equality (96%) and tolerance (92%). However, a sizeable proportion (41%) was in favor of taking risks.

The bivariate correlations that are presented in this paper simply provide a useful indication for further investigation into the true nature of the relations between such data. Many interrelationships between items from the questionnaire's sections of aggressive driving, driver attitude toward cyclists and driver personal values were found statistically significant. The largest effect sizes were found to be those between ValEqual and ValDiffer, $rs(138) = .65$, $p < .00$, Attitude1 and Attitude2, $rs(138) = .58$, $p < .00$, and ValSafe and ValEqual, $rs(138) = .40$, $p < .00$. Furthermore, the statistically significant correlations between the different types of aggressive driving are in accordance with previous research [16], in which it is shown that drivers who engage in one type of aggressive driving behavior are also likely to engage in other types of aggressive driving behavior.

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Redesigning the Seafront Area of Paphos

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Abstract. A traffic study for the seafront area of Paphos was carried out in 2009. The most important measure included in that study was the partial and seasonal pedestrianization of the coastal avenue, which was implemented a few years later. However, the constant increase of the city tourism over the last years, has generated new conditions in the area, imposing an "update" of the proposals made in the context of the 2009 study. In fact, the area is characterized by traffic congestion and environmental deterioration, illegal parking, problems in pedestrian movement etc. In this paper, an assessment of the present situation is made, leading, among other interventions, to the proposal for a full and permanent pedestrianization of the coastal avenue. The existing traffic conditions in the seafront are examined on the basis of the results of traffic volume measurements conducted in four crucial intersections in the area, during morning and evening peak hours, in winter and summer. Moreover, the residents', shop owners' and tourists' opinion concerning traffic and environmental conditions, problems and corresponding needs, as well as the possibility of a full and permanent pedestrianization of the seafront are taken into consideration, through a detailed questionnaire survey. Finally, other measures and policies complementary to the pedestrianization are proposed, in order to complete the original redesign of the seafront area of Paphos.

Keywords: Sustainable urban mobility · Infrastructure management
Paphos seafront area · Traffic study · Redesign of an urban area

1 Scope and Objectives of the Paper

The present work aims at assessing the existing traffic situation at the seafront area of Paphos, a few years after the implementation of a traffic study carried out in 2009. The study in question included – among others – the partial and seasonal pedestrianization of the coastal avenue, a measure proved to be highly appreciated by the citizens of Paphos.

Given the changes occurred over the years in the area, an update of the proposals included in the 2009 study was considered to be necessary, so that the needs generated by the new conditions could be met. Towards this direction, the full and permanent pedestrianization of the coastal avenue is proposed in the present paper, "accompanied" by a set of complementary to it measures and policies. For this purpose, the current situation is thoroughly examined on a qualitative basis, along with quantitative data derived from relevant traffic volume measurements conducted in the area, while the

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opinion of residents, shop owners and tourists concerning traffic and environmental conditions, problems and corresponding needs, is taken into account by means of a detailed questionnaire survey.

2 General Demographic, Land Use and Transport Characteristics

2.1 Main Demographic and Land Use Data

Paphos is a coastal city in the southwest part of Cyprus and the capital of the homonymous District. The significant archeological heritage in the area has placed Paphos in the UNESCO list of cultural and natural treasures of the world's heritage, while the city was selected as European Capital of Culture for 2017 (along with Aarhus) [1].

The population of Paphos District amounts to 88.266 citizens (according to the 2011 census results), recording the largest increase at District level in Cyprus, while it constitutes a major magnet for millions of tourists throughout the year [2].

Despite the continuous attempts for the execution and implementation of urban planning studies after the mid-20th-century, the turbulent history of Cyprus did not allow for the adoption of any such study or plan until 1990 ("Paphos Local Plan") [3].

The "Paphos Local Plan", along with the updates following the next years, describes the general development strategy for the area it concerns, including development policies in sectors such as transport, education, tourism, environment, industry etc. [3]. Among others, the Local Plan aims at meeting the needs stemming from the demand for sustainable urban mobility.

2.2 Existing Traffic Conditions and Transport Infrastructure in the Seafront Area

Traffic conditions in the study area (Fig. 1) depend on the following planning and decision making characteristics [4]:

- The continuous (for many years) delays in the realization of the main urban network, as well as the insufficiency of the road network to serve supra-local transport.
- The serious traffic problems of the central area (congestion, road safety, parking, public transport, hindering pedestrian movement etc.)
- The lack of an integrated planning of the road network.
- The slow rate of construction of cycle paths.
- The lack in public car parks.
- The lack in implementing traffic management measures and policies.

The existing transport infrastructure in the area under study is shown in Fig. 2.

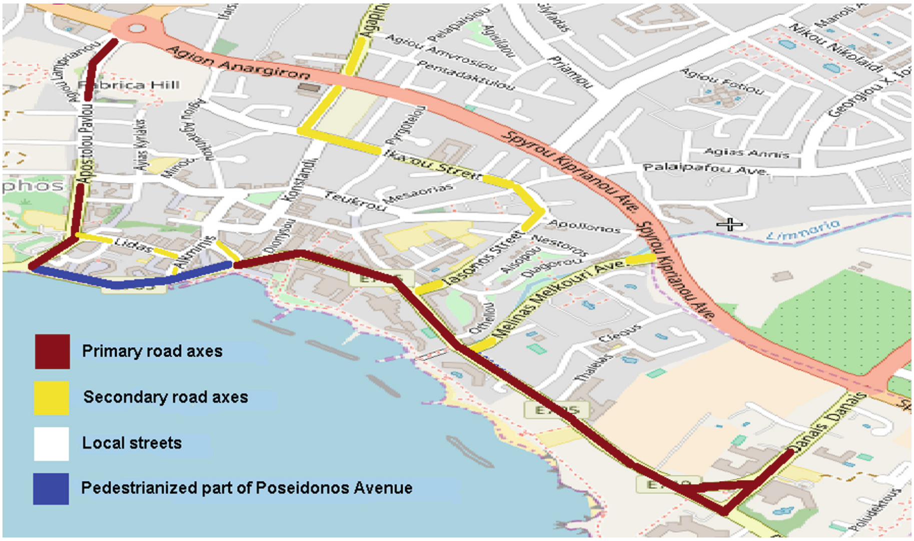

Fig. 1. Study area and road network hierarchy [5].

Fig. 2. Transport infrastructure in the area under study.

2.3 Main Principles and Implementation of the 2009 Traffic Study

The main principles of the proposals included in the 2009 traffic study, which was presented during a plenary session of Paphos Municipal Council in 2009, were the following [4]:

- Pedestrianization of Poseidonos avenue or conversion into a traffic calming zone
- Traffic management, creation of one-way road axes, pedestrianization of streets
- Rearrangement of public car parks

- Exploitation of private car parks in partnership with private sector
- Establishment of automated information system
- Creation of an integrated pedestrian network
- Optimization of sidewalks' characteristics
- Upgrade of urban equipment
- Creation of bicycle network
- Creation of bicycle storage areas
- Network development with shuttle buses and connection with city center
- Equipment upgrade, increase in frequency stops and routes.

Based on the above principles, the main transport intervention decided by the municipal council (after an extended public discussion with all stakeholders) was the partial or full (seasonal) pedestrianization of the coastal avenue, which is presented in the following Figs. 3 and 4, along with the other complementary traffic measures in the broader area.

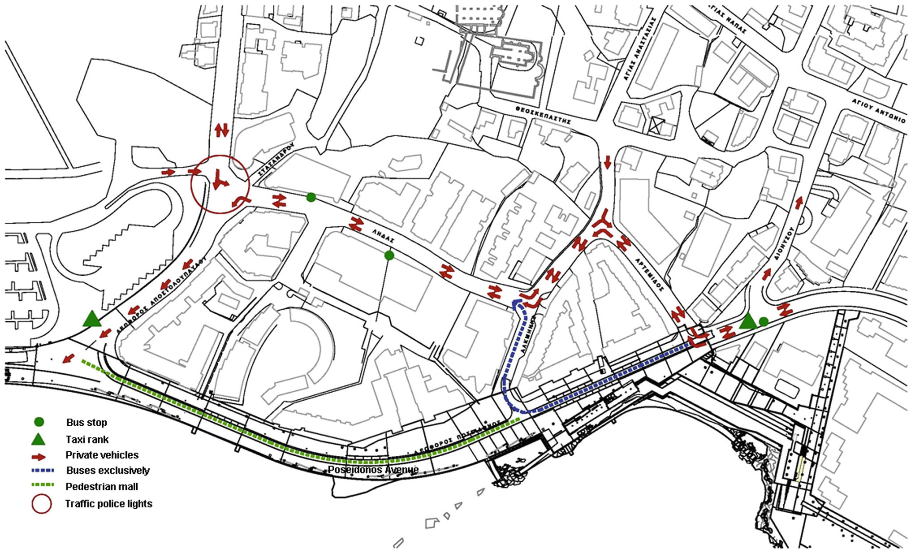

Fig. 3. Full pedestrianization from June the 1st to September the 30th [4].

2.4 Existing Traffic Volumes

The existing peak (summer) vehicle volumes in the seafront area of Paphos are presented in Fig. 5, based on the results of traffic counts conducted in four crucial intersections, during morning and evening peak hours, in winter and summer.

According to these counts, the area is more crowded in summer than in winter, while the most important problems are the following:

- High vehicle volumes in Poseidonos avenue, which hinders pedestrian movement (when and where traffic is permitted).

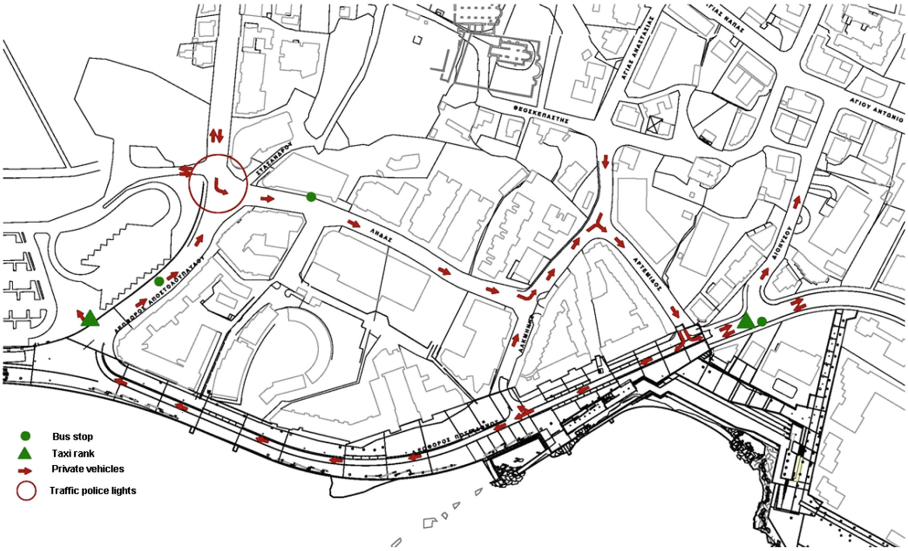

Fig. 4. Partial pedestrianization from October the 1st to May the 31st [4].

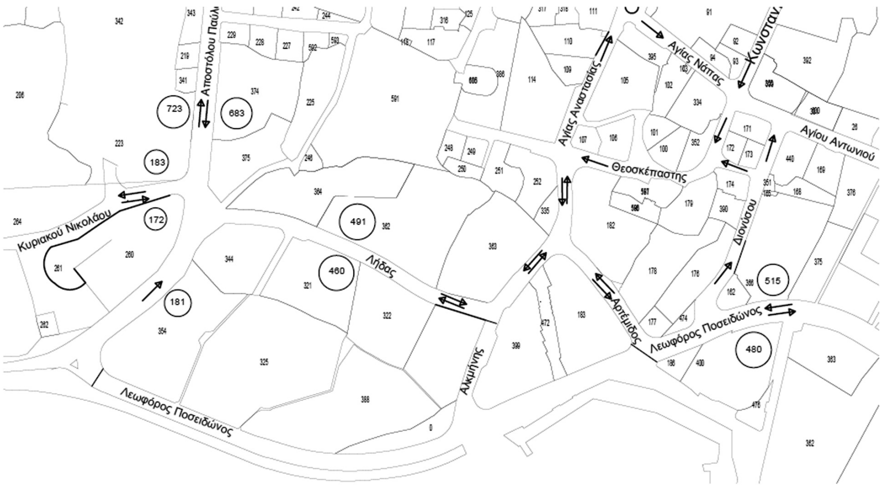

Fig. 5. Traffic volume measurements during evening peak hours in summer [5].

- Traffic congestion and delays in feeder Apostolou Pavlou avenue, especially in summer evenings, due to the pedestrianization of the coastal avenue.
- The intersection Kyriakou Nikolaou – Apostolou Pavlou – Lidas generates congestion problems because of the bi-directional movement in all three streets.
- The road axes Lidas – Alkminis – Artemidos are characterized by intense traffic problems during summer evening peak hours, due to their operation for servicing

the flows of the pedestrianized coast, despite their insufficient geometric characteristics.

3 Public Opinion Questionnaire Survey

The opinion of residents, shop owners and tourists concerning traffic and environmental conditions, relevant problems and corresponding needs, as well as the possibility of a full and permanent pedestrianization of the coastal avenue, is taken into consideration by means of a detailed questionnaire survey. The questionnaires were delivered to 300 participants in a 1:1 female to male ratio. The questions were covering all different aspects of economic, social and environmental nature, with the main answers referring to the evaluation of the existing conditions, as well as the proposed future improvements. An indicative part of the results of the questionnaire survey is shown in Fig. 6.

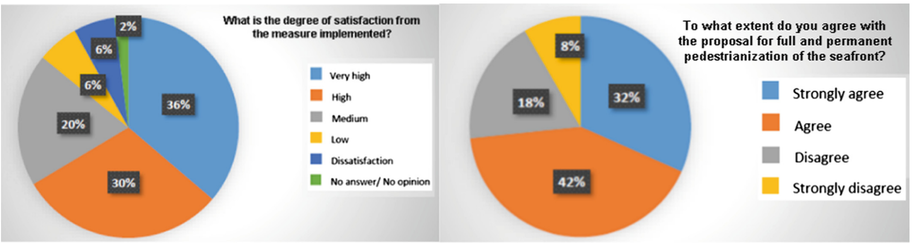

Fig. 6. Main survey answers for various stakeholders [5].

The main conclusions derived from the questionnaire survey are the following [5]:

- Concerning the existing form of the seafront pedestrianization, the residents seem to be more satisfied, while the shop owners seem to be more concerned, depending on their shop kind and position.
- It seems that people are satisfied with traffic, but the parking problem still remains.
- The pedestrianization has contributed in general to the economic growth of the shops, on the basis of shop owners' answers.
- It seems that the majority agrees with the full and permanent pedestrianization of the coastal avenue, especially residents and visitors, while shop owners seem to give more ambiguous answers.

4 Redesigning the Seafront Area of Paphos

4.1 The Proposal for a Full and Permanent Pedestrianization of the Coastal Avenue

Considering the existing traffic conditions in the area, and taking into account the opinion of citizens and tourists on the positive results of the partial and seasonal pedestrianization of a part of Poseidonos Avenue, it could be concluded that the original proposal should be upgraded by taking a total and permanent character. More specifically, the full pedestrianization of the part between Alkminis str and Apostolou Pavlou str. is proposed, along with the removal of the existing vehicle lane. This way, the pedestrianization of Poseidonos Avenue as described above, would result in an environmental upgrade, in terms of aesthetics, noise reduction and increase in road safety, leading to the transformation of the sea front to an attractive pedestrian mall for local citizens and visitors (Fig. 7).

Fig. 7. Existing situation and proposed pedestrianization of the sea front [4].

4.2 Supplementary Traffic Arrangements and Proposals

As a result of the pedestrianization, it is necessary to implement certain additional traffic arrangements in order to redirect the vehicle flows that were previously using Poseidonos (Fig. 8). More specifically, Alkminis and Artemidos streets should be turned to one-way (with direction to the north), in order to facilitate the exit from Lidas str. which will carry all diverted traffic from Poseidonos. Moreover, the stores loading and unloading operations at Lidas, are proposed to be confined to early morning hours only, throughout the year.

Furthermore, it is proposed that the circular movement around the car park of the Archeological Museum should change to one-way, a measure that would contribute to a smoother flow and a reduction of delays and congestion due to heanier traffic. Such an intervention would also “relieve” traffic flows during peak hours and contribute to an easier operation of the parking facilities.

Finally, the creation of new car parks is also proposed. More specifically, it is suggested that the temporary car parks on Apostolou Pavlou avenue and on Pafias

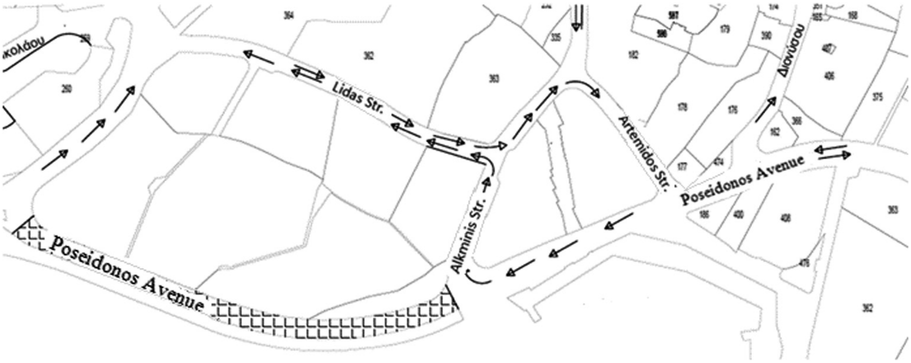

Fig. 8. Supplementary traffic arrangements.

Afroditis str must be organized as public car parks, together with the construction of a new car park on Melinas Merkouri avenue.

It can be concluded that the full and permanent pedestrianization of the part of the coastal avenue shown in Fig. 8 is considered necessary, towards a more pedestrian-friendly policy, with respect to the principles of sustainable urban mobility.

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Development of an Aggregate Indicator for Evaluating Sustainable Urban Mobility in the City of Xanthi, Greece

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Abstract. This paper aims to evaluate urban transport sustainability in the city of Xanthi through the development of an aggregate weighted index as well as to propose an action plan towards sustainable mobility. The proposed aggregated index is based on 30 indicators that assess the sustainability of the environmental, economic and social components of urban mobility. The indicators were calculated by: (a) conducting a public opinion survey on the quality of urban transport system based on a sample of 67 citizens, (b) performing spatial data analysis with geographical information systems and (c) studying the approved local spatial plans and transport studies. The weighting technique used considers the relative significance of the selected sustainability indicators with respect to 18 transport experts' opinions, which is expressed in a seven-point Likert scale. The sustainability indicators were used to perceive the deficiencies of the urban transport system and to provide the basic guidelines of an action plan to enhance sustainable mobility. The impacts of the two different policy scenarios were simulated using the weighted index: (a) the «Short-term scenario» where only partial improvements could be achieved and (b) the «Long-term scenario» where the action plan could achieve optimal results in the study area.

Keywords: Sustainable mobility assessment · Sustainable mobility indicators
Aggregate urban mobility index · Sustainable mobility action plan
Medium size Greek cities

1 Introduction

Cities are complex systems that can be decomposed into several subsystems, one of which is the urban transport system [1]. The assessment and measurability of these subsystems are crucial for implementing efficient and sustainable spatial planning decisions. Even though, there is a growing interest in the concepts of sustainability, sustainable development and sustainable transportation [2], the topic of the sustainable mobility assessment is so far partially covered over the dispersed contexts and approaches, while holistic and systematic overview is still missing [3]. In particular, the measurement of sustainability performance in urban mobility policies still remains a difficult task for policy makers [4]. Various indicators and indices have been advanced

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by many authors as being appropriate tools for this purpose [5]. Costa (2008) states that indexes are instruments responsible for the aggregation of indicators by arithmetic methods that enable simplification of complex parameters [6]. An appropriate set of indicators (index) should reflect all the relevant economic, social and environmental goals and impacts of urban mobility in order to constitute a good evaluation instrument [7]. The international experience provides methodologies, such as the Sustainable City Index, in order to compose these indicators for the assessment of an integrated measurement of sustainable mobility, which may be able to characterize each city and thus to allow comparisons with other cities of similar or different features [8]. Magagnin and Silva (2008) state that the indexes and indicators are being widely used as tools to guide appropriate policy and decision making in urban mobility area, resulting in a significant contribution to improving mobility in society, especially in large urban centers [9].

This paper provides a core set of sustainable urban mobility indicators and a suggested methodology framework to create a composite index, which takes into consideration the opinions of transport system users and transport experts. More specifically, this paper provides policy makers a tool to assess urban mobility conditions and proposes a number of measures and potential actions in order to enhance sustainable urban mobility in the city of Xanthi.

2 Study Area and Research Methodology

The study area is the city of Xanthi, the biggest city in the Region of Eastern Macedonia and Thrace. The area of Xanthi is 330 ha, while its population according to the national statistics agency was 43.730 permanent residents in 2011. The road network consists of primary, secondary and collecting streets, radial to the city center. The city center is the main origin and/or destination of 30.000 vehicles daily, while 20.000 vehicles per day enter or exit the city. In terms of peak time and traffic speed, according to the General Transportation Study, it's between 14:00–15:00 and 30 km/h, respectively [10]. Regarding the city's spatial structure, the main core of central operations is the central square, called Plateia Dimokratias, and the surrounding areas. The structure of the Old City area is a special case since it's a single residential complex with a traditional character and distinctive features from the rest of the city.

The methodology of the research consists of the following steps: (a) indicators system development, (b) assessment and normalization of indicators, (c) indicators weighting, (d) development of aggregate indicator and (e) sensitivity analysis and action plan elaboration.

Through an extensive literature review of several sources, the implementation of the selection criteria led to 30 sustainable urban mobility indicators. The main selection criteria of those indicators were the following [11, 12]: (a) data availability describing the study area, (b) measurable indicators that can be calibrated, (c) indicators that could be successfully used in other cities. The indicators were divided according to the three sustainability dimensions (economy, environment, society) and four strategies towards sustainable urban mobility (integrated spatial and transport planning, public transport and soft modes development, traffic and parking management, environmental measures and technologies promotion [13]).

In order to obtain the necessary data for the calculation of the selected indicators, various methods were used: (a) questionnaire survey conducted on a sample of 67 citizens regarding the level of safety, comfort and satisfaction for each transport mode; (b) officials' interviews about local buses services and car use data; (c) geographical information systems to calculate transport systems density, length etc.; (d) study of approved local plans, transport studies and statistics. Concerning the transport system assessment, the survey was based on closed-ended questions made on a Likert base scale ranging from 1 to 5 (worst to best condition).

After their assessment indicators were normalised in order to render them comparable. The selected normalization scale was from 1 to five 5 (worst to best condition) [14–16]. Concerning the normalisation of the survey's results, the median of answers was used as the value from each related indicator (question) since it is assumed to be not affected by the existence of extreme values.

Within the process of building composite indicators (indices), the step of weighting and aggregation of indicators is crucial in all modelling frames, where a large amount of information must be condensed, so that the final results are more easily comprehensible, while retaining all or most of the available information. The weighting procedure was held according to experts' opinion. The experts group consisted of 18 transport engineers - 13 academics of the Greek Universities and 5 Xanthi's local engineers. They were asked through a questionnaire survey to rank the indicators in a Likert scale from one 1 to 7 (min to max importance) regarding the significance and relevance of each indicator to the sustainable urban mobility principles, as well as based on their suitability for the study area. There is a slight preference to use a 7-point scale among respondents with high cognitive ability, verbal skills, and experience with questionnaires (such as experts) and a 5-point scale when respondents belong to the general public [17]. The median of the experts' answers distribution was finally used as the weighting score for each indicator.

The weighted arithmetic mean (see formula 1) has been chosen to aggregate the 30 indicators [18]. Aggregated weighted indices were applied to assess the total sustainability performance of the Xanthi's urban transport system (composite index), as a well as the distinct performance of the environmental, economic and social aspects of urban mobility (sub-indices).

$$\bar{X} = \frac{x_1 w_1 + x_2 w_2 + \cdots + x_v w_v}{w_1 + w_2 + \cdots + w_v} = \frac{\sum_{j=1}^{v} x_j w_j}{\sum_{j=1}^{v} w_j} \tag{1}$$

The results from this analysis will be used to perceive the deficiencies of the urban transport system in the city of Xanthi, as well as to provide basic guidelines of an Action Plan to enhance sustainable mobility. Namely, an Action Plan will be developed to identify areas for improvement (key indicators that should be improved), as well as to form two different policy scenarios (a short term and a long term), The potential impacts of these scenarios will then be simulated by means of the aggregate weighted indices.

The indicator system elaborated for the city of Xanthi as well as the values, the standardized scores and the weights of each indicator are presented in Table 1 in the Appendix.

3 Sustainable Mobility Assessment and Action Plan

According to the range of values of the composite weighted index, four levels of urban mobility sustainability were defined: (a) sustainable $(\bar{X} \geq 4)$, (b) moderately sustainable $(4 > \bar{X} > 3)$, (c) weakly sustainable $3 \geq \bar{X} > 2)$ and (d) non-sustainable $(2 \geq \bar{X} > 0)$.

The aggregated values of the weighted index, concerning the environmental (8 indicators), social (15 indicators) and economic (7 indicators) sustainability component were found equal to 1.93, 2.62 and 3.26, respectively. So, the urban transport system of the city of Xanthi can be considered as: (a) environmentally non-sustainable, (b) weakly sustainable in the social aspect and (c) moderately sustainable in the economic sense. Concerning the full set of 30 indicators, the aggregated weighted index was found equal to 2.61, indicating a weakly sustainable transport system for the city of Xanthi.

It should be noted that from the whole set of indicators (Table 1 in Appendix), 13 indicators were selected by the group of experts as important ones (i.e. having a median value higher than 5 in the 7-point Likert scale) having though low x_j-value (i.e. indicator's score equal or lower than 3 in the 5-point scale). These *critical indicators* are listed here following a classification based on the three pillars of sustainability:

- <u>Environmental pillar</u>: Bicycling routes length (x_j = 1), Traffic calming roads length (x_j = 1), Vehicle age of public transport's (PT) fleet (x_j = 1), Air emissions from road traffic (x_j = 1).
- <u>Economic pillar</u>: Share of public transport (x_j = 1), Share of private transport (x_j = 1).
- <u>Social pillar:</u> Public transport's vehicles per 1000 persons (x_j = 1), Walking comfort (x_j = 3), Walking safety (x_j = 3), Cycling comfort (x_j = 2), Cycling safety (x_j = 2), PT comfort (x_j = 2) and PT safety (x_j = 3).

On the other hand, there are several characteristics (indicators) of Xanthi's urban transport system that can be considered as very satisfactory, having a final x_j-value (indicator's score) equal or higher than 4 in the 5-point scale. Particularly, both private and public transport costs were considered as very reasonable in the study area, car ownership was seen to be desirable (i.e. relatively low), while traffic congestion was not considered as a serious problem. In addition, the average age of private cars and the pedestrian network density were rated as satisfactory. Finally, the PT (bus) accessibility for people with disabilities, the PT spatial accessibility and geographical coverage as well as the city center accessibility by walking were all considered as very satisfactory.

The aggregate weighted value for the core set of indicators (2.61) indicates – as already stated – a weakly sustainable transport system, which requires an Action Plan to be set in order to improve all the critical indicators and thus to achieve (in the short-term or in the long-term) a sustainable transport system. In this framework, the proposed Action Plan includes the following measures/actions:

- Upgrading the quality of public transport services by modernizing the bus fleet with the supply of new vehicles
- Improving the public transport reliability and comfort by increasing bus routes frequency especially during the peak hours.
- Wider use of traffic calming measures, car traffic restrictions and/or entry restrictions of heavy vehicles in the city center.
- Extending the cycling network and creating bicycle parking spaces

These measures/actions are expected: (a) to increase the attractiveness and use of public transport, (b) to reduce the use of private cars and the associated air emissions, as well as (c) to upgrade public space and ensure a safe and comfortable pedestrian and cycling network. In order to evaluate the impact of the proposed Action Plan, we estimate the aggregate weight indices for the case of the following two scenarios:

1. **Short-term scenario:** Partial improvements can be achieved to all the 13 *critical indicators*. These improvements correspond to one-unit shifts in each critical indicator's x_j-value. Following this scenario, the composite weighted index increases from 2.61 up to 3.12, so that the urban transport system can be considered as a moderately sustainable one. The proposed Action Plan value has a positive impact on all the components (pillars) of sustainability. The environmental sub-index increases from 1.93 to 2.48, the social sub-index shifts from 2.62 up to 3.19 and the economic one increases from 3.26 to 3.62 (Fig. 1).
2. **Long term scenario:** Optimal results can be achieved in the study area by assigning the maximum value ($x_j = 5$) to all the critical indicators. In this case the composite weighted index increases from 2.61 to 4.20 and the urban transport system may be

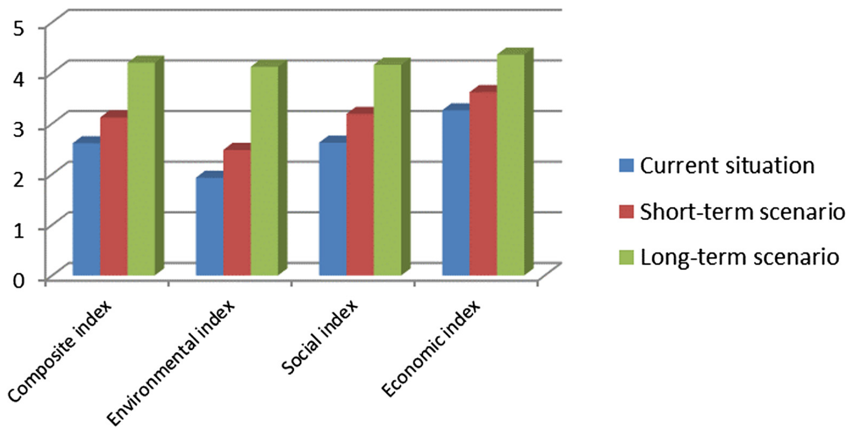

Fig. 1. Changes of the weighted indices under different policy scenarios.

considered as sustainable. The environmental, social and economic sub-indices take the following values respectively: 4.12, 4.16 and 4.36 (Fig. 1).

4 Conclusions

The need for assessing the impacts of policies and actions on sustainable urban mobility makes necessary the elaboration of a continuous/systematic monitoring and evaluation process concerning the urban transport system. Sustainable urban mobility indicator systems constitute important monitoring and control tools, as they are able to assess the performance of a transport system, and evaluate the progress towards specific policy targets (including all the dimensions of sustainable development). The construction of a composite index is not a trivial process as it necessitates several assumptions, simplifications and approximations that should be carefully undertaken in order to avoid an unreliable index.

In this paper we attempted to develop an integrated system of qualitative and quantitative indicators for assessing the level of sustainable mobility in the city of Xanthi (Greece), by taking into account the spatial, urban and transport characteristics of the city. An interesting point in the proposed methodology is that it can detect critical or lagging set of indicators that should be improved to attain a more sustainable transport system. Furthermore, the present work suggests specific “improvement” actions through an Action Plan. The most important recommendations of the proposed Action Plan are: (a) the modernization of the bus network, (b) the adoption of traffic management measures to limit the car use, and (c) the promotion of walking and cycling. The gradual implementation of those actions in the long-term period is expected to have a very positive impact in the study area. However, even a limited and more realistic intervention, as suggested in the short-term scenario, may bring significant benefits in terms of urban sustainable mobility.

The proposed methodology could be used by local authorities and stakeholders for the development of a sustainable urban mobility plan and particularly at the stages of scenario building and scenario evaluation. It could be also used in order to assess the impact of specific actions, measures and policies. Future work could try to overcome some spatial data limitations in the study area, as well as to enrich the methodology by: (a) using a different aggregate technique to generate the composite indexes and then perform a sensitivity analysis based on aggregation methods; and (b) using the indicator system for a comparative evaluation of Xanthi with other Greek cities of similar size and spatial characteristics.

Appendix

Table 1. Sustainable mobility indicators system for the city of Xanthi.

Name of indicator	Definition and measurement unit	Pillar of SD[1]	SUM strategies[2]	Value	Normalisation (x_j)	Weight (w_j)
GPD	€ per capita/per year	ECON	ISP	10.000–20.000	2	3.0
Car ownership	# of vehicles/1000 residents	ECON	TPM	301–400	4	5.0
PT use expenses	% of GPD	ECON	PTSD	0.5–1.0	4	5.0
Car use cost	% of monthly income	ECON	TPM	5–10	4	4.5
Traffic congestion (Peak/Off Peak travel time)	%	ECON	TPM	<1.25	5	6.0
Share of car use	% total trips	ECON	TPM	51–60	3	6.0
Share of PT use	% total trips	ECON	TPM	<10	1	7.0
PT vehicles' age	Years	ENV	EMTP	>10	1	5.0
PT engine technology	Euro1/2/3/4/5 +	ENV	EMTP	Euro2	2	4.0
Car vehicles' age	Years	ENV	EMTP	6.1–12.0	4	4.0
Air emissions	CO^2 tons/resident	ENV	EMTP	>2.5	1	5.0
Road network density	Km/Km^2	ENV	PTSD	>13	1	4.0
Pedestrian network density	Km/Km^2	ENV	PTSD	>0.5	5	4.5
Bicycle network length	% road network length	ENV	PTSD	<9.0	1	5.0
Traffic calming streets	% road network length	ENV	PTSD	<20	1	5.0
Population density	residents/ha	SOC	ISP	100-200	2	5.0
Road accidents	#/10000 residents	SOC	TPM	10.5–16.0	3	3.5
PT vehicles accessible by disabled people	% of bus fleet	SOC	PTSD	61-80	4	3.0

(*continued*)

Table 1. (*continued*)

Name of indicator	Definition and measurement unit	Pillar of SD[1]	SUM strategies[2]	Value	Normalisation (x_j)	Weight (w_j)
PT spatial coverage within 350 m. distance from stops	% of total population	SOC	ISP	>90	5	4.0
City center accessibility by walking within 350 m.	% of total population	SOC	ISP	61–80	4	4.0
Walking comfort	1–5 Likert	SOC	PTSD	3	3	6.0
Walking safety	1–5 Likert	SOC	PTSD	3	3	6.0
Cycling comfort	1–5 Likert	SOC	PTSD	2	2	6.0
Cycling safety	1–5 Likert	SOC	PTSD	2	2	6.0
PT comfort	1–5 Likert	SOC	PTSD	2	2	5.5
PT safety	1–5 Likert	SOC	PTSD	3	3	4.0
PT reliability	1–5 Likert	SOC	PTSD	3	3	6.0
Car safety	1–5 Likert	SOC	PTSD	3	3	4.0
Bicycle parking availability	Lots/1000 residents	SOC	PTSD	<10	1	4.0
PT vehicles availability	Population/# of buses	SOC	PTSD	>1450	1	6.0

[1]Pillars of Sustainable Development: ECON = Economic, ENV = Environmental, SOC = Social
[2]Sustainable Urban Mobility Strategies: ISP = integrated spatial and transport planning, PTSD = public transport and soft modes development, TPM = traffic and parking management, EMTP = environmental measures and technologies promotion

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Performance Evaluation of GLOSA-Algorithms Under Realistic Traffic Conditions Using C2I-Communication

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Abstract. The aim of Green Light Optimized Speed Advisory (GLOSA) systems is to assist individual vehicles approaching an intersection with speed advices (either as single target speed or as complex speed-distance relation) in order to fulfill a given objective. Common objectives include the minimization of fuel usage, emissions and/or delay. The literature provides a wide selection of GLOSA-algorithms addressing different aspects of a real world application, like surrounding traffic, fixed time or actuated traffic lights and mode of communication. However, previous research usually addressed only a subset of possible aspects. Therefore, our goal is to investigate how the existing algorithms hold up in a scenario under largely realistic conditions. We measure the performance (in terms of overall fuel usage, carbon dioxide emissions and delay) of the different GLOSA-algorithms and identify potential shortcomings.

Keywords: GLOSA · Speed advisory system · Connected vehicles ITS-G5

1 Introduction

Intelligent Transportation Systems (ITS) are thought to be one way to overcome the problems associated with the ever increasing traffic. The initiative "Synchrone Mobilität 2023"[1] aims to combine recent developments in ITS with developments in automated driving, leading to various forms of synchronization between different traffic participants. Goals of the initiative include increasing the capacity of the existing transport infrastructure, harmonizing traffic flows and improving interactions between individual and public transport, thus contributing to the reduction of pollutant emissions and traction energy, as well as

[1] https://www.synchrone-mobilitaet.de/en.html.

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to an increased appeal of public transport. In this context, connected and automated vehicles are seen as a key technology to allow even more effective traffic control and management compared to today's ITS measures.

Among the several research and development projects of the initiative, this paper refers to work carried out within the projects SYNCAR[2] (Synchronized Automated Driving in Urban Areas) and HarmonizeDD[3] (Connected and Automated Driving for Mixed Traffic with Heterogeneous Communication Infrastructure). For both projects, we developed novel roadside units (RSU), consisting of a WLAN802.11p modem and additional compute units. This enables applications, which may require processing power directly at the intersection, such as the generation of Green Light Optimized Speed Advisory (GLOSA) messages.

The idea behind GLOSA is to provide the vehicle/driver with information regarding the next traffic light and recommend a certain speed/trajectory to optimally reach the intersection, with the goal of minimizing emissions/fuel usage and improving traffic flow as well as driving comfort. The literature provides several different approaches. For example, Stebbins et al. [10] report a 32% reduction of fuel usage using a GLOSA, which also reduces delay, whereas Widodo et al. [11] also report reductions in fuel usage and emissions when using a constant speed (30 km/h on a 70 km/h lane) as recommendation. Katsaros et al. [6] report a 80% reduction in stop time and a 7% reduction in fuel usage. All of the cited results where obtained under only partly realistic conditions, i.e., Widodo et al. only considered a single intersection with a simple geometry, whereas Stebbins et al. did not consider the additional latency caused by ETSI ITS-G5 communication and Katsaros et al. assumed that the future traffic light state when the vehicle actually reaches the intersection is already known, which is only possible with certainty when the traffic light uses a fixed-time control. In this paper, we want to examine how existing GLOSA algorithms hold up in a more realistic scenario. Besides the algorithms of Widodo et al. and Stebbins et al. we also consider a simple GLOSA, where the recommended speed only depends on the distance to the intersection, and a two-phase (deceleration, then constant speed) approach.

The paper is organized as follows: The next section describes our scenario and the IT architecture used for the experiments. Section 3 summarizes the measurements and discusses the results. The paper is concluded in Sect. 4.

2 Experimental Setup

2.1 Scenario

To evaluate the GLOSA applications under conditions as realistic as possible, our microscopic traffic simulations are based on a representative peak-hour scenario derived from actual traffic data. The calibrated scenario was prepared and

[2] https://www.synchrone-mobilitaet.de/en/projects/syncar.html.

[3] https://www.synchrone-mobilitaet.de/en/projects/harmonizedd.html.

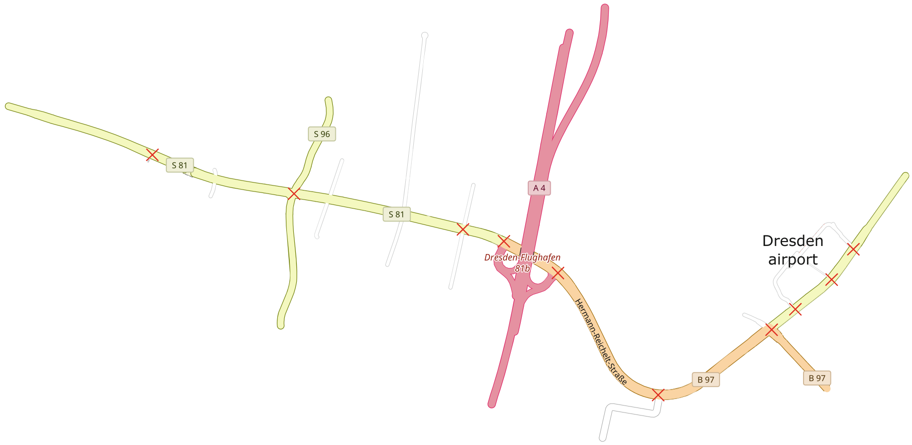


Fig. 1. Street corridor used in the simulation, located in the north of the city of Dresden. It consists of suburban (part left of the highway A4) and urban areas (part right). The crosses mark the positions of traffic lights, which are assumed to be equipped with RSUs.

kindly provided to us by the Chair of Traffic Control and Process Automation at Dresden University of Technology.

The scenario uses the microscopic traffic simulation SUMO [8]. It comprises definitions of more than 16,000 individual vehicle trips through a ca. 3.5 km long, four-lane suburban corridor in the northern outskirts of Dresden. The corridor and the positions of the traffic lights are shown in Fig. 1. Each of the trips is characterized by departure time, route, and vehicle type. In this context, the scenario distinguishes between some 250 vehicle types, each of which representing a certain set of vehicle characteristics as well as driving behavior parameters. All of the trips start within a two-hour morning peak interval (6 am to 8 am) of a typical Monday. Three bus lines frequenting the corridor are also included in the scenario.

Along the corridor, there are ten traffic lights, all of which use traffic-actuated control responding to traffic flow and public transport vehicles. As the real control algorithms were not available, the scenario uses a simplified control pattern based on time gaps, which was calibrated to replicate the real traffic light behavior as closely as possible.

We use SUMO's HBEFA3 module to measure CO_2 emission and fuel usage. To do so, every vehicle was assigned an emission stage (Euro 1 – Euro 6) following the actual distribution of emission stages in Germany [2].

Cooperative Awareness Messages [1] (CAMs) are generated using the vehicle values available through the TraCI API. Since acceleration values are not directly available, these are approximated using finite differences. Furthermore, to obtain a more realistic behavior, the exact vehicle positions available through TraCI are disturbed according to the positioning errors achieved by Schindler [9]. To model a realistic near term scenario, we assume that 50% of all Euro 5 & 6 vehicles are able to communicate. Additionally, we assume that RSUs can receive CAMs in a 300 m radius.

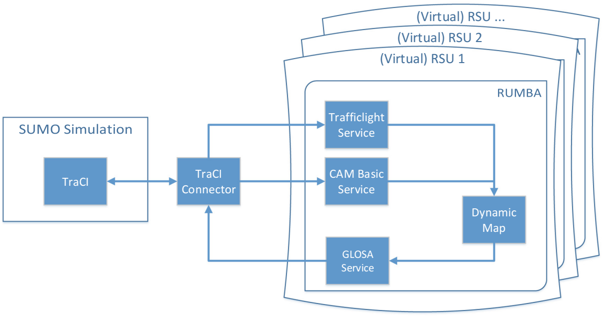


Fig. 2. IT setup used in the experiments. Starting with a SUMO simulation, CAMs and traffic light data are extracted using SUMO's TraCI API. This information is then send to the virtual RSUs, where it is processed and GLOSA messages are generated. Finally, GLOSA advice is fed back into the simulation using the TraCI connector.

2.2 IT Architecture

Our simulations use the roadside unit modular architecture (RUMBA) framework, which will also be used in real world testing. RUMBA is an easily extensible micro-service based collection of packets. At the heart of RUMBA lies a dynamic object map, which holds the state of the traffic environment and offers additional services like prediction of vehicle movements. The map is complemented by modules for importing data from several sources, e.g., a microscopic traffic simulation (SUMO), a traffic light controller or a WLAN802.11p modem, and modules for generating GLOSA messages. Furthermore, modules for diagnosis and communication with a backend server are possible. Communication inside the road side unit is realized by using gRPC [3] and Protocol Buffers [4]. Communication with outside facilities, e.g., the WLAN802.11p modem, uses LCM [5]. Figure 2 shows the RUMBA setup as used in our experiments. All ten roadside units were simulated inside a virtual machine on one computer (four cores, 8 GibiByte RAM, host: Intel Core I5-6600, 4 cores/8 threads, 16 GibiByte RAM), which also ran the SUMO simulation and SUMO import/export functionality.

3 Simulation Results and Discussion

Figures 3, 4 and 5 summarize the simulation results. The results for the base case were derived by repeatedly sampling the vehicle emission stage from the KBA statistic [2]. From these scenarios, we chose one reference scenario as our basis for carrying out the examination of the GLOSA algorithms. In this scenario, 4053 vehicles are active, i.e., are able to communicate and receive GLOSA

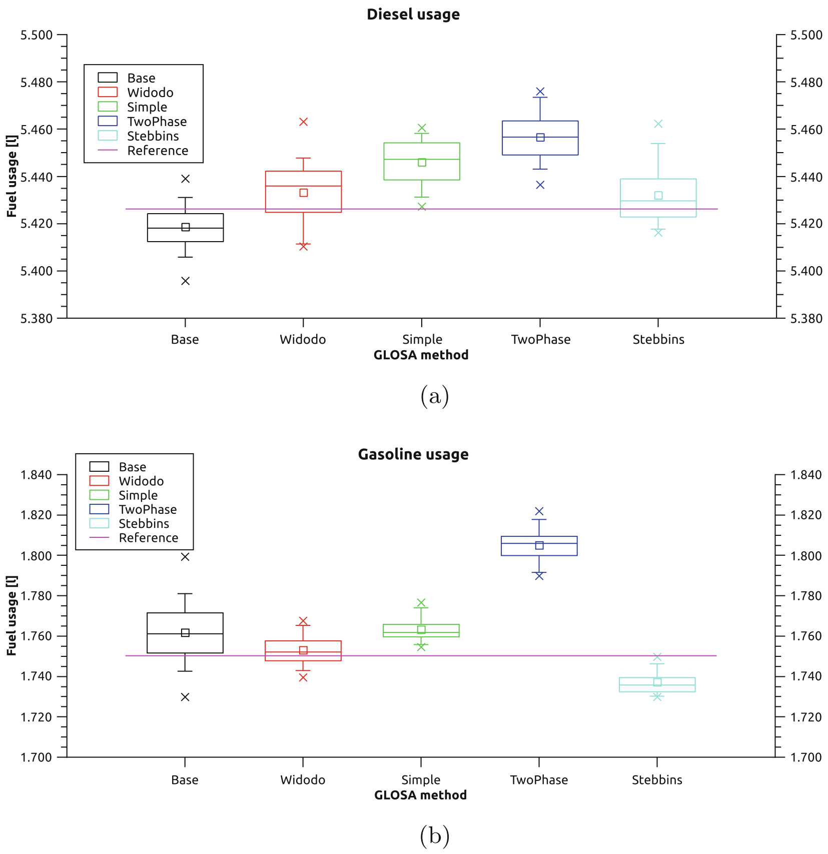
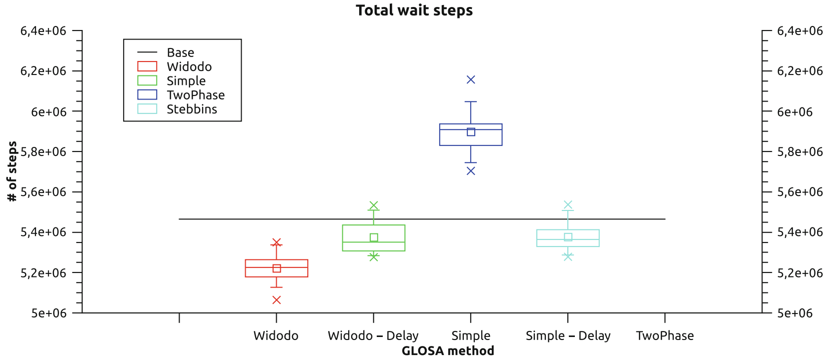
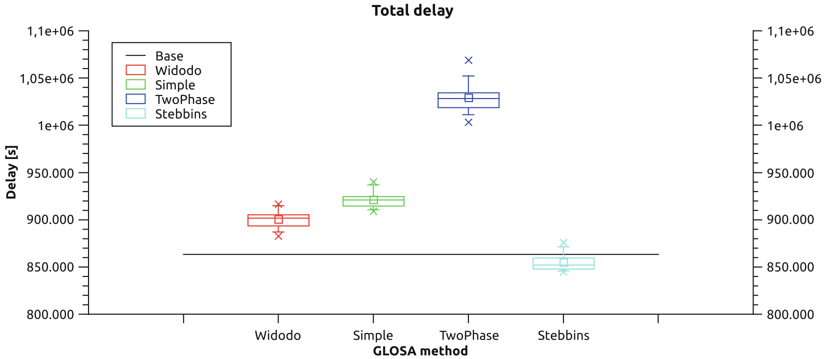


Fig. 3. Details on fuel usage for the base case and the different GLOSA algorithms. All algorithms show increased Diesel usage in (a), whereas the GLOSA of Stebbins et al. achieves at least a reduction in gasoline usage in (b).

advice. ANOVA tests reveal that there are significant (at the 0.05 level) differences between the means of the different GLOSA algorithms and the base case. This is true for CO_2 emissions as well as fuel usage, delay and wait steps. The overall best performance is achieved by the approach of Stebbins et al. Interestingly, even though overall fuel usage and CO_2 emission are reduced, the same is not true for Diesel vehicles, which show a increased fuel usage and emissions. At the moment, we cannot offer an explanation for this behavior. The worst performance is achieved by the two phase (deceleration, then constant) approach. It mainly fails because of tailback and dynamic traffic light control rendering the current trajectory invalid. Furthermore, the deceleration in the first phase may hinder the following vehicles. Please note that all of the results are specific to our given scenario and cannot be generalized, i.e., the algorithms under examination might show a totally different behavior given other circumstances.

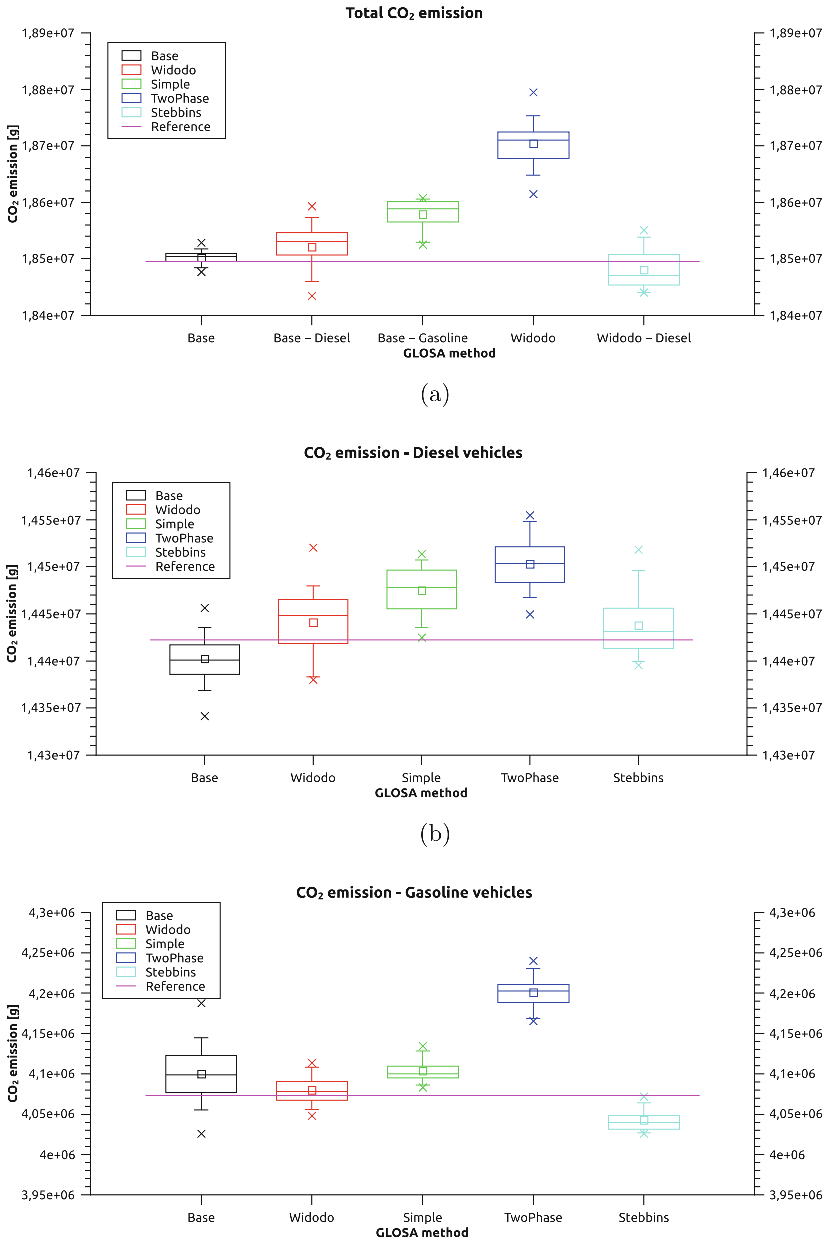


(a)



(b)

Fig. 4. Details on total wait steps (simulation steps when a vehicle had a velocity near zero), where the step length was 0.1s and total delay. All GLOSA algorithms, with the exception of the two phase approach, show a significant reduction in wait steps. On the other hand, only the approach of Stebbins et al. achieves a reduction in overall delay in comparison to the reference scenario.



(c)

Fig. 5. Details on total CO_2 emission and emissions from Diesel and Gasoline vehicles. In (a), all approaches except the approach of Stebbins et al. show an increase in total CO_2 emission. The same holds true for the emission from Gasoline vehicles (c), whereas all GLOSA algorithms show an increased CO_2 emission in (b).

4 Conclusions and Future Work

The simulation results have shown that most of the examined GLOSA algorithms perform suboptimal with regard to CO_2 emissions and fuel usage under the largely realistic conditions presented by our scenario, with the exception of the approach of Stebbins et al. On the other hand, most algorithms manage to reduce the time vehicles are standing. Another interesting find is that Gasoline vehicles seem to profit more from GLOSA advice, whereas Diesel vehicles consistently show increased CO_2 emission and fuel usage. As a next step, we want to analyze the reason for this different behavior between Diesel and Gasoline and possible come up with an improved GLOSA, which takes into account the fuel of the vehicle. Future work includes the simulation of additional GLOSA approaches, and testing the best approaches on our real world test field. Furthermore, we need to examine the relation between traffic light control and GLOSA more closely. For example, van Katwijk et al. [7] report positive results for a cooperative adaptive control, which influences the vehicle as well as the traffic light. Another interesting aspect of future research is how effectiveness of GLOSA is influenced by automated vehicles vs. humans responding to the speed advisory.

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Transport Data and Analytics

Measuring Spatial Accessibility of Public Transport: The Case of the New Urban Rail Systems in the City of Thessaloniki, Greece

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Abstract. This paper aims to evaluate the level of spatial accessibility of the new urban rail systems in the city of Thessaloniki, that is the metropolitan network under construction by Attiko Metro S.A. and the proposed tramway lines by Thessaloniki Public Transport Authority. Accessibility measures constitute a suitable planning tool for assessing the spatial impacts of transport scenarios, the transport networks connectivity and the land use transport interactions. In this research, location-based measures were applied, such as the integral, the isochronic and the potential accessibility indicators. The 2011 population census data in reference to the city block level and the origin-destination travel time data between the 68 future urban rail stations (simulated by GIS software) were used to calculate the relevant indicators. Thus, population accessibility was measured rather than opportunity accessibility, which is the usual research practice, due to the lack of adequate employment or land use data at the city block level. Nevertheless, the results can be interpreted as the potential attractiveness of the new urban rail stations. The analysis outlines the connectivity weaknesses of the proposed Metro and Tram system and therefore the direction for possible improvements on the urban rail network spatial coverage.

Keywords: Accessibility measures · Transport planning
Urban railway systems · Public transport · Thessaloniki

1 Introduction

Within the framework of the decision making process for the development of urban transport systems, the use of accessibility indicators is a useful tool for planning and evaluating the transport and land use systems interaction [1, 2]. Accessibility refers to the ease of access to goods, services and activities [1, 3] and comprises a distinctive measurement that connects the location and spatial distribution of human activities with the networks of transport systems [4]. As it is not an easily comprehensible and measurable concept, it constitutes an important research topic in spatial planning during the past 40 years. Geurs and Wee [1] propose a classification of accessibility indicators

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into four categories: location-based measures, infrastructure-based measures, utility-based measures and person-based measures. Though in literature there is a multitude of indicators for the measurement of accessibility [5, 6], their use is not as widespread as an instrument of transport planning [7] and is usually restricted to the ex-post evaluation of the infrastructures. An interesting example of accessibility indicators application is the evaluation of the urban transport system in the city of Montreal, Canada [8] where the choice to develop specific public transport infrastructures was based on the evaluation of the accessibility offered by public transport system compared to that of private car. Also, the case of public bus network in Denizli, Turkey, shows that an important parameter of influencing accessibility is the bus route frequency [2].

The aim of the paper is to assess the spatial accessibility of the future high capacity urban rail systems -that is Metro subway and Tramway- in the city of Thessaloniki. The main Metro line, 9.6 km long and 13 stations, is in the final stage of construction by Attiko Metro S.A. within the limits of the Municipality of Thessaloniki, while extensions have been planned for the neighbouring Municipalities of Kalamaria in the southeast, as well as Stavroupoli and Evosmos in the northwest. Additionally, a new Tram network consisting of three lines of a total length of 24 km and 43 stops is proposed within the framework of the feasibility study elaborated by Thessaloniki Public Transport Authority [9]. The basic research questions are the following: Which will be the spatial coverage of a fully developed, integrated Metro and Tram network? Which parts of the city are most to benefit as regards the service level? Are there any differences between Metro and Tram regarding the provided accessibility level? Which will be the Tram contribution in enhancing the urban rail network spatial coverage?

2 Study Area and Methodology on Measuring Accessibility

Thessaloniki is the second biggest town in Greece and of an intensely Metropolitan character. This research examines the greater Thessaloniki area, with a population of 816,382 inhabitants [10]. The agglomeration is defined by a high rate of private car use and by a lack of urban railway network, in contrast with other European cities of similar demographic and spatial features [11]. Both the new Metro line, with its scheduled extensions, and the proposal for the development of a Tram network are attempting to cover this gap. Fully developed, these two mass transport modes will comprise 68 different stations and stops.

For the evaluation of this future high capacity transit system of Thessaloniki, three basic accessibility indicators were employed, all belonging to the location-based accessibility measures: the integral, the isochronic or cumulative opportunities and the potential or gravity accessibility. For the estimation of an accessibility indicator, spatial data is needed concerning the location of certain activities, opportunities or land uses (e.g. labour, commerce, entertainment etc.) or the demographic characteristics (residents per zone, employees per economic sector) as well as the travel times between geographical zones [12].

Due to the lack of real observed data for the Metro and Tram, a simulation of travel times was conducted by employing the ArcMap of ESRI, Network Analyst extension software. By using this software, the theoretical times from station to station were estimated[1], taking into consideration the transit interchange time[2] between lines. The location of the Metro stations and Tram stops were derived from relevant maps of Attiko Metro S.A. [13] and the relevant Tram feasibility study elaborated by Thessaloniki Public Transport Authority [9] (see Fig. 1).

The analytic mathematical formulation of the three indicators is presented in Table 1. As there is no unique method of accessibility estimation, conclusions may vary [14]. The integrated accessibility indicator assesses the service level of a station considering the travel time in relation to the rest of the network stations [15]. Low values indicate good accessibility, high values indicate the opposite. Even though the assessment of the indicator is relatively simple and comprehensible, it does not take into account the spatial distribution of land uses. The isochronic indicator measures the cumulative opportunities (e.g. employment positions) which may be approached from a specific point of the network, within a given travel time. In this paper, contrary to common research practice, the isochronic indicator assesses the population which can be approached from a network node within a certain time limit of 15 or 30 min. The use of population became necessary due to the lack of reliable data on employment opportunities or land use at city block level. It is to be noted that to every station corresponds the population located within the 400 m of direct influence (800 m for terminal stations) after having deducted the overlapping between the zones of neighbouring stations. Isochronic indicator can be easily comprehended and interpreted both by researchers and policy makers, which actually constitutes its basic advantage. However, by selecting a time distance limit *a priori*, we are likely to artificially exclude some significant destinations or opportunities located outside the predefined time limit. In contrast, the advantage of the potential accessibility indicator based on gravity transport models is that it takes into consideration all the possible destinations/opportunities to which a network node is connected in function of the distance or the travel time. As it takes into account the spatial distribution of opportunities, it is valued as more reliable but also more difficult to comprehend and interpret [6]. Furthermore, we distinguish between the active and passive accessibility indicator. Active accessibility assesses the attractiveness level of a zone, while the passive one estimates the ease of access to the zone by potential users [16]. In the case study of Thessaloniki, passive accessibility was taken into account. Thus, every station is considered as a specific destination zone and the ease of access by the population from all other network nodes to this destination is assessed.

3 Accessibility Level of Metro/Tram Network

The results of the accessibility indicators for the planned urban rail systems of Thessaloniki are presented in Figs. 2, 3 and 4. It is worth noting that, due to different calculation methodologies of indicators, the results are not directly comparable among

[1] Commercial speeds: Metro 31 km/h and Tram 21 km/h.

[2] 4 min for interchange [12].

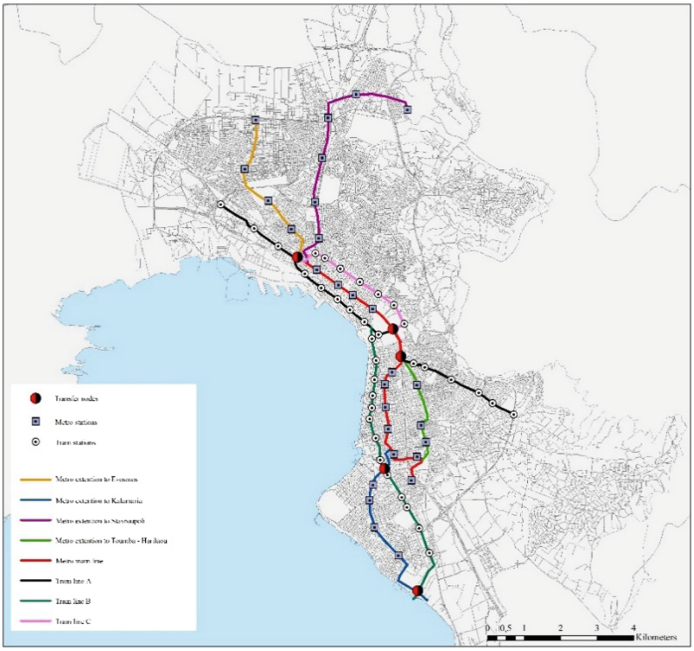

Fig. 1. Planned Metro/Tram lines.

Table 1. Equations of the estimated accessibility indicators.

Indicator	Estimation function	Parameters
Integral accessibility	$A_j = \sum_i^n \frac{t_{ij}}{n}$	t_{ij}: *travel time i j* *i: Origin station* *j: Destination station* *n: number of OD pairs*
Isochronic accessibility	$A_j = \sum_i^n O_i * \gamma$	O_i: *population of station i catchment area* *i: Origin station* *j: Destination station* *n: number of OD pairs* γ: *indicator equal to 1 when* t_{ij} *is smaller than the defined travel time limit, and 0 otherwise*
Passive potential accessibility	$A_j = \sum_i^n \frac{O_i}{t_{ij}}$	O_i: *population of station i catchment area* *i: Origin station* *j: Destination station* *n: number of OD pairs* t_{ij}: *travel time i j*

them. However, a comparative evaluation can be achieved, and therefore pinpoint stations and areas of low or high accessibility.

Concerning the integrated accessibility measures, we note that the stations of the main Metro line and certain Tram stations located near central transit interchanges are

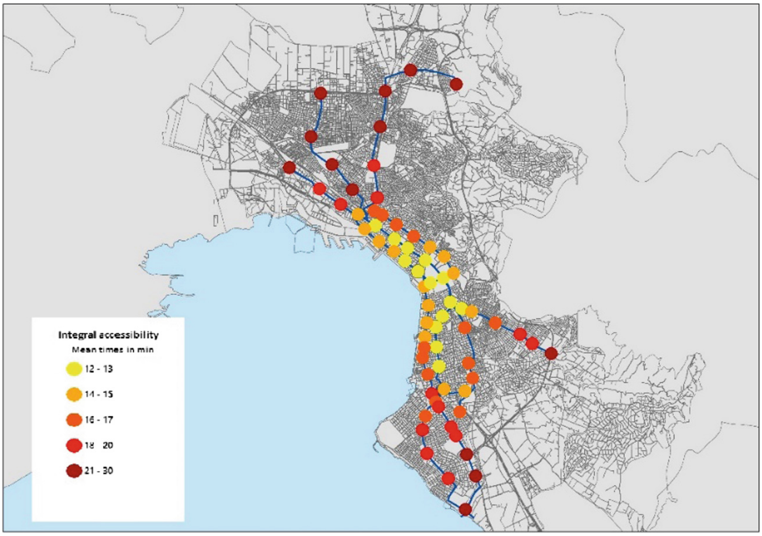

Fig. 2. Results of the integral accessibility indicator.

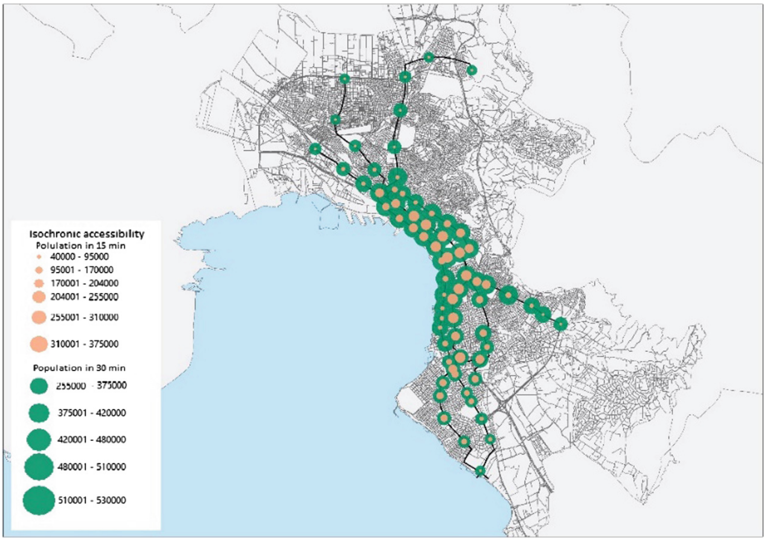

Fig. 3. Results of the cumulative opportunities accessibility indicator.

of the highest level of accessibility. Generally, the areas of high population are characterised of satisfactory accessibility levels. In particular, higher levels of accessibility correspond to the stations of the southeast part of the city, except for the stations towards the end of the network lines. In contrast, in the northwest areas, accessibility declines significantly as we move away from the main Metro line.

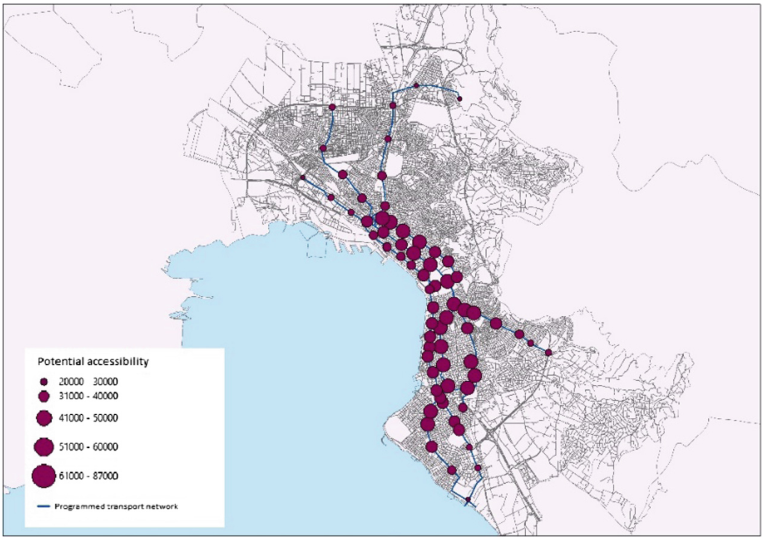

Fig. 4. Results of the potential accessibility indicator.

The results of the isochronic measures for trips within 15 and 30 min from each station further support this contrast. Lower accessibility levels correspond to almost all network nodes that serve the northwest areas, even at stations located near the main Metro line. On the contrary, higher accessibility levels are observed at the central and southeast section of the network, even for the Tram stations within the time limit of 15 min. The terminal Metro/Tram stations are the only exception. Finally, the main Metro line provides higher levels of accessibility to the centre of Thessaloniki in comparison with the corresponding Tram lines, due to higher commercial speed. However, the role of the Tram network is crucial for the overall accessibility improvement of the urban railway network, due to the increased spatial coverage. With the Tram, the isochronic accessibility of the transit system is increased by 245% and 334% comparing to the accessibility level offered only by the Metro lines, for the limits of 15 and 30 min respectively.

The results of the potential accessibility measures verify the previous observations. The differentiation of the level of transit network coverage between the southeast (mainly middle and upper class) districts and the northwest (mainly working class) districts of the agglomeration is noteworthy. In this case, the contribution of the Tram to the accessibility is even higher. The total potential accessibility of the Metro-Tram network increases by 193% compared to network configuration without the Tram lines.

4 Conclusions

Although the implementation of accessibility indicators is gaining ground, it is not a common practice in transport planning. In this paper, an evaluation of the spatial accessibility levels of the urban rail transit systems that are under construction, scheduled and proposed in Thessaloniki is attempted. The integrated accessibility indicator takes into account only the structural and operational characteristics of the network, while the isochronic and the potential accessibility indicators consider also the spatial distribution of the population. The methodology implemented verifies the usefulness of the accessibility analysis in the framework of the feasibility study and the decision making process for the development of public transport infrastructures. The adopted research approach could be easily applied and transferred to other locations, as it requires standard spatial and transport network data, numerical calculations and software tools.

Through the analysis of the findings, the basic weaknesses of spatial coverage of the Metro-Tram network are pinpointed and potential proposals for improvement are highlighted. Travel time is revealed as the most significant factor influencing the results. The Metro, by offering higher commercial speeds than those of the Tram, provides higher accessibility levels within the city centre. However, the Tram contributes to improve significantly the spatial accessibility in city areas not covered by the Metro. Therefore, the utility of the Tram project seems fully justified. Finally, the higher Metro and Tram network connectivity level in the southeast part of the agglomeration comparing to the northwest one is evident. This contrast is attributed to the radial form of the urban rail network, the low density of stops and the lack of transverse connections of the lines serving the northwest peripheral municipalities. Thus, the expansion of the Metro and/or Tram to connect these municipalities could increase the accessibility levels. Decision makers should consider these findings for future urban rail projects in Thessaloniki or other cities. Metro and Tram are complementary transport means and good interconnection between them is essential for a high level of public transport system accessibility.

Let us point out that, regarding the isochronic and potential accessibility indicators, the population likely to approach a station is estimated without accounting for the activities/opportunities located inside the station catchment area. It is very probable that the results would have been different if employment positions had been used as location factors. Consequently, the basic weakness of the research lies in the fact that the analysis was based on the population served and not on the trip attractiveness factors, as is the common practice, due to lack of detailed spatial data at urban block level. Moreover, the accessibility analysis does not consider the technical restrictions that have affected the network lines layout as well as the location of stations and stops.

The perspectives for the continuation of the research are mainly related to addressing the restrictions and shortage of spatial data, aiming towards the enrichment and improvement of the applied methodology in the following: (a) accessibility level estimation of the Metro and Tram to various opportunities such as employment by economic sector, different land uses or city functions and activities; (b) impact assessment of alternative scenarios on the location of lines and stations aiming at enhancing the total urban rail accessibility; and (c) accessibility evaluation of the integrated public transport network (Metro, Tram and public bus routes). Finally, a benchmarking analysis comparing the accessibility findings with those of other European cities of similar spatial characteristics, could provide a more complete and clear picture of the quality of transport service and the efficiency of the future urban rail systems of Thessaloniki.

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TAToo – A Tracking for Planning Tool Applied to Cycling and Walking Data

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Abstract. Tracking cyclists and walkers may open a new window of opportunities for urban planning and policy and become a relevant part of cycling and walking planning and policy processes in the near future. Within the development of the project "TRACE – Walking and cycling tracking services", parallel to different apps and initiatives that promote behaviour change, a new tool was developed in order to improve planning and decision-making processes: TAToo – Tracking Analysis Tool. This tool aims to transform the available tracking data of cycling and walking trips into relevant data, by map-matching the GPS trajectories with the network and calculating a set of key performance indicators (KPI) for nodes, links, areas and origin-destination pairs. Volume, number of trips, average speed, level of service and congestion are some of those KPI. TAToo may use both cities' maps or export one from the open-source platform OpenStreetMap, and is also ready to deal with cities' own zoning systems. This paper presents a description of TAToo development and usage, its potential of application to help cities or transport authorities to support their decisions related to the cycling and walking infrastructures, and presents examples of different analyses possible with the results from the tool.

Keywords: Tracking · Cycling · Walking · Map-matching

1 Introduction

Considering the growing existence of data related to the walking and cycling trips, turn this data into valuable information is one of the biggest challenges of transport planners and transport authorities or cities that want to improve the quality of life of the citizens.

Having this in mind, and within the development of the project "TRACE – Walking and cycling tracking services"[1], TAToo – Tracking Analysis Tool was developed. This tool aims to be an instrument for tracking data analysis for urban mobility planning and policy making.

Section 2 presents a short literature review on the walking and cycling tracking potential, and a brief description of the TRACE project. Section 3 presents TAToo and its main functionalities, while in Sect. 4 some results from its usage are shown.

Finally, Sect. 5 summarizes some conclusions regarding the subject.

[1] TRACE – Walking and cycling tracking services, Horizon 2020 under grant agreement number 635266. http://h2020-trace.eu/.

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https://doi.org/10.1007/978-3-030-02305-8_8

2 The Importance of Tracking Services

Due to the omnipresent existence of smartphones and tracking mobile applications, people are now being tracked at each second of their days. Tracking data allows a better perception of people's movements and trips, and could turn into very important information in planning and policy processes [1].

Most of the tracking data is recorded during training activities [2], but it also represents a relevant improvement from the traditional data collection methods, like counting sites. Indeed, counting does not allow knowing neither the origin or the destination of each person. To obtain more detailed information about the users' trips, surveys are frequently used, that sometimes lack of reliability, particularly in the scope of cycling and walking [1].

Tracking data applied to motorized traffic have already been used in different work for years [2–4], but only recently applications like CyclePrint[2] became available in limited locations.

However, they've already been used to improve cyclists' life. In Ghent (Belgium), the technicians of the municipality observed the GPS data from the B-Riders mobile application[3], and discovered that, instead of using the new bicycle "motorway", people continued to use their usual route, parallel and across the channel, not realizing that they could arrive much faster and more comfortable. A new signal was enough to change this unexpected behaviour.

In Lisbon, in the discussions that preceded the cycling route in the main axis of the city, there was also an important influence of the tracking data. A simple visualization of the heat map of the Strava[4] application made it possible to perceive that, despite the constraints to the date (a lot of cars and less space for cycling), cyclists still wanted to use the most direct route towards the downtown.

The type of questions that the observation and analysis of tracking data raise varies greatly according to the level of adhesion to the bicycle. In "beginner" cities, questions are more basic, such as where and where to create cycle paths, or, as in Bologna (Italy), to set up priority bicycle parking sites. In "advanced" cities, issues tend to be more related to fluidity (speeds and delays) [1].

One difficulty from tracking data analysis should not be forgotten: it doesn't allow to infer absolute volumes but only relative volumes, since it does not capture all users; counting are still essential to obtain absolute flow volumes [1]. It seems, however, that the combination of tracking data with GIS tools covers a big set of user and stakeholders' needs.

3 The TRACE Project and TAToo

The TRACE project, running since 2015, has the mission of assessing the potential of movement tracking services to better plan and promote walking and cycling in cities,

[2] http://app.cycleprint.eu/.
[3] http://www.briders.nl/.
[4] https://www.strava.com.

but also developing tracking tools that will fuel the take up of walking and cycling measures.

Dedicated TRACE tracking-based tools to promote behaviour change and support mobility planning were tested so far in eight different European cities or regions: Breda (NL), Águeda (PT), Southend-on-Sea (UK), Bologna (IT), Luxembourg (LU), Belgrade (RS), Plovdiv (BG) and Flanders (BE), and evaluated in terms of impacts, success factors and benefits.

All the apps and initiatives developed under the TRACE project, but also other commercial apps like Strava, Moves[5] or Naviki[6] (just to name a few), generate GPS data of walking or cycling trips, which can be very valuable for planning and policy-making purposes.

To that end, it is necessary to "transform" the available data into clear and legible information. TATo (acronym for "Tracking Analysis Tool") translates that georeferenced trajectory data into useful indicators and analyses that characterize the observed flows over the mobility network, through indicators that reveal the demand for cycling and walking, its behaviour and the performance of the existing infrastructure. It is created to address the needs of cities, transport authorities or organizations that want to analyse their data and characterize its demand and infrastructure.

In fact, during the project, the potential of using tracking data to influence policy processes, particularly in the mobility and urban planning areas was very clear. According to the workshop participants and to the surveys carried out, the GPS trajectories of cycling ("rough") are nowadays a valuable source of information for 62% of transport consultants. However, it was surprising to note that the perceived utility of this type of tool by the stakeholders consulted was more "political" rather than technical: the number one reason for using trajectory data was to "communicate with policy makers".

TATo is already referred in the CIVITAS Tool Inventory[7].

3.1 Development Objectives

Therefore, the high-level objectives for the development of this tool were to make available to stakeholders, particularly mobility planners and policy makers, relevant information on the use of walking and cycling infrastructure, enabling them to identify needs and problems, prioritize actions and evaluate measures.

The specific objectives for the tool were to:

- Translate walking and cycling trajectory data into relevant indicators;
- The output on indicators should be applicable for analysis in GIS tools;
- The tool should be compatible with different trajectory data (from multiple sources), map data and GIS tools;
- The tool should be, as much as possible, easy to use.

[5] https://moves-app.com/.
[6] https://www.naviki.org/.
[7] http://civitas.eu/tool-inventory/tatoo-tracking-planning-tool.

Emphasis is given to the strategic option not only to use data from a diversity of sources (the historical input data can be collected from any tracking application according with general specifications), but also to provide the ability to use its results on an open basis, i.e., the results should be presented in such a way that any existing commercial or open source transport planning and/or GIS tool should be able to read them and produce outputs and visualizations.

3.2 TAToo Indicators

The selection process of the indicators to be included in TAToo was based on a stakeholder consultation (predominantly mobility technicians and user representatives), not only through surveys but also by a workshop that occurred in 2016, resulting in a list of desirable indicators (classified in terms of importance and its development priority).

TAToo calculates indicators for four "dimensions" of network analysis: "nodes", "links", "zones" and origin-destination pairs (Table 1).

Table 1. Indicators calculated in each dimension.

	Node	Link	Zone	OD pair
Volume of users	✓	✓		✓
Number of trips (origin)			✓	
Number of trips (destination)			✓	
Average speed		✓		
Level of service	✓	✓		
Average distance				✓
Average trip time				✓
Congestion		✓		
Waiting time	✓	✓		

It is worth to mention the concept applied to two of the indicators ("congestion" and "level of service") as they reflect the topic of the call to which TRACE applied and relate to the developments of the FLOW project[8] (other ongoing H2020 project). Unlike motorized traffic, "congestion" of pedestrians and cyclists is a concept with a limited application in most urban mobility planning environments, and the definition of what it should be is not widespread. TAToo considers a definition similar to the one applied for car traffic, where the indicator reflects in some way what is the loss of time in relation to a free flow situation, where free flow speed is defined by the average speed that occurs when the infrastructure is uncongested, i.e. there are no delays caused by other vehicles. This definition is static in relation to the design of the infrastructure, in the way that it considers free flow speed for the infrastructure as it is (including for example traffic lights).

To fully accommodate the multimodal time assessment, TAToo also considers the Level of Service as an additional indicator, which does not take the infrastructure design

[8] http://h2020-flow.eu/.

as static, by considering a free flow speed that corresponds to the average speed that would happen if there would be no constraints whatsoever (like traffic lights) in the infrastructure. The level of service indicator thus allows assessing the time conditions for a mode independently of the current infrastructure design. In other words, it considers both the time delays caused by other vehicles or people and by infrastructure constraints. In this scope, it is the indicator that should be considered when assessing possible infrastructure design changes.

3.3 TAToo Application

The "map-matching" algorithm developed by PTV SISTeMA and improved specifically for walking and cycling trajectories consists in the allocation of the recorded trajectories into the nodes, links and zones of the network, creating the possibility of allocating location trajectories given by points into concrete links and nodes where each person/vehicle has passed.

One of the strong aspects of the tool is the possibility of using a city's own map (e.g., from their own GIS system) or to automatically download a map based on OpenStreetMap (OSM), which is available worldwide. The conversion required from the OSM format to the one required by TAToo is done by the module developed by INESC-ID. TAToo also allows a user-defined zoning system, like parishes or neighbourhoods, but in case the user does not have his own zoning, the tool is able to create one automatically.

Segmentation by user type, with gender, age, employer, or any other available parameter that is useful to perceive the behaviour of different segments of users, is also a reality. Analyses can also be viewed separately for each day of the week and period of the day.

Once the desired information is filtered, the results can be viewed using GIS software and graphics produced by TAToo itself. To facilitate visualization in GIS and to enhance its use by non-proficient users, the tool automatically produces a set of thematic maps that can be viewed in the free QGIS software.

4 The Cloche d'Or Trial

A partnership between the Corporate Social responsibility network IMS Luxembourg and the mobility consulting company LuxMobility (member of the TRACE project consortium), co-financed by the European Commission and the Luxembourg Ministry of Sustainable Development and Infrastructure, worked with seven major employers (total of 7.800 employees) of the district of Cloche d'Or, in Luxembourg, and decided to tackle local mobility problems that have cross-border origins and effects [5].

Using the mobile application "Positive Drive" (from the TRACE project), 750 employees of the participating companies had their mobility behaviour analysed, by being tracked during five consecutive weeks (between May and June 2017) and a total of 27 working days. Although TAToo aims to analyze essentially walking and cycling trajectories, it is possible to combine almost every type of mode, as long as the data available allows the identification of the tracked mode.

Overall, about 18 million data points were collected, covering a total distance of more than 1,5 million travelled kilometres and above 19.000 "daily trips" (includes the home-work-home path). After the removal of weekends, holidays, data points before 6:00 a.m. and after 8:00 p.m. and outside the defined "gamezone", over 7,5 million data points were considered for analysis.

A zoning system based on the administrative boundaries of Luxembourg, Belgium (Wallonia region), Germany and France (Moselle, Meurthe-et-Moselle and Meuse communes), plus a dedicated zone considering the Cloche d'Or area, was created, leading to a total of 1.020 zones. The map with the network was extracted from OpenStreetMap.

The used configuration parameters limited the analysis to the weekdays and to the five segments of the trips (walking, cycling, car, bus and train), although the mode detection of the app was not highly reliable in this phase; for this reason, a cleaning process was mode in order to work mainly with the car trajectories.

Different maps were produced, showing the trip volume in each link (Fig. 1a) or node, and the trips from and to the Cloche d'Or district (Fig. 1b), usually for each period of 30 min of the morning and evening peak periods (6:00 a.m. to 9:30 a.m. and 4:00 p.m. to 7:30 p.m.). Maps for the entire day were also produced.

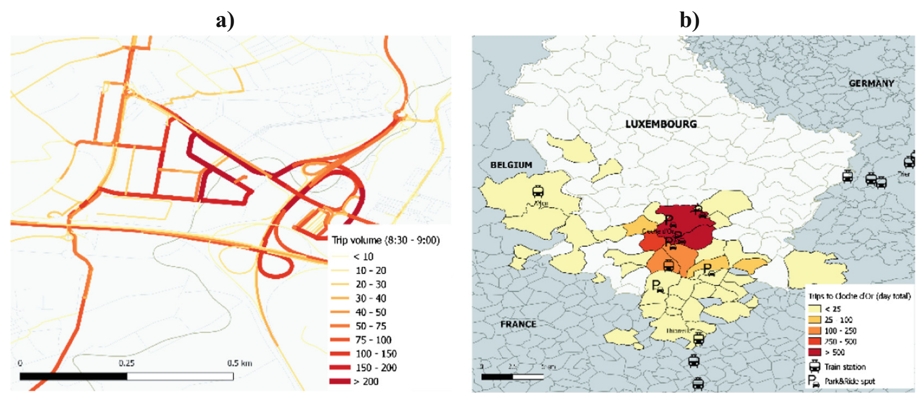

Fig. 1. Examples of results given by TAToo – (a) trip volume in the links; (b) volume of trips ending in the Cloche d'Or district.

Using the data calculated for the nodes, a "carpool potential" analysis was developed, using an empirical formulation given by the following formula:

$$CP_t = \frac{V_{it} \cdot \varepsilon_i}{d_t} \tag{1}$$

V_{it} stands for the volume in the node i in the time period t, ε_i is the distance between the node i and the centroid of the Cloche d'Or zone, and d_t is the duration of the analysis time period t. Therefore, CP_t would be defined as the "car.km/hour travelled from/to Cloche d'Or".

The results are presented in Fig. 2. This figure shows that there a couple of places – nodes of the network – where the volume of trips by car increases substantially and creates a corridor in the direction of the Luxembourg city. Some of these nodes occur in zones like Arlon (Belgium) or Thionville (France), which would become potential places for "carpooling strategies" organized by the Cloche d'Or companies.

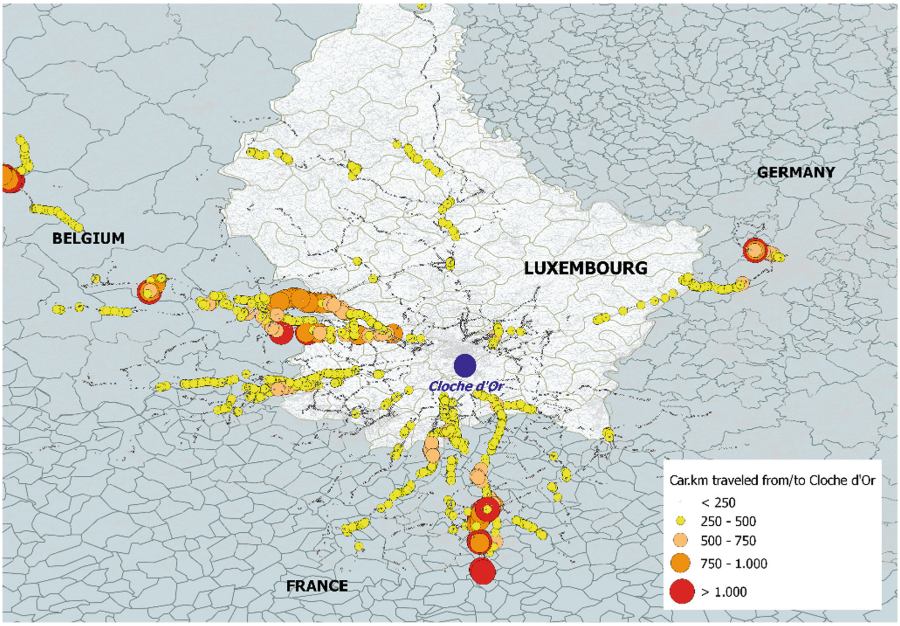

Fig. 2. Results from the "carpool potential" analysis during the morning peak period.

5 Final Remarks

TATоо is a joint development of TIS[9] (a consultancy company specialized in mobility and transport, based in Lisbon, Portugal), INESC-ID[10] (a R&D institute dedicated to advanced research and development in the fields of information technologies, electronics, communications and energy, based in Lisbon, Portugal), both members of the TRACE project consortium, and PTV SISTeMA[11] (a company of the PTV Group founded in 2009 with headquarters in Rome, Italy).

The tool aims to go beyond the state of the art of the existing applications by providing a lightweight, interoperable and multi-purpose information tool that can be

[9] http://www.tis.pt.
[10] http://www.inesc-id.pt.
[11] http://www.ptvgroup.com/it/.

coupled with any existing commercial or open source transport planning and/or GIS tool.

Although it is not clear yet what the actual influence of tracking data might become in the future, TATioo will turn possible, for instance, the calculation of global indicators describing pedestrian and cyclable mobility in a given area. This should allow not only comparisons between different locations, but also to analyse specific characteristics of the flows in an area, and which are the most chosen routes. The preparation of sustainable mobility plans and the definition of cycling or bikesharing networks should be facilitated with a tool like this. At a more “micro” level, it should be possible to draw relevant conclusions from TATioo on possible network bottlenecks or to identify sites with lower circulation quality. It is also possible to monitor the effect of interventions on the network, or to cross the tool’s indicators with other available information (such as the influence of land uses on the use).

Indeed, apart from the results from the Cloche d’Or district trial, a big number of other analyses were developed using the data provided by the TRACE project apps but also by other commercial and research apps: comparisons with zones travelling potential in Lisbon (Portugal), preferred paths in universities’ campus in Oporto (Portugal), confirmation of the higher walking potential of some streets in Hasselt (Belgium), just to name a few. These new possibilities not only complement the existing information used by the decision-makers, but also expand the set of analyses that can be developed to support the actual decisions.

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Combining Land Use, Traffic and Demographic Data for Modelling Road Safety Performance in Urban Areas

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Abstract. Road accidents form a leading cause of death globally. Despite the recent progress that have been made, Greece continues to be among the worst performing countries in the EU, in respect to road safety. This research deals with the spatial analysis and modelling of road accidents, in the metropolitan area of Thessaloniki, Greece. Total accidents pertained to be the dependent variable whereas various land use, demographic and macroscopic traffic modelling data were considered as explanatory variables. As required, the model inputs were aggregated to the TAZ level. First, a properly specified OLS model was developed, followed by the application of the GWR method. Unlike OLS models that are considered to be global, GWR allows the relationships modelled to vary over space, in line with spatial non-stationarity of social processes. This latter approach, improves the goodness of fit statistics of the OLS model and is helpful for policy-making at a local scale. A number of interesting correlations have been found, between accidents and a variety of statistically significant factors, such as the number of leisure establishments, pedestrian volume and length of particular types of roads. The GWR model built, uncovered the spatially varying relationships, dictating specific areas where these explanatory variables are strong or low predictors of the dependent variable.

Keywords: Spatial data analysis · GIS · Road traffic accidents
Ordinary least squares regression – OLS
Geographically Weighted Regression – GWR

1 Introduction

Road traffic accidents have emerged as a crucial public health issue, forming a leading cause of death globally [1]. Given the vital importance of road safety, several studies have explored the relationships between accident statistics and a variety of explanatory variables. Most of the statistical models developed are Generalized Linear Models – GLMs, which are global oriented: this kind of models represent the relationships between the dependent and a set of explanatory variables, estimating global regression parameters that are fixed over space [2].

However, socio-spatial processes are characterized by "*spatial non-stationarity*", meaning that the degree of influence that each factor has on the phenomenon examined

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may differ locally [3]. As a consequence, the utilization of global models may lead to misleading results in terms of local scale, covering up the potential underlying spatial variations. To fill this gap, various local model approaches have been developed, also termed "*spatial models*". The latter take into account the special characteristics of spatial data in their computations, being a part of spatial data analysis [4].

The method utilized in the present study, "*Geographically Weighted Regression*" (*GWR*), is a relatively new method used in spatial modelling, that takes into account the spatial non-stationarity of social processes. GWR is a sophisticated extension of the conventional linear regression framework, allowing different relationships between the variables examined to exist, at different points in space [5]. Shortly, GWR constructs a separate local model/equation for each point in space (regression point i), in the calibration of which all or some observations of the dataset are taken into account, after having been weighted in accordance with their proximity to the regression point. For detailed information on the theoretical background of GWR, the reader is referred to [3, 5].

Although widely utilized in several research fields, there are only a few GWR applications in transportation field, the majority of which are related to traffic safety. Vaz et al. [6], Erdogan [7], Zheng et al. [8], Rhee et al. [9], Hadayeghi et al. [10] built GWR models, seeking to detect spatial variations in the relationships between accident statistics and different sets of explanatory variables. Despite their differences in terms of the dependent and explanatory variables as well as the geographic units used, all the above-mentioned studies concluded that GWR approach yielded more accurate and reliable results, providing a better statistical fit than the conventional models built by capturing spatial non-stationarity.

The contribution of this paper is twofold. First, we identify the major factors that are correlated with and affect the total number of road traffic accidents at the TAZ level of the study area, developing a conventional OLS model. Second, we examine the potential existence of spatial variations in the relationships modelled, in order to identify the different degree of influence of each parameter across space. To that end, we develop a Geographically Weighted Regression – GWR model. The introduction of the space component in the forthcoming road traffic accidents modelling attempt, will reveal the local relationships and processes that may characterize the phenomenon examined, helping stakeholders to design localized interventions.

The rest of this paper is structured as follows: Sect. 2 presents the research methodology used in the study, in relation to the data collection and preparation process and the models' development. Section 3 provides and discusses the results of the OLS and GWR models developed, before moving into Sect. 4, which concludes the paper with recommendations for future research.

2 Methodology: Data Collection, Preparation and Methods Used for Models' Development

The required information to develop the road accident models consist of accident data, accompanied with network - traffic, land use and demographic data. Information for accidents occurring in the regional unit of Thessaloniki in 2015 was recorded and provided by the local traffic police department, in a spreadsheet format. The database contained 1.904 crashes, 1.109 of which were falling within the metropolitan area of Thessaloniki and geocoded using the Addr. Locator tool in an ArcGIS environment.

Hourly peak morning traffic data have been provided by the VISUM macroscopic 4-step model of the greater Thessaloniki area, developed by the Laboratory of Transportation Engineering of Aristotle University of Thessaloniki. Data included link-based (length, category/hierarchy, number of lanes, free flow and current speed, traffic and pedestrian volume, capacity and vehicle kilometers travelled), node-based (signalized and non-signalized nodes, traffic volume and number of links served by each node) and Public Transport bus stop-based information (number of bus lanes passing, number of boarding, alighting and transfer passengers). These line and point data were exported from PTV VISUM to shapefile formats and imported to ArcGIS.

Further, data related to road network characteristics, transport infrastructure and land uses, were collected by different open internet sources [11, 12] in shapefile formats and imported to ArcGIS as well. Data included the exact locations of pedestrian crossings, stop signs, traffic lights, bus and railway stations, leisure establishments, green areas, etc. Demographic data, namely the permanent population aggregated to the TAZ level of the study area, was collected in shapefile format and provided by the aforementioned Laboratory. Moreover, some information was manually digitized in ArcGIS, such as the exact locations of schools and metro construction sites.

The geographic units chosen to be used for the statistical analysis/modelling exercise, were the 243 TAZs of the study area. All the above-mentioned data were transformed into the Greek Grid national projected coordinate system and aggregated to the aforementioned geographic units.

A total number of 45 GIS developed candidate explanatory variables was formed and examined, largely based on the international literature. The OLS model was developed in an ArcGIS environment, using the technique of backward (step-down) selection. The model initially included all the 45 candidate explanatory variables and at each step, the least statistically significant variable was removed. The process was continued until no nonsignificant variables remained. The level of statistical significance was taken as $\alpha = 0{,}05$.

After confirming the cut-off criteria[1], which dictated that a properly specified OLS model had been constructed, a GWR model was developed in an ArcGIS environment as well. The spatial non-stationarity in some of the relationships modelled was implied by the Koenker (BP) Statistic, which appeared to be statistically significant (p value < 0,05). The GWR model included the explanatory variables, the coefficients of which were found to be statistically significant in the OLS model. An adaptive rather than a fixed spatial kernel was used, the bandwidth of which was chosen to be automatically optimized using the AICc [3].

[1] (1) confirm that coefficients have the expected sign, (2) check for redundancy among the explanatory variables – VIF values < 7,5, (3) check that the coefficients of all the explanatory variables are statistically significant – p values < 0,05, (4) examine if the model's residuals are normally distributed – Jarque-Bera Statistic has to be statistically nonsignificant (p value > 0,05), (5) check model's performance – adequately high R^2 and Adj R^2 values, (6) check that model's residuals are free from statistically significant spatial autocorrelation - –1,96 < Global Moran's I z score < +1,96.

3 Models' Results and Further Discussion

Presenting the appropriate statistics, the current section provides the results of the OLS and the GWR models developed, while a comparison is being made with the results of relevant studies. The results for the global – OLS model, are presented in Table 1. The explanatory variables that found to be significantly associated with the dependent one, are:

- number of leisure establishments (nm_lei_est)
- number of bank branches (nm_bank)
- number of traffic lights (nm_tra_lig)
- permanent population (perm_popul)
- average number of alighting and transfer passengers at bus stops (nm_pal_avg, nm_ptr_avg)
- total length (in kms) of collector – distributor roads (li_tp5_len)
- total road network capacity (cap_prt_su)
- total pedestrian volume (vol_per_su)
- total length (in kms) of 2, 4 and 6 – lane roads (li_2la_len, li_4la_len, li_6la_len)

Table 1. Summary of OLS Results – Total Accident Model.

Variable	*Coefficient*	*StdError*	*t-Statistic*	*p-value*	*VIF*
Intercept	–0,217283	0,344958	–0,629881	0,529398	—
NM_LEI_EST	0,156854	0,046893	3,344897	0,000973*	1,921903
NM_BANK	0,593020	0,213389	2,779050	0,005902*	1,569933
NM_TRA_LIG	0,379031	0,071986	5,265351	0,000001*	1,589245
PERM_POPUL	0,000603	0,000072	8,358685	0,000000*	1,433915
NM_PAL_AVG	–0,006185	0,002712	–2,280475	0,023483*	2,702895
NM_PTR_AVG	0,011365	0,005116	2,221333	0,027291*	1,468504
LI_TP5_LEN	0,902999	0,366811	2,461753	0,014551*	1,425019
CAP_PRT_SU	–0,000051	0,000025	–2,031164	0,043382*	3,674251
VOL_PER_SU	0,000143	0,000041	3,452534	0,000673*	2,980714
LI_2LA_LEN	1,392235	0,434544	3,203900	0,001559*	1,254749
LI_4LA_LEN	2,546445	0,972612	2,618152	0,009422*	1,350105
LI_6LA_LEN	5,237709	2,089957	2,506133	0,012889*	2,133739

OLS Diagnostics	
Dependent Variable: Total Accidents	Number of Observations (TAZs): 243
Multiple R^2: 0,64	Adjusted R^2: 0,62
Akaike's Information Criterion (AICc): 1193,8	Moran's I (Std. residual): 0,027 (z-score: 1,52)
Koenker (BP) Statistic: 32,6 Prob (> chi-squared), (12) degrees of freedom: 0,001116*	
Jarque-Bera Statistic: 11,8 Prob (> chi-squared), (2) degrees of freedom: 0,002680*	

* indicates significant level < 0.05

The results for the GWR model, are presented in Table 2. Since GWR technique constructs individual regression equations for all 243 TAZs, only the minimum and maximum value of the estimated regression parameters for each explanatory variable are presented. It is worth mentioning that all 243 neighbors/TAZs were incorporated in the calibration of each local model, in line with the optimized bandwidth suggested by the AICc.

Table 2. Summary of GWR Results – Total Accident Model.

Variable	*Coefficient*		*GWR Diagnostics*
	min	*max*	
Intercept	-0,376363	0,112267	Dependent Variable: Total Accidents Bandwidth (Neighbors): 243 Residual Squares: 1629,90 Multiple R^2: 0,66 Adjusted R^2: 0,63 Akaike's Information Criterion (AICc): 1195,6 Moran's I (Std. residual): 0,029 (z-score: 1,59)
NM_LEI_EST	0,151473	0,192602	
NM_BANK	0,239659	0,930106	
NM_TRA_LIG	0,363165	0,408422	
PERM_POPUL	0,000475	0,000603	
NM_PAL_AVG	-0,007581	-0,005967	
NM_PTR_AVG	0,01088	0,01376	
LI_TP5_LEN	0,46216	1,275638	
CAP_PRT_SU	-0,000066	-0,000032	
VOL_PER_SU	0,000118	0,000159	
LI_2LA_LEN	1,300984	1,581078	
LI_4LA_LEN	1,99662	2,944211	
LI_6LA_LEN	3,958806	6,324557	

GWR results can be cartographically represented, in order to depict the different effect of explanatory variables for different TAZs within the study area. In this way, TAZs with higher than average coefficients can be identified. In accordance with relevant studies, the graduated color renderer was used to depict the local coefficient estimates of GWR, being one of the most widely used renderer types in order to represent quantitive information – especially for polygon feature classes. The classification - namely the number of classes and the class breaks - was manually adjusted, depending on the difference between the minimum and the maximum value of the locally estimated regression parameters for each explanatory variable and in order for these differences to be noteworthy and visible.

Figure 1 shows the estimated parameters for each TAZ, regarding the total length of collector – distributor roads. Taking into account that the average coefficient for this explanatory variable is 0,89, total length of collector roads has a greater influence on the total number of road traffic accidents in TAZs located at the city center and in northwestern areas of Thessaloniki, compared to TAZs located in southeastern areas. Figure 2 depicts the spatial variation of the estimated regression parameters, concerning the total pedestrian volume. The relationship between the total number of road traffic accidents and total pedestrian volume, seems to be slightly stronger in TAZs located in the northwestern areas of Thessaloniki compared to TAZs located at the city center and in the southeastern areas. In other words, the total pedestrian volume variable is a stronger predictor of the total number of road traffic accidents, in TAZs located in the northwestern areas of Thessaloniki.

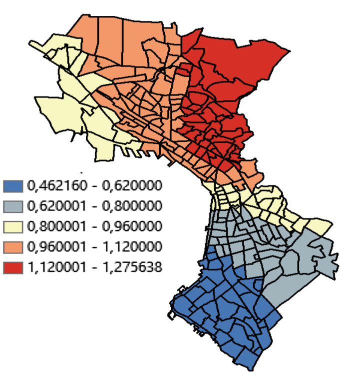

Fig. 1. GWR coefficient estimates on the total length of collector – distributor roads.

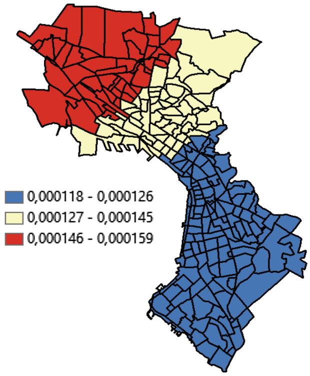

Fig. 2. GWR coefficient estimates on the total pedestrian volume.

The results of the OLS regression, presented in Table 1, can provide various outcomes regarding the relation between the dependent and explanatory variables: Concerning demographic factors, more accidents occurred in TAZs with higher population density. Permanent population reflects exposure and was found to be positively correlated with frequency of road traffic accidents. Increased pedestrian exposure – expressed by total pedestrian volume – was also found to be an important contributing factor to high accident frequency. Further, as it has already been suggested by previous researches [13, 14], increased road length leads to increased number of crashes. The types of roads the length of which was found to be significantly and positively associated with higher number of road traffic accidents, are the collector-distributor roads as well as the two, four and six – lane roads. This may be due to the poor road geometrics of some collectors and the increased traffic congestion that is experienced by wider roads, which increases crash risk.

A larger number of leisure establishments in a TAZ was found to be linked with more accidents. This may possibly be relevant to the increased alcohol consumption, which is observed in areas with such land uses. Number of bank branches, which was used to determine the degree of centrality of each TAZ, was also found to be positively correlated with the number of accidents. Such finding suggests that the number of accidents increases, as the distance between TAZs and CBD areas of each municipality decreases. Furthermore, higher traffic light density was found to lead to increased number of accidents. Taking into account that most of the traffic lights are positioned at road intersections, the aforementioned positive relationship is in line with relevant studies [15, 16] which have already suggested that more accidents occur in areas with higher intersection densities.

Bus stops are points where the possibility of conflicts between the different road users is higher [9]. Despite the fact that the total number of bus stops was not found to be correlated with the total number of accidents, the increased average number of transfer passengers at bus stops appeared to be significantly associated with higher accident frequency. On the contrary, the coefficient of the average number of passengers alighting at bus stops appeared to have the unexpected (negative) sign. Nevertheless, the variable was chosen not to be omitted from the OLS model, in order for the GWR model to indicate if there are some individual TAZs where this relationship is positive.

Total road network capacity was found to be negatively associated with the total number of accidents. Generally speaking, the relationship between the road network capacity and the number of accidents remains unclear and volume over capacity ratio is widely used instead, determining the traffic congestion. Previous researches [10, 17] have been found this relationship either negative or following a U-shaped graph.

4 Conclusions and Recommendations for Future Research

In this research, a practical application of the GWR technique for the spatial analysis of road traffic accidents, is presented. The GWR model captured spatial non-stationarity, but the goodness of fit was not significantly improved compared to the OLS model. Based on the Multiple R^2 and Adjusted R^2, the GWR model performed slightly better than the OLS model. On the other hand, based on the AICc which also takes into account models' complexity, the OLS model appeared to be slightly better. The difference between the AICc values for OLS and GWR model appeared to be less than 3, meaning that there is little to choose between the two models.

Poisson or Negative Binomial regression, are considered to be more appropriate than linear regression methods for analysis of count variables, such as road traffic accidents. OLS and GWR are both linear regression methods, a basic assumption of which is that models' residuals are normally distributed. The latter hypothesis was found to be violated by the Jarque-Bera Statistic. Probably, an extended Geographically Weighted Poisson Regression (GWPR) approach would yield better results.

So far, we have developed an OLS model to identify the major contributing factors to the total number of road traffic accidents and a GWR model to uncover the spatial variations in the relationships modelled. Our next step in the research is to include more candidate explanatory variables in order to strengthen models' predictive power and also to develop different models for different accident categories (accidents occurring on intersections, accidents involving pedestrians, accidents occurring during peak and non-peak hours, etc.). Future work will explore the potential weighting of the dependent variables (number of accidents/population or m^2 area) and will use accident data referring to other years for models' enrichment and validation purposes. Another research topic is to develop different types of models – such as GWPR models, Poisson and Negative Binomial regression models – using the appropriate software packages, in order to provide comparisons between their results.

To conclude, the GWR model built uncovered the spatial variation in the relationships modelled, dictating TAZs where explanatory variables have a greater influence on the total number of road accidents. In broad terms, the emerging spatial variation of the locally estimated regression parameters did not appear to be quite intense. Such fact is dictated by the relatively small differences between minimum and maximum values of local coefficient estimates, the absence of spatial structure/autocorrelation in the OLS model's residuals and the suggestion of the AICc in order for all the neighbors/TAZs to be incorporated in the calibration of each local model.

The different effect of independent variables for different TAZs, should be a stimulus for local remediation strategies in order for the road safety level to be improved. For example, TAZs located at the city center and in northwestern areas of the city should deal with the poor geometrics of the collector roads (Fig. 1). Moreover, pedestrian quality of service improvement is mainly required in TAZs located in the northwestern areas of Thessaloniki (Fig. 2).

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Urban Form and Transportation Infrastructure in European Cities

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Abstract. In this paper data from the 2006 Urban Atlas are used to analyze the relationship between urban form and the length of the road network. Urban Atlas includes information on the land use in every city block of the 305 largest cities in EU. The length of the road network (highways, other roads) is estimated from the UA data and road availability indicators are introduced. Various urban form characteristics are estimated from the UA and reported for 5 different European regions (UK & Ireland, Scandinavia, Central Europe, East Europe and South/Mediterranean countries) and 5 different city size groups. Urban form characteristics and population densities differences are reflected in the road availability indicators. The results of a correlation analysis between road availability indicators and the various urban form characteristics are reported. A regression analysis is performed and the results show that the road indicators are a function of urban form characteristics.

Keywords: Urban form · Transportation infrastructure · Built up densities
European cities · Urban Atlas

1 Introduction

Urban form is related to the built up areas characteristics and the geometry of the cities and is defined by the densities, the land uses and the transportation infrastructure. Urban form changes through time since cities expand in the periurban areas, new construction and/or redevelopment lead to a different spatial distribution of densities and new transportation networks affect accessibility and land uses. Transportation infrastructure is a necessary ingredient of urban form analysis since it separates the urban area into a well-organized pattern of city blocks and accounts for 20% of built-up areas in EU. The components of the transportation system (road network, transit system, bus system, and various transport related operators) collectively provide connectivity among different neighborhoods and activities. Connectivity affects accessibility, the ability to reach desired destinations goods, services and activities- at a minimum cost, least environmental impacts and at the greatest convenience for the trip maker. Urban form and connectivity define mobility, the actual movement of people in urban areas expressed as km travelled per person and other similar indicators.

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Analysis of the relationship between urban form and trip making usually concentrates on analyzing various mobility, environmental and energy consumption aspects of urban transport. Emphasis is placed on analyzing travel propensity in different neighborhoods with similar or different urban form and/or socioeconomic characteristics [1–8]. A typical analysis estimates various travel behavior characteristics (the number of vehicle miles travelled, modal split, energy consumption etc.). In this paper a different approach is followed. Using 2006 Urban Atlas the length of the road network in European cities is analyzed as a function of urban form characteristics such as distribution of built-up densities, characteristics of the geometry of the city blocks and population density.

The Urban Atlas (UA) database was released by EEA in 2011 [9]. It is a database that includes land use information for the 305 largest EU cities for year 2006. Twenty different land use classes are recognized, 17 of which represent artificial surfaces that is land that is developed/built-up. Six of the classes are referred to as "urban fabric" and represent areas of different built-up densities and are usually associated with residential areas. There is information on the land use of every city block. With the UA data the road network length can be estimated and road network "availability"/ "density" network indicators (population/road network) can be related to urban form characteristics such as the distribution of built up density levels, land uses and the geometry of the city (area and perimeter of the city blocks). The analysis is "supply" driven since the focus is on indicators that describe road network availability and not trip making rates. It is also aggregate since it covers the whole urban area and differences in densities/land use mix and the provision of transport infrastructure in different subareas are not considered.

The paper consists of 5 parts. In the second part there is a description of the Urban Atlas dataset and the transport related indicators that can be estimated from these data. In the third part a comparative analysis of the European cities in different regions with respect urban form and the size of the road network is provided. The results of a correlation analysis between transport infrastructure and other aspects of urban form and of a regression analysis between road network availability indicators and urban form characteristics are reported in the fourth section. Conclusions and issues for further research are presented in the last section.

2 Datasets and Indicators to be used

The UA database identifies 20 different land use classes; 17 represent "artificial" surfaces, built-up areas and areas that have a designated purpose in the urban environment/ecosystem (for example green areas). Six of these, urban fabric, describe different built up density levels on the basis of the imperviousness/soil sealing degree (s.d.). Soil sealing degree values are between 0% and 100% (fully developed) and represent for every urban fabric polygon the loss of soil resources as result of the coverage of land by housing, roads or other construction [10]. The group of the remaining 11 artificial classes includes 5 classes for transport infrastructure (fast transit roads, other roads, railroads, ports and airports), and 6 classes for other uses (industrial/commercial/public facilities, mineral extraction/dump sites, construction, land without use, green urban areas and sports/leisure facilities). In addition to the 17 artificial area classes, there are 3 classes that account for the non-developed/natural land (agricultural/semi-natural/wetlands, forests and water bodies).

The database is in vector format and has been developed from the analysis of satellite images of 2006 ± 1 year. The map scale is 1:10.000 and minimum mapping unit is 0.25 ha (50×50 m). The high resolution of the database permits the identification of all city blocks as separate entities with their associated land use. Roads are also identified as a separate land use. This is true for both central city areas with high densities but also for periurban areas where densities are significantly lower. Data are available for 305 urban areas in EU for which statistical information are published through the Urban Audit program (http://ec.europa.eu/eurostat/web/cities/data/database). The cities participating in the Urban Audit program include most EU cities with population exceeding 100,000, but also some with less population. Recently, EEA updated the 2006 UA database, however the analysis reported in this paper is based on data available on line until 2017 (currently available at https://www.eea.europa.eu/data-and-maps/data/urban-atlas). EEA also issued the 2012 version of Urban Atlas with land use information for year 2012 (http://land.copernicus.eu/local/urban-atlas/urban-atlas-2012).

An important issue when analyzing urban areas is the delineation of the boundaries of the area to be studied. Eurostat defines three concepts with respect the territorial extent of cities (http://ec.europa.eu/eurostat/web/cities/spatial-units); the Core city is the core administrative unit of the area and its name defines the whole area; the Greater city is an approximation of the urban area and stretches far beyond the administrative boundaries of the core city and; the Functional Urban Area, or Larger Urban Zone (LUZ) that covers an area significantly larger than what would be normally considered metropolitan area. Land use information in UA are available for the whole LUZ area and this is the level of analysis used in this paper. For the average city, artificial surfaces account for 15% of total land with the remaining being natural areas (agricultural, forests etc.). In the 305 UA cities urban fabric accounts for 48% of artificial land, industry 19%, transport infrastructure 19%, sports and recreation areas 6%, green areas 6% with the remaining classes each accounting for less than 2% of the built up area.

The analysis of the transport infrastructure in this paper concentrates on the road network that is the two land use classes, "highways" and "other roads", which account for 17% of the artificial surfaces. Since the road network length is a function of the urban area size and population, two indicators are introduced for comparing cities. These are:

(a) Population based road network availability (PRA): it is defined as the ratio of the road network length and population and is expressed in meters per person. Low values imply that the network is less dense, whereas high values that the network is more extensive.
(b) Developed area road network availability (DRA): it is defined as the ratio of the road network length and the artificial surfaces area and is expressed in m/ha (meters of road network per hectare of developed land). Low values imply that compared to the size of the area the road network is more compact whereas high values imply that the road network is more extensive.

It should be acknowledged that the length of the road network is estimated using the UA data and therefore depends on the accuracy of the road representation in this database. An alternative procedure would be to estimate road network from the OpenStreetMap (OSM).

3 Data by Country, Region and Population Size

Urban form characteristics of individual cities are summarized by region and by population based city-size groups. Five different regions are recognized:

- UK/Ireland: UK and Ireland
- Scandinavia: Denmark, Sweden, Finland
- Central Europe: France, Germany, Belgium, Netherlands, Luxemburg, Austria
- South Europe: Portugal, Spain, Malta, Italy, Greece, Cyprus
- East Europe: Poland, Czech Republic, Hungary, Slovakia, Slovenia, Romania, Bulgaria, Latvia, Lithuania, Estonia

Cities are grouped into 5 different groups on the basis of their population size (Table 1). In the following discussion the term "large cities" is used to define cities with population exceeding one million people. Population density (population divided by artificial land) for each region and city size group is presented in Table 1. Population density is the lowest in Scandinavian cities and the highest in South European cities. Population density differences between the large cities in South EU and the other European cities are very significant. In all regions population density increases as the size of the city increases. Table 2 shows of urban fabric (UF) distribution among the six urban fabric classes that describe built up levels. For cities in UK/Ireland and Scandinavia high density built-up areas account for a very small percentage of urban fabric (3%) whereas for cities in East EU they represent 23% of the urban fabric. Low density areas (sealing degree > 30) represent 66% of urban fabric in Scandinavia, 37% in South EU and only 12% in East EU.

Table 1. Population densities (persons/hectares of artificial surface).

City size/Region	Pop < 200*	Pop 200–500*	Pop 500–1000*	Pop 1000–2000*	Pop > 2000*	All cities
UK/Ireland	10	18	25	25	36	28
Scandinavia	8	11	13	22	18	15
Central EU	17	19	23	26	32	26
South EU	16	24	32	45	58	39
East EU	18	19	21	25	34	23
All cities	15	19	23	28	37	27

* Population in thousands (000), Population estimates are for years 2013/2014 and were obtained from the Urban Audit database in 2015.

Table 2. Distribution of urban fabric among the six classes.

Land use class/Region	% UF_1 s. d: 80–100	% UF_2 s. d.: 50–80	% UF_3 s. d.: 30–50	% UF_4 s. d.:10–30	% UF_5 s.d.: <10	% UF_6 isolated Struct.
UK/Ireland	3	41	34	12	1	10
Scandinavia	2	15	16	24	22	20
Central EU	14	46	23	9	1	6
South EU	18	25	20	19	8	10
East EU	23	48	14	3	0	11
All cities	14	40	22	11	4	10

The Mean Sealing Degree (MSD) of urban fabric is presented in Table 3. It is estimated as the area-weighted average sealing degree of the six urban fabric classes it is therefore an indicator of the average built-up density. The highest density (59) is in the former Socialist European countries in which years of centralized planning have led to very compact cities. The lowest built-up density levels area in Scandinavia (25), while the second lowest density levels are in UK/Ireland (45) and South EU (45).

Table 3. Mean sealing degree.

City size/Region	Pop < 200*	Pop 200–500*	Pop 500–1000*	Pop 1000–2000*	Pop > 2000*	All cities
UK/ Ireland	33	37	46	47	48	45
Scandinavia	13	24	27	39	15	25
Central EU	53	51	52	56	56	54
South EU	39	43	39	50	51	45
East EU	57	58	55	55	69	59
All cities	44	48	47	52	54	50

* Population in thousands (000)

Table 4 shows some key characteristics of the geometry of UA polygons which as discussed earlier correspond to city blocks. For all regions the average size of polygons is the smallest for class 1 (s.d. 80–100) (isolated structures excluded), probably because they are usually in the older part of the city, and increases for class 2 (s.d.: 50–80) and further increases for class 3 (s.d.: 30–50). Class 4 polygons are slightly smaller than those of class 3. City blocks in South EU cities are significantly smaller than those in cities of other European regions with their area often being only 60%–70% of the area of city blocks in other regions (same land use class). This is a significant difference in urban form and as discussed earlier it has implications for the road network length.

The road network availability indicators (PRA and DRA) for the different regions and city size groups are tabulated in Table 5. The analysis of the two indicators leads to the following conclusions:

Table 4. Average size (ha) and perimeter (m) of urban fabric polygons/city blocks.

Land use class/Region	UF_1 s. d: 80–100		UF_2 s. d.: 50–80		UF_3 s. d.: 30–50		UF_4 s. d.:10–30		UF_5 s. d.:< 10		UF_6 isolated struct.	
Area/Perim.	A*	P**	A*	P**	A*	P**	A*	P**	A*	P**	A*	P**
UK/Ireland.	0.6	365	1.9	834	2.4	963	1.8	656	1.3	510	0.6	334
Scandinavia	1.0	456	2.1	834	2.1	807	1.9	754	1.7	658	0.6	328
Central_EU	1.0	459	1.7	667	1.7	680	1.5	595	1.6	541	0.6	325
South EU	0.6	348	1.0	508	1.2	563	1.1	544	0.9	448	0.5	308
East EU	1.3	549	1.9	702	1.8	667	1.4	585	0.9	453	0.5	300
All cities	0.9	439	1.6	670	1.7	707	1.5	611	1.3	537	0.5	319

* A Area of the average polygon in hectares
** P Perimeter of the average polygon in meters

(a) In all regions both indicators are the highest in small cities (population < 200,000) and then decrease as population increases. This is reasonable since smaller cities are less compact, population density is lower and development is more dispersed.
(b) The differences of the two indicator among regions are usually evident across all city size groups an indication that transport infrastructure provision follows regional/national norms.
(c) The highest PRA indicator (all cities) is in Scandinavia (14.2) which compared to other regions has the lowest population density and the lowest built up density level (as expressed by the MSD variable). The lowest PRA indicator is in UK/Ireland (5.3). In the other regions the values of this indicator are between 6.3 and 7.8.
(d) For large cities (population > 1,000,000) the lowest PRA is in South EU since population density of cities in this region is the highest. The differences of the PRA indicator of large cities in other regions (with the exception of Scandinavia) are not significant (about 20%).
(e) The highest DRA indicators (all cities) is in South EU (242). This can be attributed to the small size of city blocks of all classes and the relatively high percentage of class 1 (18% UF_1) in which polygons are just 0.6 ha. DRA indicators in South EU are the highest for all city size groups. The lowest DRA indicator (151) is in UK/Ireland.
(f) For large cities the highest DRA is in South EU cities. For cities with 1,000,000–2,000,000 population it is 247 while for cities of the same size in other regions it is less than 171. For cities with at least 2,000,000 inhabitants the DRA differences between cities in South EU and cities in the other regions are less pronounced but are still significant.
(g) For all city size groups the lowest DRA indicator is in UK/Ireland an indication that despite the lower population and built up levels (MSD) the transport network fills the urban space more efficiently. This can be attributed to the high percentage of urban fabric being class 2 and/or 3 (75%), two classes in which the area of the average polygon is respectively 1.9 ha and 2.4 ha one of the highest for these

classes. An equivalent argument can be made for large Scandinavian cities; the DRA indicator is about 150, lower than that of Central Europe (about 160) probably because 78% of the urban fabric is class 2,3,4 and 5 and the size of the city blocks for all four groups is about 2.0 ha, whereas average size of city blocks of these four classes in Central Europe is about 1.6 ha about 20% less.

Table 5. Average road network availability indicators (PRA and DRA) by region and city size.

City size/Region	Pop < 200*	Pop 200–500*	Pop 500–1000*	Pop 1000–2000*	Pop > 2000*	All cities
PRA (road network meters/person)						
UK/Ireland	17.7	12.0	6.1	5.9	3.6	5.3
Scandinavia	47.8	20.6	15.5	6.6	8.2	14.2
Central_EU	14.1	10.7	8.5	6.5	4.9	6.9
South EU	21.2	11.3	7.7	5.5	3.0	6.3
East EU	11.4	10.7	9.0	6.9	4.2	7.8
All cities	17.3	11.4	8.5	6.3	4.1	7.0
DRA (road network, meters/ha artificial surfaces)						
UK/Ireland	185	210	156	149	131	151
Scandinavia	361	221	208	145	151	208
Central_EU	234	205	194	171	156	178
South EU	349	273	248	247	177	242
East EU	201	204	186	170	143	182
All cities	262	220	197	174	153	188

* Population in thousands (000)

It must be pointed out that the PRA and DRA indicators represent the supply of the road network and should not be confused with actual mobility patterns. The high DRA indicators in South European cities do not lead to the conclusion that there is more connectivity, and the low DRA indicators in UK/Ireland do not necessarily indicate lack of connectivity. The regional differences of these indicators are the result of the different urban forms and different population densities.

4 Correlation and Regression Analysis

The analysis of the previous section indicates that road network availability indicators are related to urban form characteristics such as population densities and built-up levels. To further explore this relationship a correlation analysis was performed using the data for all 305 cities. The variables used in the correlation analysis describe density levels, while others (city block area, perimeter) describe the geometric characteristics of the urban area. The correlations coefficients appear in Table 6. The acronym "MPA" denotes the average area of the polygons of the respective land use class, "Percent" the percent of urban fabric that this class represents and "Perim" the perimeter of the average polygon of the respective class.

Table 6. Correlation analysis results.

	PRA Meters road per person	DRA Meters road per ha artif.		PRA Meters road per person	DRA Meters road per ha artif.
PRA	1	.676**	MPA_UF	−.304**	−.601**
DRA	.676**	1	MPA_UF_1	−.107	−.392**
Logarithm_total_area	.351**	.175**	MPA_UF_2	−.221**	−.566**
Logarithm_population	−.433**	−.336**	MPA_UF_3	−.195**	−.477**
Popul_density_total area	−.482**	−.372**	MPA_UF_4	−.117*	−.252**
Popul_density_Artif. area	−.620**	−.272**	MPA_UF_5	−.043	−.106
Percent_Artif.	−.504**	−.503**	MPA_UF6	−.075	−.341**
Percent_UF (of Artif.)	−.074	−.326**	Perim_artif_transp[a]	−.383**	−.633**
Mean_sealing_degree	−.494**	−.414**	Perim_artif_UF_transp[b]	−.335**	−.536**
Percent_UF_1	−.333**	−.151**	Perim_UF	−.349**	−.600**
Percent_UF_2	−.317**	−.400**	Perim_UF_1	−.137*	−.413**
Percent_UF_3	−.030	−.096	Perim_UF_2	−.275**	−.583**
Percent_UF_4	.241**	.316**	Perim_UF_3	−.224**	−.431**
Percent_UF_5	.324**	.332**	Perim_UF_4	−.075	−.158**
Percent_UF_6	.524**	.405**	Perim_UF_5	.009	−.010
Percent_UF_5_6	.545**	.468**	Perim_UF_6	−.020	−.206**
MPA_artif_transp[a]	−.350**	−.635**	MPA_Natural_areas	.076	−.060
MPA_artif_UF_transp[b]	−.316**	−.557**	Perim_Natural_areas	.089	−.047

[a] Artificial surfaces area/perimeter excluding the 5 transportation classes
[b] Artificial surfaces area/perimeter excluding the urban fabric and the 5 transportation classes
* Correlation significant at the 0.05 level (2-tailed)
** Correlation significant at the 0.01 level (2-tailed)

The two indicators are correlated to most urban form variables at the 0.01 significance level. The correlations of variables related to population are higher with the PRA indicator, whereas for variables describing city blocks geometry correlations are higher with the DRA indicator. Most correlations are negative with the notable exception of the variables denoting low densities (total area, percent class 4, 5, 6).

A regression analysis was performed to determine the set of variables that replicate the PRA and the DRA indicators. To account for differences arising from the population size of the urban area four 0-1 variables were introduced, one for each city-size group (POP_01_200 takes the value of 1 for all cities with population less than 200,000 and zero for all other cities, etc.). To avoid collinearity problems, since several urban form variables are highly correlated, the set of independent variables considered in the regressions included only variables for which the pairwise correlation was less than 0.6. The results are presented in Table 7.

Table 7. Regressions for the PRA and DRA indicators.

	Unstandardized coefficients		Standardized coefficients	t	Sig.
	B	Std. error	Beta		
PRA Regression, R^2 = .84 (stepwise)					
(Constant)	24.008	4.086		5.875	.000
Logarithm_population	−15.018	.795	−1.693	−18.902	.000
Logarithm_total_area	15.263	.746	1.665	20.461	.000
Pop_density_artf_area	.249	.031	.401	7.951	.000
Percent_Artificial	.482	.042	.634	11.586	.000
Percent_UF_5_6	.058	.019	.094	3.098	.002
Perim_artf_transp	−.006	.003	−.067	−2.104	.036
Perim_Natural	−.004	.000	−.280	−8.557	.000
POP_01_200	2.186	.686	.104	3.187	.002
DRA Regressions, R^2 = .68 (stepwise)					
(Constant)	521.362	22.273		23.408	.000
Percent_Artificial	−1.823	.241	−.284	−7.575	.000
Percent_UF	−3.308	.395	−.345	−8.371	.000
Percent_UF_5_6	1.067	.202	.206	5.287	.000
MPA_UF_2	−13.655	6.755	−.109	−2.021	.044
MPA_artf_UF_transp	−49.600	5.684	−.433	−8.726	.000
POP_01_200	14.482	6.415	.082	2.258	.025

For the PRA indicator the “Population density” and the “Percent artificial” variables enter in the PRA equation with positive signs although they are negatively correlated with the PRA indicator. For the DRA indicator the signs of all independent variables are the same as in the corresponding correlations.

5 Conclusions

The analysis presented in this paper demonstrates that the length of the road network is related to various urban form characteristics and that differences in urban form are reflected in different road availability indicators. The DRA indicator is significantly higher in South EU cities because the layout of the cities is different. City blocks are smaller and this leads to higher values of the DRA indicator.

Future research efforts should analyze how the results reported in this paper affect various travel characteristics. For example, a useful analysis might be to analyze at the aggregate level whether various mobility characteristics such as average trip length, accident rates, transportation pollution are affected by urban form characteristics.

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Assessing the Impact of Changes in Mobility Behaviour to Evaluate Sustainable Transport Policies: Case of University Campuses of Politecnico di Milano

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Abstract. Started in 2011, the "Città Studi Campus Sostenibile" project (CSCS), promoted by Politecnico di Milano and Università degli Studi di Milano, is aimed at turning the common university district in a model for quality of life and environmental sustainability. One of the topics of this project relates with transport and sustainable mobility.

In this framework, during the last three years, the Sustainable Office of the University, in collaboration with the university mobility manager, carried out two surveys on mobility and commuting, among students, professors and administrative staff. In 2015 were surveyed about 12.000 people and about 14.000 in 2017, respectively 27% and 24% of the total population of each year.

Through the analysis of the data of the last survey, we firstly provide a description of the current mobility patterns of the university population, then we calculate CO_2 emissions from mobility activities to access Politecnico campuses. In order to estimate CO_2 emissions of every trip, we utilize local emission factors for each transport mode. Previous studies evidenced how this component accounts for more than 40% of the total emissions of Politecnico di Milano.

Lastly, in order to identify in which context policy packages, aimed at increasing the modal share of sustainable transport modes, are more effective and efficient in reducing CO_2 emission, we analyse a set of scenarios involving both different territorial contexts inside Lombardy region and different campuses population.

Keywords: Mobility behaviour · CO_2 emission estimation Sustainable transport policies · University survey

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1 Introduction

An increasing number of European and extra-European universities have begun to monitor their energy consumption, drawing up inventories of greenhouse gas emissions (GHG) in order to assess how to improve the sustainability of their activities.

In this context, since 2011 Politecnico di Milano and Università degli Studi di Milano have launched the "Città Studi Campus Sostenibile" project (CSCS) with the aim to turn Città Studi university district into an example for quality of life and environmental sustainability. Among the various initiatives launched by Politecnico, specific attention has been paid to study and promote solutions aimed at reducing the modal share of private vehicle for trips direct to each Politecnico campus and, thus, to contain the emissions into the atmosphere, primarily those of CO_2. In particular, both awareness activities and studies on the University itself were undertaken for students and staff.

Being CO_2 emission related to transport activities one of the most relevant impacts a university has on society and environment [1], particular attention was devoted to understand students and staff commuting patterns. In the case of Politecnico di Milano CO_2 emission related to transport activities accounts for 40% of the total university emissions [2].

Throughout studying commuting patterns, other universities were able to introduce in their plans and programmes some actions aimed to enhance campuses accessibility without increasing individual mobility based on private vehicle [3–5].

A possible strategy to predict the potential impact of targeted actions, and consequently to achieve GHG reduction goals, is to build, compare and assess scenarios based on key sustainable policies aimed to raise modal share of public or active modes and to increase private vehicle occupancy rate [6, 7]. In order to define these scenarios, an ordinary starting point is to reconstruct a comprehensive framework of the predominant travel patterns of the academic population and thus identify, for specific situations, which economical and/or socio-demographic characteristics can support users' behavioural change [7, 8]. The distribution to the academic population of detailed commuting surveys represent the most common approach to obtain this type of information [e.g. 9–11 among others]. Politecnico already used this tool several time in the past years, but only since 2010 surveys were specifically designed to determine the impact of commuting behaviour in terms of CO_2 emission (e.g. a specific question on private vehicle engine displacement was included in the survey) [12].

In 2015 about 12.000 people were surveyed, representing 27% of the total university community of that year. Thanks to the results of that survey, the Sustainable Office of the University was able to understand that the majority of CO_2 emissions (67% of the total) were related to the use of private vehicle to access Politecnico campuses. Interestingly, these emissions correspond to just 20% of total students' trips and 28% of staff [2].

Due to these results, the Sustainable Office includes in the CSCS projects, among others, specific focuses on:

- redevelop traffic and routes in the Città Studi district through a working group with the Municipality of Milan and the Agency for Mobility and the Environment (Amat);
- regulate car parking on campus;
- study mobility credits to encourage sustainable mobility of students and employees;
- activate agreements with companies providing sharing mobility services.

In this article we will use the most recent survey on mobility and commuting of the two main Politecnico campuses in Milan (distributed during the A.Y. 2016/17) to determine in which context sustainable transport policies should be applied in order to obtain higher effects in terms of CO_2 emission reduction.

The paper is structured as follows. Section 2 introduces the methodology applied to collect commuting data, shows how the sample was expanded, briefly presents the current mobility pattern of the university population and explains the formula for CO_2 calculation. Section 3 presents the three scenarios considered for future sustainable transport policy packages and estimates their effects. Section 4 concludes.

2 Methodology

Of the 51,921 surveys distributed among the entire community[1] of the two Milanese Politecnico campuses between June and September 2016, 13,034 responses were obtained, yielding an overall response rate of 25.1%, which is similar to the results of other researches [8, 10].

After data cleaning operations, consisting in 42 different filters, incomplete and unrealistic survey responses were removed. A total of 11,394 entries were found to be suitable for data analysis. The response rate of this cleaned sample is 18.5% for employees (representing teaching, technical and administrative staff) and 22.7% for students.

Respondents were asked to indicate both characteristics of their primary trip to and from Politecnico and, possibly, to provide the same information for their second best choice trip. In order to distinguish recurrence of these two typology of trips they were asked also to indicate an average trip frequency. Being the survey specifically designed to provide an estimation of GHG emission, the peculiar characteristics of each trip include: mode, vehicle type, distance or minutes travelled and frequency on weekly working days base (both during course and exam period).

Later, the initial 11,394 entries, through SQL queries procedures, were disaggregated into 27,646 single trip records representing, respectively 11,394 primary double-way trips and 2,429 secondary double-way trips, each one associated to a weekly frequency. Since the sample size of the survey represents only a fraction of the total individuals commuting to University Campuses, the number of respondents was expanded to represent the entire population. For students, sampling weights were based

[1] The population of the two campuses is divided as follows: 42,328 are students (58% of Leonardo campus and 42% of Bovisa campus) and 9,593 are employees (55% of Leonardo campus and 45% of Bovisa campus).

on belonging campus and university career (bachelor, master or single course students). Similarly, employees' weights were generated on belonging campus and job category (administrative staff, technical staff, professors, research fellows or PhD plus M.B.A. and other master students).

The average weight for employees corresponds to 7.2[2] and to 4.8 for students. As a primary result, the modal share of both campuses and for both sub-samples of students and employees was calculated (Table 1). Being the two campuses located in mixed-use neighbourhoods inside the city of Milan and well connected with public transports, not surprisingly the combined share of non-motorized and public modes represents, on average, 66% of the total commuting trips. Staff, for both campuses, is positively associated to a higher use of private means of transport. This phenomenon depends on the excellent public transport accessibility of both campuses and scarce parking availability, also being the scarce internal parking lots reserved to employees. Car use in 2017 is considerably lower than the same derived from the survey of 2015 (28%). Its counterpart is represented by the percentage of non-motorized modes that, from a 10% of 2015, reached an average of 18.1% [2]. Similar trends, even if with lower intensity, can also be found for the student sample.

In total, 85% of the trips are associated to the use of a motorized mode of transport and, on those, CO_2 calculation are made. In order to estimate the CO_2 emission linked to commuting trips, we calculate the total kilometres travelled by the expanded university sample on an annual basis by each mean of transport, and we multiply them for their specific CO_2 emission factor[3] (Eq. 1).

$$ECO_2 = \sum_i \left(\sum_j D_{i,j} * Nt_j \right) * EF_i \tag{1}$$

where:

ECO_2 are annual emission of carbon dioxide generated by motorized transports
$D_{i,j}$ are the distances [km] covered with each mode of transport i in each trip j
Nt_j are the number of annual occurrence for each trip j
EF_i are the specific CO_2 emission factor of each mode of transport i

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[2] The highest value for employees is due to a limited number of respondent between PhD or M.B.A. and other master students. The average value of this category is 8.8 for Leonardo campus and 23.5 for Bovisa campus.

[3] CO_2 emission factors were based on different sources. For private means of transport and road public transports, vehicles were categorized by displacement and fuel system and, for each of them, a specific value was used, taken from the Lombardy Region emission inventory [gCO_2/pxkm] [13]. Values considered varies from 19 (suburban bus) up to 277 (Gasoline car > 2000 cc). Train and underground coefficients are both 12 [gCO_2/pxkm] [derived from 14, 15]. Finally, tram coefficient is equal to 25 [gCO_2/pxkm] [derived from 16].

Table 1. Modal share by campus and type of user [%].

Campus	Population category	Private vehicle only [PR]	Private and public transport [PR – PT]	Public transport only [PT]	Non-motorized modes
Leonardo	Students	4.3	26.4	51.1	18.2
	Staff	13.2	16.2	46.0	24.6
Bovisa	Students	5.6	27.1	58.7	8.6
	Staff	20.0	23.3	45.0	11.7

3 CO_2 Emission Scenarios

Commuting trips attracted by the two Politecnico campuses of Leonardo and Bovisa are originated in a widespread area covering several regions. In order to study the effect of changes in campuses population's mobility behaviour, we chose to divide the commuting trips in three groups according to macro areas of origin based on specific public transport networks and administrative boundaries (Fig. 1).

We have therefore set three concentric zones where to study the effects of modal share changes: Milan municipality, Milan metropolitan area (the former Milanese province) and the outer area. These areas are linked to the structure of the public transport network serving the campuses. At the urban scale, it can be assumed to be available in a variety of alternatives and is managed by the municipality[4] itself. In the metropolitan area, it assumes a composite form with bus and train lines converging to the main city. This network is under the supervision of local transport Authority[5]. Finally, in the outside area there is a prevalence of the train mode, under the supervision of the Lombardy Council for regional trains[6] and the national operators for the long-distance ones.

The distribution of the annual trips and annual cumulate kilometres is showed in Table 2.

Setting the CO_2 emissions as an indicator for the impact of mobility on the environment, we build three scenarios to estimate the modal shift performances in terms of overall CO_2 reduction for each zone, to understand where the effectiveness of new sustainable transport policies could be most relevant.

Scenarios have been based on the assumption that a certain transport mode, from a specific municipality to one of the two campuses, is available if at least one of the respondents uses it. Therefore, the redistribution of trips for each origin-destination pair is realized through a redistribution of defined percentages of kilometres travelled with the private mode to the public mode (as a primary choice) or the private-public mode (if the previous is not available). In the case that, beside private mode, no other alternative

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[4] Through the public transport service contract with the local transport company ATM.

[5] The "Agenzia per il Trasporto Pubblico Locale del bacino di Milano, Monza e Brianza, Lodi e Pavia" is in charge of the public transport planning at a sub-regional scale, actually larger than the Milan metropolitan Area, including other portions of Lombardy.

[6] Through the public transport service contract with the regional train operator Trenord.

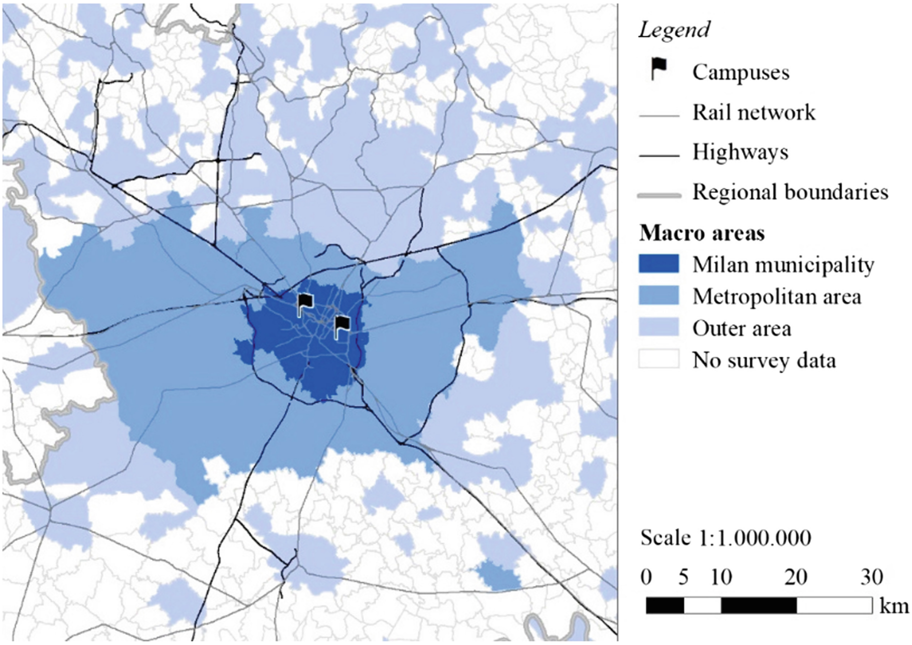

Fig. 1. Campuses' location and macro areas subdivision.

Table 2. Annual trips and annual cumulate km for each zone of analysis.

Zone	Trips	Trips [%]	Cumulate km	Cumulate km [%]	Average trip length [km]
Milan municipality	7,219,792	45	33,016,704	9	4.6
Metropolitan area	2,403,904	15	49,066,499	13	20.4
Outer area	6,346,033	40	294,234,359	78	46.4
Total	15,969,729	100	376,317,562	100	23.6

means of transport were used by respondents, no redistribution takes place and trips remain car-based.

For each macro area, we hypothesized three scenarios with a progressive cumulate kilometres reduction (of 25%, 50% and 75%) of private mode. The current situation (reference) and the three scenarios' results are shown in Table 3.

The most interesting result is that, even though trips originated from the Metropolitan area are considerably less than those from the others (accounting for just the 15% of the total), a change in their modal share leads proportionally to the most relevant change in the overall CO_2 emissions. The second interesting result is that, despite the fewer cumulative kilometres associated to staff trips, their change towards a more sustainable mobility behaviour would have proportionally a wider impact than the

Table 3. Results of CO_2 emissions for current situation and scenarios'.

Reduction scenarios	Zone		Staff	Student	Total	Over whole reference [%]
–	Outer area	CO_2 [kTon]	1,779	7,628	9,407	–
	Metropolitan city	CO_2 [kTon]	576	1,727	2,303	–
	Milan municipality	CO_2 [kTon]	210	597	807	–
25%	Outer area	CO_2 [kTon]	1,683	7,428	9,111	−2.4%
		Δ on reference [%]	−5%	−3%	−3%	
	Metropolitan city	CO_2 [kTon]	511	1,614	2,125	−1.4%
		Δ on reference [%]	−11%	−7%	−8%	
	Milan municipality	CO_2 [kTon]	191	560	751	−0.4%
		Δ on reference [%]	−9%	−6%	−7%	
50%	Outer area	CO_2 [kTon]	1,587	7,228	8,815	−4.7%
		Δ on reference [%]	−11%	−5%	−6%	
	Metropolitan city	CO_2 [kTon]	446	1,502	1,948	−2.8%
		Δ on reference [%]	−23%	−13%	−15%	
	Milan municipality	CO_2 [kTon]	172	524	696	−0.9%
		Δ on reference [%]	−18%	−12%	−14%	
75%	Outer area	CO_2 [kTon]	1,491	7,028	8,519	−7.1%
		Δ on reference [%]	−17%	−8%	−9%	

(*continued*)

Table 3. (*continued*)

Reduction scenarios	Zone		Staff	Student	Total	Over whole reference [%]
	Metropolitan city	CO_2 [kTon]	381	1,390	1,771	−4.3%
		Δ on reference [%]	−38%	−21%	−23%	
	Milan municipality	CO_2 [kTon]	153	487	640	−1.3%
		Δ on reference [%]	−30%	−19%	−21%	

same change for students. Finally, even if a hypothetical policy were able to trigger a modal shift of 75% from private cars to public transports, this result will produces a very limited reduction in CO_2 emissions (less than 13%). This is a consequence of the already high modal share in favour of public transport of the Politecnico population.

4 Conclusions

Through the realization of a detailed survey, focused on quantifying the mobility habits of Politecnico di Milano population, the Sustainable Office of the University has been able to collect a wide range of data on the mobility patterns linked to campuses activities. Via the analysis of these data, we found that the access to the Milanese campuses of Politecnico takes place mainly thanks to public transport for both students and employees. From a first comparison with the survey of 2015, we notice a slight modal shift (almost 10%) from private means of transport to public and non-motorized modes.

Aiming at strengthening this trend, we try to understand in which context sets of sustainable transport policies are potentially more effective. Annual CO_2 emissions were estimated and utilized as an indicator to assess different scenarios, based on a subdivision of the Politecnico catchment area following public transport network structure. An interesting finding is that the area in which the more effective results can be achieved is at the metropolitan scale (Milan city excluded) and not the outer area, where most of km are travelled. In fact, in the metropolitan area the reduction in the CO_2 emissions is proportionally higher considering the lower number of trips generated in comparison to the other zones. Another result is that a shift in the modal share for employees has proportionally a bigger effect than the same shift for students.

Considering these findings, Politecnico could strengthen some already undergoing actions like parking lots regulation (e.g. introducing fares or restrictions) and counterbalance them with incentives as discounts on integrated public transport subscriptions.

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Neural Network-Based Road Accident Forecasting in Transportation and Public Management

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Abstract. The development of Information and Communication Technology (ICT) has influenced transportation management in multiple ways. The application of artificial intelligence techniques has gained ground lately in many scientific sectors. In this research, artificial neural network models were constructed in order to predict data about the road accidents in the study area. Several parameters were taken into consideration in order to optimize the predictions and to build the optimal forecasting model such as the number of the neurons in the hidden layers and the nature of the transfer functions. A Feed-forward Multilayer Perceptron (FFMLP) was utilized, as it is considered as one of the most suitable structures for time series forecasting problems according to the literature. The optimal prediction model was tested in the study area and the results have shown a very good prediction accuracy. The road accident predictions will help public management to adopt the appropriate transportation management strategies.

Keywords: Artificial neural networks · Transportation management
Transportation safety · Public management

1 Introduction

The increased number of road accidents in urban cities has a negative impact on the citizen's lives and it is considered as an important factor in transportation management and planning and also in developing accident prevention strategies. The development of communication and information technology has facilitated the construction of new technology-based management systems in public administration [1, 2] and also the development of new intelligent systems in urban areas for facilitating decision making in transportation management [3, 4]. These kinds of intelligent systems can be applied in a more efficient way when they are fed with multiple kinds of useful transportation data. Road accident prediction data are very rare. In this research the derived forecasting data can also be used for supplying prediction information in intelligent transportation systems.

The rapid development of artificial neural network-based technologies has led to new prediction techniques. Several researches studied the application of artificial intelligence in transportation by implementing neural network-based methodologies in

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forecasting data related to transportation factors [5–7]. Also, several researchers have studied various prediction techniques based on neural networks in order to forecast road accidents to improve transportation management strategies in urban areas [6–8].

In a study, [6], the researchers have proposed the utilization of a Radial Basis Function (RBF) neural network for predicting the number of the traffic accidents. The results have shown a very good prediction accuracy in forecasting traffic accidents.

In another research [7], the researchers have applied probabilistic neural networks in combination with decision trees for efficient accident prediction. The road accident data were collected by the Cyprus Police during the year 2005. The results have shown that the proposed methodology can be used efficiently to predict accident data in the study area.

Another research [8] has implemented multivariate fuzzy time series prediction technique for forecasting car road accidents in Belgium by taking into consideration the historical data of the last three years. The results of the study have shown that the proposed technique can be utilized for forecasting road accidents with a better accuracy than others.

In this research, a Multilayer Perceptron (MLP) was implemented in order to forecast the road accident data in Great Britain based on the historical data of the previous years. In the next sections the methodology, the results and the discussion are presented.

2 Theoretical Background

2.1 Artificial Neural Networks

Artificial Neural Networks (ANNs) are computing systems that are trying to simulate the structure of the brain system. A neural network elaborates data from the input parameters. The information traverses via connections to produce an output according to the input parameters [9]. Artificial neural networks were used in this research to forecast the number of the road accidents, since they are capable of modeling non-linear relationships between input and output. A Feedforward Multilayer Perceptron (FFMLP) was used, as many researchers consider it as one of the most suitable for time series forecasting problems [10].

2.2 Scaled Conjugate Gradient Algorithm

The scaled conjugate gradient (SCG) algorithm was proposed by Møller [11]. The scaled conjugate gradient algorithm which is a second order conjugate gradient algorithm was chosen as the learning algorithm for the feedforward neural network, since it is considered as a faster learning algorithm compared to other algorithms such as backpropagation learning algorithms [11].

3 Research Methodology

The research methodology includes three basic stages: data collection and preparation, neural network forecasting model creation, testing the optimum neural network model in the selected study area. Firstly, transportation data regarding road accidents were collected and prepared for feeding the neural networks by removing inconsistencies and null values. In the second stage, artificial intelligence was used in order to develop and compare neural network prediction models based on the Multilayer Perceptron architecture, so as to find the optimal network forecasting model. Several different network architectures were investigated in order to discover the optimal one. In the final stage, the optimum developed neural network model was implemented in order to predict the number of the road accidents in the study area (Fig. 1).

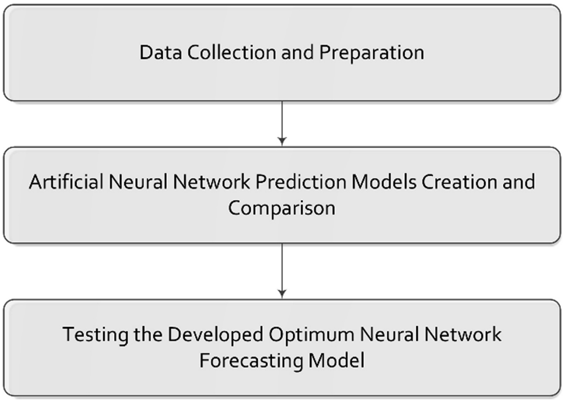

Fig. 1. Overview of the followed methodology.

4 Results and Discussion

4.1 Data Collection and Preparation

Road accident transportation data were collected for the time period 1949–2016 for the Great Britain[1]. The data types that were selected to be analyzed by implementing artificial neural network-based techniques were: the number of accidents per year, the population, the total number of the licensed vehicles and the traffic index. The collected data were prepared and preprocessed for duplicates or other incoherencies.

4.2 Artificial Neural Network Models

The artificial neural network models were constructed by using the collected data as input data in order to forecast the number of road accidents. The four inputs of the

[1] Source: https://www.gov.uk.

neural network are: the number of road accidents per year and three other factors that may affect the number of road accidents: the population, the total number of the licensed vehicles and the traffic index. The output of the network is the number of road accidents.

The scaled conjugate gradient algorithm was selected as the learning algorithm in a Multilayer Perceptron (MLP), since it is a very fast learning algorithm compared to other algorithms such as backpropagation algorithm [11]. The data were divided into different parts. The 70% of the data was used as the training set, the 15% of the data was utilized as the validation set and 15% for the test set. The developed neural network models were trained by using the collected historical data. By using the validation set, the neural network performance was evaluated. The topology of the constructed neural network models, was defined according to the performance of every constructed neural network. The Mean Squared Error (MSE) and the Root Mean Squared Error (RMSE) were used to assess the performance of the developed network models with the final goal to choose the optimal prediction model.

Several neural network topologies were investigated regarding the number of the hidden layers, the number of the hidden layer neurons and also the type of the transfer functions in the hidden layers of the network. The transfer functions that were tested in the hidden layers were: Log-Sigmoid Transfer Function (LSTF), Linear Transfer Function (LTF) and Tanh-Sigmoid Transfer Function (TSTF). The optimal topology was found to be the one with two hidden layers with eleven neurons in the first hidden layer and the Linear Transfer Function (LTF) as the transfer function and sixteen neurons in the second hidden layer and the Linear Transfer Function (LTF) as the transfer function. The optimum model had the minimum MSE compared to all other neural network models. The Mean Squared Error (MSE) of the optimal model was found to be 13.6096 at epoch 6. Figure 2 shows the neural network training performance of the optimum model according to Mean Squared Error (MSE).

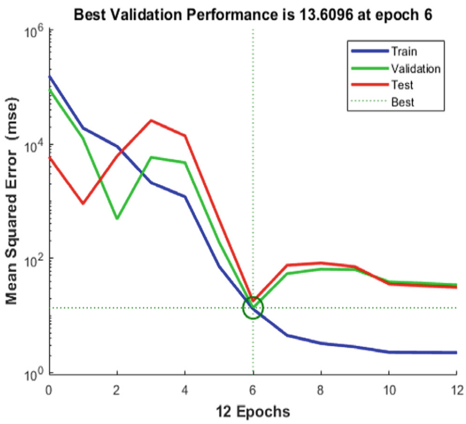

Fig. 2. Neural network training performance of the optimum model according to Mean Squared Error (MSE).

4.3 Optimum Neural Network Model

The optimum neural network prediction model was used in order to predict the number of the road accidents in the study area. Firstly, the constructed model was tested by using the test data of the dataset for the years 2007–2016 in Great Britain. The final results showed a very precise prediction accuracy. The Mean Squared Error (MSE) of the test set was found to be 17.8079 and the Root Mean Squared Error (RMSE) was 4.2199. The regression analysis was used in order to estimate the prediction accuracy. The R linear coefficient was found to be 0.99111. Figure 3 shows the regression plot of the output and the target for the test set.

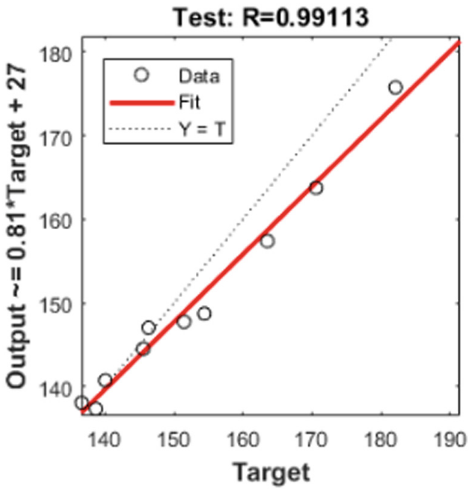

Fig. 3. The regression plot of the output and the target for the test set.

5 Conclusions

The adoption of artificial intelligence techniques in transportation can be very valuable in public decision making. In this research, artificial neural network models were developed and compared according to their performance in order to discover the optimal model capable of predicting efficiently the number of road accidents in the study area of Great Britain. Several neural network architectures were tested in order to find the optimal forecasting model, regarding the nature of the transfer functions and also the number of the neurons in the hidden layers.

Compared to other researches [6, 7] this research utilizes more network input factors that could affect the prediction accuracy such as the population, the total number of the licensed vehicles and the traffic index. The final results of this research have shown a very good forecasting accuracy in the study area of Great Britain. The proposed methodology for developing the optimal neural network prediction model for forecasting the number of the road accidents can be very valuable in public management, urban planning and transportation management, and also in designing and planning proactive policies and strategies in order to prevent road accidents and preserve human lives.

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Assessment of Drivers' Perception of Quality of Service on Urban Roundabouts

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Abstract. Modern roundabouts are a type of intersection which is used successfully in many countries globally due to their advantages. More specifically, it is widely accepted that owing to their geometrical and operational characteristics the roundabouts enhance traffic capacity, cause an important reduction in delays and improve the road safety levels, for the benefit of the users. Moreover, their formation assures not only financial benefits, but environmental too, compared to other junction types, like signalized intersections. The engineering society launches research projects to develop guidelines for the assessment of such facilities in order to improve them. As a result, the concepts of level and quality of service have been introduced. The Level of Service (LoS) evaluates the traffic handling ability of a transportation facility and it is estimated by the use of specific techniques. The Quality of Service (QoS) assesses the performance of a transportation facility, as the drivers and the users perceive it. In this paper, the meaning of Quality of Service (QoS) of roundabouts is examined. A questionnaire' s survey aimed at collecting data from users in Greece, regarding the factors that affect drivers' satisfaction, during their driving through a roundabout. The results of the survey show that the quality of service perception on urban and rural roundabouts is influenced by several factors, such as the clarity of road signs, the presence of on-street parking, the lightning etc.

Keywords: Roundabouts · Quality of service · User perception · User survey Greece

1 Introduction

Roundabouts are being implemented worldwide in a variety of situations. Although available information shows that roundabouts offer a number of advantages compared to other types of intersections [1, 2], there has been some questioning to apply them due to the perceived differences in driver behavior [3]. The Highway Capacity and Quality of Service Committee of TRB, which oversees the development of the Highway Capacity Manual, has formally recognized a need to improve the methodologies of their performance analysis [4]. Among the concerns of various methodologies is the extent to which LOS estimates correspond to road users' perceptions. As a result it has been proven necessary to incorporate drivers' opinions with regard to the quality of service.

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In other words, to investigate and assess the factors that users consider as influential. Various surveys on urban streets have identified a number of factors that are important to road users and affect their perception of service quality. Following extensive literature review and other survey investigation [5], a comprehensive list of factors influencing users' perception has been shorted in order to examine roundabout QOS in Greece. Additionally, important results of this survey have depicted users' knowledge regarding the operating rules of roundabouts.

2 Literature Review

Back in the 1965, NCHRP[1] and FHWA[2] have identified the need to develop tools that would measure roundabout performance in terms of quality. They introduced the concept of the LOS, recognizing that the driver's point of view of a transportation system - facility is important to consider [6]. That first approach defined LOS as "a qualitative measure used to relate the quality of a traffic service" [7]. This approach continues to evolve towards an improved and more detailed understanding, that resulted to the separation of the concepts LOS and QOS. The latest edition of the HCM (2010) separates the two measures by delineate **Quality of service** (QOS) as a qualitative measure and **Level of service** (LOS) as a quantitative measure [8].

Previous work on roundabouts quality of service is not extended. The number of studies focusing on drivers' opinions and road use quality has increased in recent years. The literature review provided into this section describes the findings of various surveys used to assess road users' perception for roadways and intersections.

Hall et al. (2001) studied "freeways quality of service and what really matters to drivers and passengers". The survey was addressed to commuters who discussed their views about determinants of the freeway quality of service that they experience. The most important determinant for them was the total travel time, in addition to traveler information, safety, and maneuverability [9]. Pecheux et al. focused on identifying drivers' perceptions at urban road facilities and they ended up with fifteen potential quality factors that may influence the users' LOS perception at signalized intersections [10]. Flannery et al. (2008), studied the analysis and modeling of automobile users' perceptions of quality of service on urban streets. In this study the researchers try to identify quality factors that enter into users' perceptions and the interface between intersections on urban streets, the research also describes various efforts that have been taken to analyze and model automobile level of service from driver's perspective. The result showed five effective variables; stops per mile, median type, width of parking lane, presence of exclusive left turn, and presence of trees [11] McKnight, Khattak and Bishu, in 2018, conducted a survey study in Nebraska in to which they try to identify relationships between characteristics of drivers and knowledge (i.e. familiarity and unfamiliarity) of roundabout navigation. Results of the study revealed that younger and specialty drivers understand the rules of roundabouts better than older car drivers. In other words, age and proper education influence performance [12]. Zhang and

[1] National Cooperative Highway Research Program (NCHRP).
[2] Federal Highway Administration - US department of Transportation.

Prevedouros found out that delay, left turn treatment (for countries with anticlockwise movement in roundabouts) and pavement markings are the most important factors that influence users' perception of LOS at signalized intersections [13]. Ibrahim Hashim Khliefat analyzed "drivers' perception of quality of service on urban roundabouts". The findings of this study showed that the quality of service perception of urban roundabouts is influenced by several factors, including approach level of service, pavement quality, pavement marking, pedestrians' activity, clarity of road signs, and presence of landscaping [14]. Othayoth, Darshana and Krishna Rao aimed to identify the factors influencing the users' perception of LOS at signalized intersections in India [15]. The survey used a questionnaire and the analysis carried out identified the factors that needed future improvement; waiting time at the intersections and road surface quality were proven to be of top priority. In other words, waiting time is the most important factor influencing their perceived LOS i.e. the least satisfied factor. The least important factor has been proven to be aesthetics [15].

3 Methodology Used

Initial purpose of the study was data collection. The methodology used includes the design of a survey questionnaire. The initial questionnaire was tested in a pilot study. Based on the results of the pilot study, changes were made and the final questionnaire was constructed. The survey was carried out from 13th September 2017 to 24th December 2017. It was conducted among road network users in Greece. It was carried out by a combination of site interviews and online running, with the aid of a cloud-based software, www.surveymonkey.com. Simple random sampling was used to ensure that each potential respondent within the target population stood an equal chance of being included in the sample. The analysis was developed using statistical software – SPSS, (Statistical Package for the Social Sciences).

4 Questionnaire Design

The questionnaire consists of 25 questions divided into four different sections; The majority of the questions are close-ended. Only one is open ended, declaration of "residence". The first part contains "**General Information**" about gender, age, level of education, city/town residence, driving license and driving experience in years. The second part reflects to users "**Familiarity and Unfamiliarity**" to roundabout use. In particular, it investigates how often drivers navigate through different types of roundabouts, as well as their knowledge on the particular road facility. The third part, "**Lane Assignment**", focuses on gaining information related to the appropriate choice of lanes and priority rules while approaching a roundabout. The last section of the questionnaire "**Quality of Service**" is based on the qualitative evaluation of roundabouts. It consists of 5 questions and it aims to collect data based on the individual perception of the participants. The particular questions seek to evaluate given factors that influence, positively or negatively and to what extent the feeling of satisfaction is perceived by the drivers. At the same time, through the questions asked, the aim is to evaluate the level of comfort and safety. The factors chosen are: congestion, road surface quality, landscaping, pedestrian activity, bus activity close to the roundabout, road signage, pavement markings on approaches, on-street parking, lane change, street lighting, bicycles. The qualitative evaluation was assessed by using a Likert five - point scale. Survey participants rated them according to their importance in influencing the quality by using a 1–5 scale. '1' indicates the factor is very unimportant and '5' indicates "very important".

5 Data Analysis

This section summarizes the analysis carried out on the data obtained from the survey. Prior to statistical analysis all data was edited before presented as information. This action ensured that the information provided is accurate, complete and consistent. As a result, out of 1,011 questionnaires collected, a total 778 valid questionnaires were processed.

In order to assess scores of Likert-scale questions, the study provided a stable and internally consistent measure. Cronbach's alpha reliability coefficient was calculated for each source with a mathematical self-efficacy equal to 0.82 quality factors, and 0.80 for comfort feeling. The Cronbach's alpha coefficient was higher than 0,70 however, internal consistency was ensured and statistical analysis proceeded for all questions.

5.1 Statistical Analysis

The first set of questions purposes on defining users profile. The percentages of male and female respondents to the survey approximately reflect the gender composition of the driving population in Greece. Among them 57.10% are male and 42.30% are female. Age ranges from 18 to over 65 years old, with the dominant age class being 36–45, which corresponds to the 27.60% of our sample. Ages 26–35 years old follow by 20.10% and all rest are below 20,00%. The highest percentage of men participating is 24.50% and corresponds to the age group 26–45 years old following, 23,00% to range 36–45. Corresponding percentages are also observed for women having a highest percentage in age group 36–45 33.80% and second in line the age group from 18 to 25 years old 24.90%. Educational level of survey participants is high. The majority of the respondents hold a Higher Diploma or University degree, 39.50%. Users with higher education reflect to a cumulative percentage of 88.90%. As it was expected the percentage of driving license holders was overwhelming, referring to 93.80% of all responders. Among them just 20,00% of the sample has less than 5 years of driving experience while the rest belong to range scale +5 years to 25.

Second set of questions investigates familiarity or unfamiliarity of users and knowledge of priority rules on circular intersections. Although roundabouts are fairly new in Greece, it has been proven that 95.38% of the participants have experienced driving through a roundabout and 89.00% have never thought of avoiding a route that includes such an installation. Users have experienced all types of roundabouts as shown in Table 1.

Table 1. Users navigating different types of roundabouts.

Types of roundabouts used (%)	
Single lane	40,00
Muli lane (+2)	10,00
Both	49,00
None	1,00

Based on the results mentioned above, it is clear that road users in Greece are familiar with roundabouts use. Though they do not have a clear view on the priority rules they prevail; 77.70% has declared they are aware of the road traffic rules, knowledge that they received mostly from driving schools, 62.60%. Though 58.50% of them believe that the approaching vehicle has priority while entering a roundabout. That confirms that roundabouts can be very confusing for drivers in Greece. The Greek highway code implies code implies that if the approach road does not have a stop sign, traffic on the roundabout has to give way. In case the approach road does have a stop sign, traffic already on the roundabout has priority. On the contrary responses concerning whether a car has priority versus pedestrians, and cyclists (i.e. vulnerable users), were answered correctly in most cases as it can be seen in Table 2.

Table 2. Number of correct priority responses at roundabouts for vulnerable users.

Pedestrian priority answers (%)		Bicycle priority answers (%)	
Vehicle	3,00	Vehicles	11,30
Pedestrians	91,60	Bicycles	75,50
Do not now	5,40	Do not now	13,20

Continuing on examining familiarity and unfamiliarity of drivers, the next questions asked the participants whether it is an appropriate choice to make a left turn Fig. 1, and what decision the drivers should make on exiting a roundabout at points 1, 2 or 3 as shown on Fig. 2.

Fig. 1. Left turn at roundabout entrance

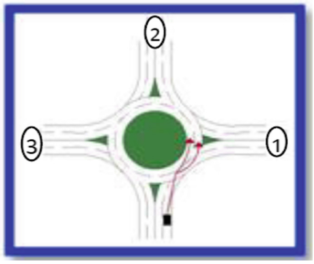

Fig. 2. Appropriate lane choice while navigating a roundabout

Fortunately, enough 97.80% replied that right turn is not allowed at a circular intersection. All answers referring to Fig. 2 exhibited the same outcome, that drivers reporting with experience chose the correct answer more often. The results imply that more experienced drivers maneuver more easily and do not hesitate to change lanes into the roundabout.

Based on initial considerations as regards to what factors might influence quality of service and roundabout performance, next section of the questionnaire included five questions with regards to the above mentioned factors, comfort while navigating, safety and general performance.

Investigation of the service quality was correlated to 11 variable factors that took values from 1 (not important) to 5 (extremely important). Figure 3 shows the average score for each factor as calculated from weighted statistical analysis. Results show that the factor that primarily affects the drivers is clarity of road signs 4.25/5, with 50,00% of the participants reporting that this factor is extremely important for them and 33,00% as very important. On the contrary, as it turned out, landscaping is the factor that affects less the users, 2,65/5. Between the two ends are other factors, which affect roughly the same degree drivers with a score ranging from 3.37 to 3.90 with slight variations, those being: congestion, lighting, on-street parking, pedestrian activity and bus activity close to roundabout.

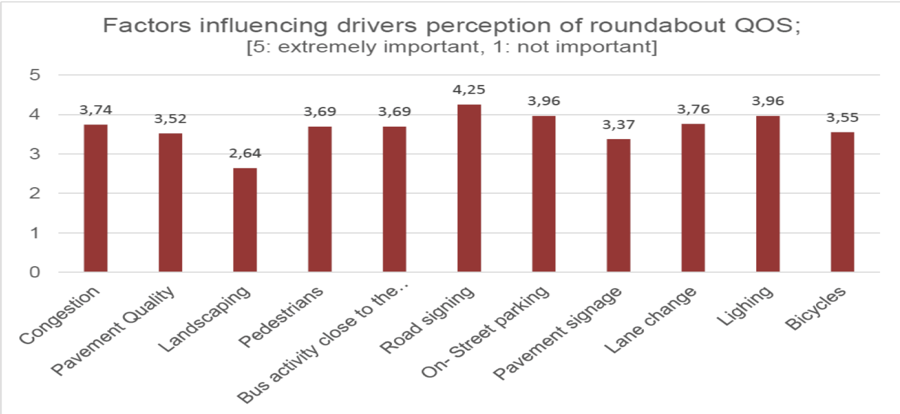

Fig. 3. Factors influencing drivers' perception of roundabout QOS, [5: extremely important, 1: not important].

The next parameter examined, identifies the degree of familiarity of drivers when entering or exiting and circulating within the circular multilane intersection. It examines, in particular, the degree of comfort of the driver in the following 4 cases: 1. Selecting the appropriate lane at entrance 2. Circulating a roundabout 3. Change lanes to the roundabout 4. exit the roundabout. Participants were asked to give numerical values on a 1–5 scale, for the degree of comfort they feel. The value 5 is "I feel very comfortable" and the value 1 in "I do not feel comfortable". Responses showed that users feel comfort and familiar in all four cases. With negligible differences, greater comfort is observed in the choice of the appropriate lane when entering the roundabout 3,9/5, navigating into the roadway 3,83/5 or exiting from it 3,87/5. The only case where participants have a lower degree of comfort is when changing lanes into the roundabout 3.08/5. However, it should be noted that, despite the ease with which drivers declare to changed lanes, in a previous question about the appropriate lane selection, there was a significant percentage of the wrong answers. Finally, the survey questioned participants on their general opinion on roundabouts. Most road users, i.e. 78.50% believe that roundabouts reduce delays and increase road safety levels, 72.20% specifically for drivers compared signalized or stop control intersections. In conclusion, it is proven that the majority of the sample, 66.20%, holds a positive attitude towards roundabouts use as a roadway intersection.

6 Discussion of Results

The main objective, of the study was to investigate drivers' perception of the operation and the quality of service of urban and peri-urban roundabouts. With the aid of a questionnaire survey it was possible, investigate familiarity or unfamiliarity of roundabout priority rules and to assess factors that are important to drivers regarding the QOS. In particular, it has been found that there is a number of factors that have great impact on users, such as the clarity of road signs, the lighting of the junction, the presence of on-street parking, congestion and activities from other users. These factors depict users' perceived assessment and they should be taken into account in combination with various other techniques that calculate its service level (delay, tail length, geometric characteristics of the intersection). An aesthetically pleasing environment is not considered as priority, maybe due to the fact that roundabouts in Greece have usually uncompleted landscaping. Though landscaping is an important component of roundabout design. Properly designed plantings provide visual cues that draw drivers' attention to the existence of a roundabout and can be used to preclude unnecessary sight distance on approach causing drivers to naturally decrease speed, improve yielding and increase safety.

Apart from the fact that these factors are related to the engineering characteristics of the roundabouts they are also related to drivers' behavior and knowledge. Greek drivers misunderstand the specific functional and design features of roundabouts, which have many advantages as a type of intersection, due to the fact that they are not widely spread in Greece and they do not get sufficient information. That was determined by the rates of wrong answers to basic rules of priority and maneuvering into the installations. It is therefore crucial to formally change the priority rule at the entrance of the intersection and align with the other European countries. Change of the Highway code and clarification of rules will effect safety improvement. It is clearly underlined that users other than automobile drivers do not feel safe at circular intersections.

In general, the results of this study coincide with the results of other recent studies of road users' perceptions of service quality. Identification of factors that influence drivers' perceptions of service quality will contribute to a more credible performance measure.

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Luminance Adaptive Dynamic Background Models for Vision-Based Traffic Detection

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Abstract. Measuring traffic flow by employing vision-based detection suffers from several challenges, particularly the illumination variation. Consequently, this research focuses on solving traffic detection problem due to both sudden and gradual illumination changes. A number of theories are proposed to define different components of an image. Specifically, first-order model for illumination variation and Fourier series for incorporating traffic arrival patterns are considered to define background and foreground, respectively. We have utilized these definitions to formulate the traffic detection problem and subsequently three adaptive dynamic background models have been developed to solve it. The third model that incorporates both luminance and pollution controlling parameters fixes the problems and limitations faced by the first and second models. Besides, a new per pixel binary threshold model related to the third model is also developed for foreground segmentation. Using a real video dataset, a constrained optimization is performed to determine the optimal values of model parameters, where the feasible regions of the parameters are obtained graphically. The model validation using a separate video dataset shows more than 95% Percent Correct Classification (PCC) value and around 90% Precision and Recall values. Additionally, a field test is conducted in three different locations and the performance of the model is evaluated. Evaluation shows that, the model achieves the highest value of 93% in terms of Average Accuracy of Object Count (AAOC) for urban arterial dataset, which represents its robustness in object detection.

Keywords: Illumination variation · Traffic detection · Background modeling Graphical optimization

1 Introduction

Vision-based systems have become very popular in Intelligent Transportation Systems (ITS) to measure the real-time macroscopic and microscopic parameters of traffic stream through object identification and tracking. Conventional technology for traffic measurements including inductive loops, sonar and microwave detectors suffer from drawbacks for being expansive to install, causing traffic disruption during installation or maintenance, not being portable and unable to detect slow or stationary vehicles. On the contrary, vision based systems are easy to install, maintain, can be integrated as a

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portion of signal control, and has the potential to utilize the extant traffic surveillance infrastructure. Moreover, these vision-based systems can be easily upgraded and offer flexibility to reform the system and functionality by simply altering the system algorithms. Currently, automated traffic state measurement employing vision system is a key technology in the management of the transportation facilities. Vision-based systems use several detection techniques. Among them, background subtraction is the most widely used technique for detecting traffic, where an estimated background is subtracted from the current frame to give a differential image. In this process, the accuracy of traffic detection largely depends on the fidelity of background estimation. Thus, the estimation model should be robust to various challenges, particularly illumination variation. It causes increase or decrease in the intensity of pixels, resulting in false positive or overestimation. Although numerous models were proposed to capture the background dynamics, none of those specifically concentrated on the issue of illumination variation in traffic detection.

Previously, conventional basic models such as mean [1], median [2], and histogram [3] were used for background modeling. These models suffered biasness of central tendency of an aggregated data. Afterwards, such background models were forced into several parametric distributions, such as Gaussian [4, 5], to overcome the limitation of the basic models. Unfortunately, these unimodal models could not handle dynamic backgrounds. Accordingly, Gaussian Mixture Model (GMM) [6] was introduced to model background. However, background having fast variations cannot be accurately modeled with a few Gaussians. Advanced statistical models removed the flaws of the old statistical models by making themselves robust. Student-t Mixture Model (STMM) [7] and Dirichlet Mixture Model (DMM) [8], which use distribution other than Gaussian are proven to be robust in dynamic background than GMM. It is because of their more heavily-tailed nature. However, real-time implementation of both STMM and DMM are difficult due to massive computational complexity.

Non-parametric model [9] was also introduced to estimate per pixel background probabilities from many recent samples over time, using Kernel density estimation (KDE). For approximation of the background color distribution, Ding et al. [10] used a mixture of KDE and GMM. Barnich et al. [11] proposed Visual Background Extractor (ViBe), a sample-based algorithm which uses random selection policy that ensures a smooth exponentially decaying lifespan. However, it faced problem with challenging scenarios such as darker background, shadows, and frequent background changes. Hofmann et al. [12] proposed Pixel-Based Adaptive Segmenter (PBAS) which models the background by a history of recently observed pixel values.

Besides, filter based approaches were adopted to dominate over statistical methods. Wallflower, a pixel-level algorithm, was proposed by Toyama et al. [13] which makes probabilistic predictions about the background pixel values using a single step Wiener prediction filter. It works well for periodically changing pixels; however, disadvantage occurs when a moving object corrupts the history values. Karnna et al. [14] proposed Kalman filter based background estimation which is an optimal estimator of the state of processes. Although it gives the optimal solution to the estimation problem when all the processes are Gaussian, it offers a sub-optimal behavior in non-Gaussian arising challenging situations.

Some authors proposed to isolate the background and the foreground in a different domain. Wren et al. [4] estimated the background model for capturing spectral signatures of multi-modal backgrounds by using Fast Fourier Transform (FFT) and inconsistent signatures were used to detect changes. Using Walsh Transform (WT), Tezuka et al. [15] modeled the background incorporating the GMM which is applied on multiple block sizes. Gao et al. [16] adopted Marrwavelet kernel and used binary discrete wavelet transforms to achieve foreground detection. Guan [17] used Dyadic Wavelet (DW) to detect foreground objects where the difference between the background and the current images is decomposed into multi-scale wavelet components.

From the literature survey, it was revealed that none of the above background model gives any explicit solution to illumination variation while traffic detection. To this end, this paper focuses on solving the illumination variation as a part of traffic detection problem by defining different components of an image (foreground and background) and finding explicit solutions.

The rest of this paper is organized as follows. In Sect. 2, we define different components of image. Theorem depiction, problem formulation and solution models are presented in Sects. 3, 4 and 5, respectively. Calibration and validation of model's parameters using different real video dataset are presented in Sect. 6. Using the calibrated model, a field testing is conducted in three different locations and the results are illustrated in Sect. 7. Section 8 concludes this paper.

2 Definitions

Let, v be the collection of frames I_n where $n = \{1, \ldots\ldots, N\}$, N being the total number of frames. Frame I_n is a space containing pixels P of the n^{th} frame where $P = f(\lambda)$. λ is the space variable which can be defined as $\lambda = \{(i, j, c) | i, j, c \in (\omega \times \eta \times \pi)\}$, where $\omega = \{1, 2, \ldots\ldots\ldots, W\}$, $\eta = \{1, \ldots\ldots\ldots, H\}$ and $\pi = \{1, 2\ldots, \Pi\}$. W and H are the total number of pixels along width and height of the surface I_n, respectively. Π is the number of color channels within the space of I_n. In a particular frame, there are two types of pixels: one is the background pixel (B_n), which does not include the object of interest and the other is the foreground pixel, which includes the object of interest. In case of traffic detection, vehicle/pedestrian is the object of interest and the rests are considered background. The object of interest is also known as foreground (F_n).

3 Theorems

Theorem 1. $\underset{\lambda \in \lambda_B}{\frac{\partial^2 I_n}{\partial n \partial \xi}} \neq \underset{\lambda \in \lambda_F}{\frac{\partial^2 I_n}{\partial n \partial \xi}}, \forall (\lambda_B, \lambda_F) \in \lambda, \; |\lambda_B| + |\lambda_F| = |\lambda|.$

The inequality in Theorem 1 implies that the rate of change in foreground is different than that of background. Thus, this inequality warrants distinguishing background pixels set from the foreground.

Theorem 2. No two pixels of different object can co-exist at same λ in I_n.

Remark. From Theorem 2, it is clear that no two type of pixels can co-exist at the same place of a frame. Therefore, background and foreground pixels are apart spatially on the surface I_n.

Theorem 3.

$$I_n = B_n + F_n \tag{1}$$

Remark. Using this theorem, any frame I_n can be written as an addition of background and foreground.

4 Problem Formulation

In this section, the traffic detection procedure has been introduced. This detection procedure has been explained by incorporating the background as defined in Sect. 2. In each step of detection, limitations arise and consequently the limitations are overcome. The most widely used technique for traffic detection is background subtraction [18]. In this regard, a background is subtracted from a frame to obtain a distance matrix. The distance matrix is compared with a set of threshold values to convert it into binary image b_t, where, $b_t \in [0, 1]$.

The distance matrix can be obtained from the difference between the Frame I_n and any other frame Υ, where, $\Upsilon \in v$

$$\delta_n = I_n - \Upsilon. \tag{2}$$

The segmentation of vehicle can be done by,

$$b_t = \begin{cases} 1, \delta_t \geq \tau_t \\ 0, otherwise \end{cases}, \forall \lambda : (mt \geq \tau_t) \vee (l_t \geq \tau_t) \rightarrow 1. \tag{3}$$

Where, τ_t = Threshold at time t, $m =$ Illumination gradient, l_t = Foreground magnitude.

From (3), two such conditions can occur for a particular pixel:

Case i. The threshold value is not enough to suppress the effect of illumination variation in b_t; and
Case ii. The threshold value suppresses the vehicle.

5 Solution Models

In this section, three models will be presented which progressively overcome this limitation.

5.1 Model 1 (M1)

Considering case i and case ii, the precondition becomes as follows.

$$I_n^{'} = I^{'}(x,y,n) = \begin{cases} I(x,y,n), \; if \; I(x,y,n) - B_e(x,y,n-1) \le \delta_c \\ (1-r_i)B_e(x,y,n-1) + r_i I(x,y,n), \; otherwise \end{cases}$$

δ_c and r_i are called pollution controlling parameters. By applying this precondition on each frame, the background estimation can be done using (4).

$$B_e(n) = \frac{1}{N}\sum_{n=i}^{i+N} I_n^{'} \tag{4}$$

5.2 Model 2 (M2)

To strengthen the capability of M1, a new parameter–resampling interval (N_r), is introduced. This parameter facilitates dividing the entire time span T, $T = t_2 - t_1$ into small intervals If the operation (4) is confined within a smaller interval, the error reduces to a minimum value. N_r represents the predefined number of frames after which the estimation process restarts without recalling the previous frames. If this process is included in the estimation equation, (4) looks like as follows,

$$B_e(n) = \frac{1}{n - qN_r}\sum_{n=qN_r+1}^{(q+1)N_r} I_n^{'}, q = \left\| \frac{n}{N_r} \right\|. \tag{5}$$

5.3 Model 3 (M3)

To improve M2 further, a new parameter (sample lag N_l) is introduced to memorize the estimated backgrounds and to prevent accumulation of vehicles within the background. In particular, N_l is a weightage factor over the previously estimated backgrounds. The static background B^* is estimated from median of several frames

$$B_e(n) = \begin{cases} \frac{1}{(n-qN_r)+N_l}\left(\sum_{n=qN_r+1}^{(q+1)N_r} I_n^{'} + N_l B_e(n-(q-1)N_r)\right), \; if \; q > 0 \\ \frac{1}{(n-qN_r)+N_l}\left(\sum_{n=qN_r+1}^{(q+1)N_r} I_n^{'} + N_l B^*\right), \; if \; q = 0 \end{cases} \quad q = \left\| \frac{n}{N_r} \right\| \tag{6}$$

As the final background model (M3) has been obtained, traffic detection task would be achieved by a per pixel binary threshold model. In this regard, the distance matrix δ_n of frame n is determined using (6) incorporating the estimated background $B_e(n)$ (6) and the input image I_n. Afterwards, the distance matrix is fed into (8), which considers that a higher threshold value should be provided to a lower difference value within the distance matrix and vice-versa. This is essentially a simplified linear equation between difference and threshold values. It gives the per pixel threshold using the maximum and minimum thresholds ($\tau_{\max}$ and $\tau_{\min}$).

$$\delta(n) = |I_n - B_e(n)| \tag{7}$$

$$\tau(x, y, n) = \tau_{\max} - \left|\frac{\tau_{\max} - \tau_{\min}}{\delta_{\max} - \delta_{\min}}\right| \times (\delta(x, y, n) - \delta_{\min}) \tag{8}$$

where
$\delta_{\max} = Max(\delta(x_1, y_1, n), \delta(x_1, y_2, n), \delta(x, y, n)\ldots..., \delta(x_H, y_W, n))$
$\delta_{\min} = Min(\delta(x_1, y_1, n), \delta(x_1, y_2, n), \delta(x, y, n)\ldots..., \delta(x_H, y_W, n))$.

The pixels having greater difference value than the corresponding threshold are classified as foreground as in (9). This results in a binary image (b).

$$b(x, y, n) = \begin{cases} 1, \ if \ \delta(x, y, n) \geq \tau(x, y, n) \\ 0, \ otherwise \end{cases} \tag{9}$$

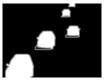
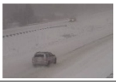
6 Calibration and Validation

Five parameters associated with M3 need to be calibrated first to make the model implementable in segmentation. In this context, we have collected six video datasets and determined the feasible region for optimization. The six video datasets [19] are: (1) 'Office'; (2) 'Pedestrians'; (3) 'PETS2006'; (4) 'Highway'; (5) 'Boat'; and (6) 'Blizzard'. Using these feasible regions, a constrained optimization is conducted. Finally, with the calibrated parameters, both qualitative and quantitative (visual) analyses are conducted for model validation. To quantify the classification performance with respect to ground-truth, four basic measures are used, such as, (1) true positives (TP): correctly classified foreground pixels; (2) true negatives (TN): correctly classified background pixels; (3) false positives (FP): incorrectly, classified foreground pixels; and (4) false negatives (FN): incorrectly classified background pixels. Precision-Recall values are assembled from the following formulas:

$$\text{Precision (PR)} = \frac{TP}{TP + FP}; \text{ Recall (RE)} = \frac{TP}{TP + FN}; PCC = \frac{TP + TN}{TP + FN + FP + TN}$$

Percentage of Correct Classification (PCC) is also used for fitness quantification in the context of background subtraction techniques. The calibrated parameters of the models are as follows: $N_l = 425$, $N_r = 255$, $\delta_c = 120$, $r_i = 0.1$, and $\tau_{\max} = 25.56$. Using these calibrated parameter values, the binary images of the validation dataset have been obtained and presented in Table 1.

Table 1. Foreground segmentation using optimized parameters.

	Qualitative analysis			Quantitative analysis		
	Actual Image	Ground Truth	Model Output	Precision	Recall	PCC
Highway				0.93	0.96	0.99
Boats				0.84	0.99	0.96
Blizzard				0.97	0.93	0.98

7 Field Implementation

Three different locations in Dhaka city are chosen to assess the performance of model M3 in traffic flow estimation. The data collection time at each location was chosen to cover the peak and off-peak period characteristics of the traffic stream. These locations comprise of different roadway and traffic characteristics. The mounting height of the cameras is at least 20ft and their angle is less than 45° to reduce detecting the object details. For the same period, ground truth count data has also been collected from the video through manual post-processing.

Using this estimated count, three measure of performances such as Mean Absolute Error (MAE), Mean Absolute Percentage (MAPE), and Average Accuracy of Object Count (AAOC) are determined applying the subsequent formulae:

$$MAE = \frac{1}{N}\sum_{i}^{N}\left|N_i^G - N_i^{M3}\right|; MAPE = \frac{100}{N}\sum_{i}^{N}\frac{\left|N_i^G - N_i^{M3}\right|}{N_i^G};$$

$$AAOC = \frac{1}{N}\sum_{i}^{N}\frac{Min\left(N_i^G, N_i^{M3}\right)}{\frac{N_i^G + N_i^{M3}}{2}}$$

where, N_i^G = Ground truth count for i^{th} sample, N_i^{M3} = Estimated count obtained using M3 for i^{th} sample, N = Number of total sample, and $N_i^G + N_i^{M3} > 0$. Small values of MAE and MAPE and large values of AAOC are considered as better result.

Figure 1 shows that for all datasets, results obtained using M3 is in harmony with the ground truth. Both MAE and MAPE value are minimum for urban arterial dataset and maximum for urban intersection dataset. The main reason behind it is the presence of large and small vehicles in the urban intersection dataset. Specifically, small vehicles like motorcycles and bicycles are eroded by the morphological operations, which ultimately reduce the estimated count.

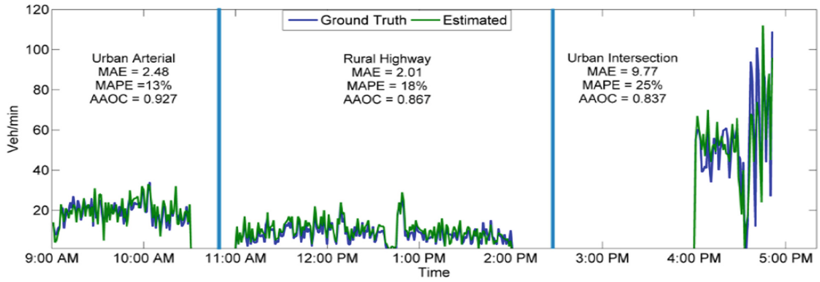


Fig. 1. Field testing of M3 in different locations.

8 Conclusion

Background subtraction is a very common approach in vision based traffic detection. However, an accurate background is needed to classify the foreground correctly. Unfortunately, it is difficult to get such background as it is not static and it is occupied with objects most of the time. Thus, the necessity of accurate background modeling emerges for accurate traffic detection. In this context, three models were developed successively; whereas model M3 addresses the discussed limitations.

Model M3 was calibrated and validated using different video dataset. The validation result shows that the model output is representative of ground truth yielding more than 95% PCC value and 90% Precision-Recall value. It was also evident from the result that the main limitation of this model is not being able to capture the background dynamics as observed in ‘Boat’ due to flowing water and camouflage as observed in ‘Blizzard’ where both vehicle and pavement were covered with snow. However, field test shows that the model achieves 93% AAOC in morning peak period, which represent its robustness in traffic detection. It also shows that the AAOC result is independent of number of vehicles present in the data input. Interestingly, as the model M3 works at pixels level, the results are independent of variation in traffic flow.

In the future, the above two challenges will be investigated using the same theoretical framework developed in this paper. Furthermore, detecting traffic at night is a great challenge, which can also be explored using this framework.

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Big Data and Transport Modelling

New Indicators in the Performance Analysis of a Public Transport Interchange Using Microsimulation Tools - The Colégio Militar Case Study

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Abstract. Public transport network organization should allow efficient and comfortable transfers in interchanges, but these infrastructures are often associated with high pedestrian flows and constraints on pedestrian movement, which discourages their use. The analysis methods for the performance of public transport interchanges are usually based on aggregate values, which may result in highly optimistic results. However, the development of microsimulation tools provides a generous amount of data, allowing the development of new ways of measuring these infrastructures' performance. Based on the idea that using average values should lead to optimistic results, and using data from the Colégio Militar/Luz subway station (in Lisbon), new indicators related to the level of service using microsimulation tools are suggested, proving that there can be different conclusions about the interchange's performance.

Keywords: Pedestrian circulation · Public transport interchanges
Level of service · Microsimulation

1 Introduction

Public transport interchanges are crucial points in the transport system, since they allow passengers to transfer between different lines or transport modes, contributing to improve the operational efficiency of the transport system [1–4]. However, the level of service of the pedestrian facilities in interchanges impacts strongly on the users' comfort and is a relevant part in their global level of service.

Simultaneously, microsimulation tools evolved in the past years, being now possible to simulate the individual behavior of pedestrians and their interactions, as well as reliably representing the surrounding environment. Since interchange analysis was not updated yet to respond to those new improvements in the microsimulation tools, average values are still used as the main indicator of the overall performance of an interchange. This work aims to contribute to the definition of a new set of indicators to provide a more realistic diagnosis of the performance of transit interchanges.

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This paper begins with a summarization of the main research developments on pedestrian circulation on interchanges, as well as the main characteristics of the microsimulation tools. On chapter 3, the suggested indicators are described, and chapter 4 presents the case study and the analysis of pedestrian circulation conditions in it, as well as the calculation of the suggested indicators. Finally, on chapter 5 the main conclusions are summarized.

2 Literature Review

Most transfers on a public transport journey require a walking connection between modes which adds an additional uncertainty to the overall travel time, making its quality a relevant aspect on the passengers' satisfaction levels. Besides, there are several critical points on an interchange, and faregates are one of the most important and complex ones, since they create an "intermediate step" on the passengers' trip, increase journey time and lead to the presence of crowds [5].

The assessment of the quality of interchanges has been studied extensively, and regarding a quantitative performance analysis, the "level of service" (LOS) is still the most used indicator [6]. Fruin [7] defined the reference values for sidewalks, corridors, stairways and waiting areas; that depend on pedestrian space, density, flow per unit width and average speed, and they are used in the Transit Capacity and Quality of Service Manual [8]. According to De Gersigny et al. [9], the LOS should be at least "C" at corridors and waiting areas, while it could reach "D" at stairways. The Transit Capacity and Quality of Service Manual suggests a LOS of "C" for urban transit systems and LOS "B" for intercity rail passenger systems [8].

Besides, explanatory models of human behavior during circulation improved significantly during the last 50 years. There are two main types of models: macroscopic models, which focus on the analysis of the observable dimensions (like density and flow), and microscopic models, focused on modeling the individual behavior of each pedestrian. On the side of microscopic models, Helbing and Molnár [10] were responsible for the "social force model". Despite its relative simplicity, this model reproduces quite accurately the dynamics of pedestrians [11]. According to the "social force model", the pedestrian desired speed is similar to a "social force", which represents the effect of the surrounding environment (pedestrians or obstacles) on the pedestrian behavior and will cause the motivation to act. Much of the success of this model is due to its ability to reproduce most of the "self-organization" phenomena observed in a real context, and since its introduction, it has been adapted and further developed to include, for instance, the effect of group walking, collision prediction or different speeds [11–13].

On the other hand, pedestrian microsimulation has become a very powerful tool in the past few years, although it usually requires higher computational resources [14]. Its success is due to the ability to simulate the behavior of each individual agent in the system, as well as the interaction of all the agents resulting in a more accurate and realistic representation of pedestrian behavior and infrastructure performance [15, 16]. Modeling an interchange with microsimulation tools allows not only for a closer view of the pedestrians' movement and the perception of the constraints that really affect them, but also for the calculation of precise indicators of the infrastructure's performance due to the amount of produced data (depending on the desired granularity).

There are several software products that allow pedestrian microsimulation. Vissim, the software used in this research, was the first professional tool to enable the simulation of pedestrians and vehicles simultaneously, as well as the interactions between them [17]. Since 2008, Vissim (through its 'Viswalk' module) uses the "social force model", allowing the definition of different types of pedestrian and their own characteristics (speed, body size, etc.) but requiring substantial amounts of data and highly accurate calibration and validation [6, 18–20].

3 A Performance Analysis Approach for Pedestrian Circulation Using Microsimulation

Even though different performance analysis of pedestrian circulation in interchanges have been conducted for decades using the work of Fruin [7], there is still a lack of guidelines regarding the use of microsimulation for this purpose [6].

The most recent version of the Transit Capacity and Quality of Service Manual [8] suggests, for the first time, a set of measures that can be reported by this kind of models, ranging from basic measures, like the average density, the flow volume and the travel time from one cordon line to another, or the instantaneous walking speed, to more complex measures like the perceived convenience or inconvenience, the fulfillment or frustration, the comfort or discomfort and the satisfaction or dissatisfaction. Aggregate measures like a weighted journey time or a generalized cost are also considered.

However, using the average density of a modelled hour or a 15-min period ignores one of the main advantages of the microsimulation, which is the more fine-grained look at the pedestrian flows [8]. Also, the use of an average value for the interchange's performance during the peak hour (or 15-min peak period) will lead to more favorable and optimistic results. In fact, and particularly in a transport interchange, the passenger movement patterns strongly depend on transit headways. For this reason, pedestrian circulation patterns often vary between dense platoons of pedestrians and periods of "emptiness" ("short-term gaps"), and considering an hourly/15-min average value would not be adequate to evaluate the interchange.

At the same time, considering the worst moment (even if it only happened once) is an excessive consideration that would lead to oversized interchanges. Other approaches, like considering the "most loaded 15-min period" also suffer from the consideration of an average value for an extended period when analyzing a transport interchange. For these reasons, a stepwise approach was defined, aiming to contribute to a more adjusted methodology of performance analysis. It is worth to clarify that there aren't either any guidelines that define the "global LOS" of the interchange, so this was simply defined as the average of the individual areas gathered for each analysis area.

The first step should be establishing a rule to synthetize the results from the current analyses, using the average density to evaluate each area's performance. Thus, if the result from the hourly average analysis is "positive" (i.e., the level of service is "A", "B" or "C"), both for each individual area or for the total interchange, it isn't necessarily true that the interchange's performance is good, and no constraints are felt by the passengers. However, if an undesirable LOS results from the average analysis of the entire period, this means that the area presents serious constraints to the passengers. Since the average value is, expectedly, an optimistic view of the performance, the passengers should experience seriously bad conditions during some of the evaluated moments. In other words, an area (or an interchange) that register, in average, a bad LOS suggests a problem of capacity, while a good LOS doesn't tell the analyst anything about the peak periods (e.g., when a train arrives, and the platoon of passengers try to leave the station).

To identify the possibility of an underestimated interchange, a "reference" value should be calculated: for each analyzed area, the density (pedestrians/m^2) that it would reach if the passenger flows were evenly distributed across the analysis period and across the studied areas. For instance, if the faregates' zone is being analyzed, it corresponds to divide the hourly/15-min demand by each one of the faregates and each moment in this period. A set of indicators are suggested to help to understand more realistically and consistently the performance of the analyzed area:

- Adjusted LOS: the average LOS only on those periods when it is above the LOS of the "reference" value; this indicator aims to "relativize" the performance considering that, even with a uniform distribution of the demand, a certain value would be reached, which corresponds to the "most perfect" situation in terms of planning;
- Constrained time and constrained flow: the percentage of time and flow that crosses the areas when the density is above the "reference" value; these calculations aim to identify those situations where only a few periods have a density above the "reference" but a greater part of the flow crosses the faregates during those moments;
- Unpleasant periods: average duration of the periods when the LOS is above the LOS of the "reference" value.

4 Case Study Analysis: The Colégio Militar Interchange

To test the suggested measure indicators, the interchange of Colégio Militar, in Lisbon, was chosen as a case study. This is an intermodal interchange which connects one of the lines of Metropolitano de Lisboa (subway operator) with several urban and suburban bus operators' services, in a total number of 21 lines stopping at this station.

The subway station has nine access points, four of them from the bus station and one with an internal connection to the biggest shopping mall of Lisbon (with about 120,000 m^2 of leasable area). The station has a central lobby that allows accessing the boarding platforms through 22 reversible faregates: 8 gates usually dedicated to incoming passengers and 14 dedicated to exiting passengers.

4.1 Calibration and Validation

To help the modelling phase, Metropolitano de Lisboa provided detailed blueprints of the station, that were complemented with *in situ* measurements of some elements.

The ticketing data (smartcard validations entering and exiting the station) of a normal week of 2014 (between May 26th and May 30th) was used. To represent the passengers' movement inside the station and attend to the demand oscillations during the peak hour, passenger flows were divided into 15 min' periods. According to the ticketing data, the morning peak hour is between 8:30 a.m. and 9:30 a.m. (with about 900 passengers entering the station and 1.200 leaving it), while the evening peak hour occurs between 6:00 p.m. and 7:00 p.m. (1.800 passengers entering and 1.900 leaving). For this reason, the analysis was focused on the evening peak hour. The passengers' transfers were distributed through the entries/exits nearest to the bus stops using passenger counts on the "decision points" (junctions) of the station (realized during the equivalent week of May 2015). To support the modeling phase, pedestrian speeds measurements and passing times through the faregates were also observed.

The station's microsimulation model (Fig. 1) consists of 134 areas (corridors or waiting areas), 208 obstacles (walls, columns or barriers) and 21 stairways (between the lobby and the platform, and between the station and the surface). The modeling of the station was limited to the entrance/exit of the subway station. Based on the ticketing data, the flows for each movement were modeled, while the subway services were created with the frequency of arrivals described by Metropolitano de Lisboa (with a random variation to ensure the existence of trains arriving to the station in both directions simultaneously). The measured walking speeds were introduced in the software.

Fig. 1. The microsimulation model (faregates detail).

The pedestrian flows at the station were represented in two different ways. The station entrances/exits' distributions obtained from the pedestrian counting and the ticketing data were introduced as "pedestrian static routes" (routes where pedestrians go from a start point to an end point using a static percentage for each destination), while the choice of the faregate to enter/exit was modeled as "pedestrian partial routes" (route for local distribution of the pedestrians according the fastest path) [20], letting the model decide which was the path (or barrier) with lower delay in each moment.

To validate the model, four key indicators have been chosen: passengers flow in each entrance and exit of the station, the walking speed in the measured section, passenger "share" in each group of faregates and visual comparison between the observed situation and the microsimulation model (reproduction of some pedestrian behaviors), for several "random seeds" of demand generation. Since the model requires a warm-up period (during which the station is not yet with the real flows), the analysis period was chosen to be the intermediate 30-min period of the simulation hour (between the seconds 900 and 2.700 of the simulation). Passengers' "choices" in the faregates zones were also compared with the ticketing data; and some visual comparisons were made; some of the observed behaviors were, in fact, reproduced in the model, like the queue formation around the faregates and the time spent in ticket booths.

4.2 Results from the Performance Analysis

For the performance analysis, LOS was calculated for a set of areas, but only the exit areas are considered in this analysis.

In these areas, during the evening peak hour, the average LOS presents values ranging from "A" to "D". In about 86% of the areas, a good performance was observed during the analyzed 30 min (Fig. 2a). However, when looking at the worst periods, all the areas registered at least one moment when the LOS reaches "E" or "F", which reveals a higher probability of longer queues (Fig. 2b).

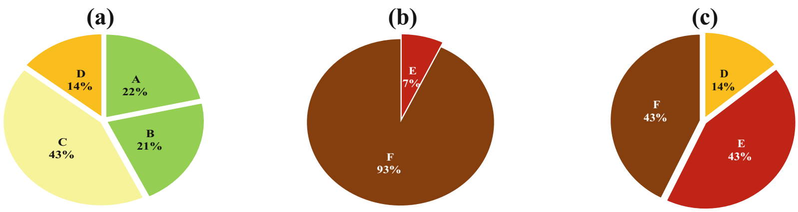

Fig. 2. LOS in the faregates' areas using the current methodology, considering (a) average values, (b) worst values, and (c) using the "adjusted LOS" concept.

To understand the real extent of the situation, the new indicators suggested previously were calculated. For that, the flow passing the exit faregates during the 30-min period of analysis was divided by the 14 existing faregates.

Thus, considering a uniform distribution through the time and the faregates, an average density of 0,37 pedestrians/m^2 was reached, which means that a LOS of "B" was felt by the average pedestrian that passed through the station.

Adjusted LOS

Using the calculated "reference" value, the results are clearly worse than the simple average: all the areas present an average LOS of "D", "E" or "F" (Fig. 2c).

This value aims to be more realistic than the previously presented results, since it considers only the moments where, effectively, passengers crossed the areas and experienced the calculated levels of service and (dis)comfort.

Constrained Time and Constrained Flow

The results from the microsimulation model are produced in 5-s periods, i.e., in the period of analysis there are 360 periods with density values for each area.

Following the suggested approach, the flow volumes were identified as having passed (or not) during the periods when the performance conditions were above the calculated "reference" value ("constrained periods"). Although the average density of the different areas was above the "reference" value in only 11% to 35% of the analyzed time, the flow during those periods is much higher: 80% of the flow passed the faregates during those more constrained moments. These results suggest the existence of visible "peak moments", mostly during the arrival of the compositions to the station.

Unpleasant Periods

One clear indicator of the (dis)comfort felt by the passengers is the time they spent in the faregates or the length of the queue they are caught in.

One way of measuring this indicator is by gauging during how much time the density of each area is above the "reference" value, which represents that there are passengers still waiting to cross the faregate.

In average terms, the constrained (or unpleasant, from the passengers' perspective) periods had a duration that ranged from 7 s to 1,5 min, with an average value of about 26 s. The gates farther from the access stairs (that have a lower number of detours calculated by the model) had lower values when compared to the average, which is consistent with the current functioning of the station, since it is rare to have queues next to these gates.

5 Conclusions

The analyses carried out highlight the potential of microsimulation tools applied to performance analysis of transit interchanges.

The results showed, for current situation, the existence of constrained moments; however, these are barely detectable when average densities are used. For that reason, new indicators should allow a better evaluation of the infrastructure's real performance.

Since the observed constraints are similar to many others that occur in other subway stations around the world, the suggested evaluation method aims to contribute to the discussion on the use of microsimulation tools on interchanges appraisal.

However, more research should be done in order to develop a more consistent and systematic approach regarding the method presented here. As stated by the Transit Capacity and Quality of Service Manual [8], "new or more-detailed standards for what constitutes preferred or acceptable pedestrian flow conditions are needed". Indeed, the standards are not defined yet, and this paper aims to contribute to the consideration of new indicators when evaluating this kind of infrastructures.

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Improving the Assessment of Transport External Costs Using FCD Data

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Abstract. This paper presents a methodology for a better assessment of transport variables used for the estimation of external costs by using FCD data. It is based on the estimation of performance spread factors able to expand to the whole day the peak hour results usually carried out by transport and impact models. The application to a real-size test case in Rome showed the promising results of the proposed approach.

Keywords: FCD data · Transport external costs · Modelling · Impacts Assessment

1 Introduction

External costs of transport play a considerable role for the assessment of policy strategies both for long-term and short-term planning.

In order to assess a policy scenario involving transport systems, transport and impact models are usually formalized and applied. Transport models should take into account all steps including motorization, traffic generation, distribution, modal split and assignment, which should be differently specified both for passengers and freight. Such transport activities are the basic inputs for impact models, which usually include generalized costs (i.e. internal effects and congestion), accidents, noise, air pollution and climate change. They usually derive from transport models that, especially in urban areas, are specified for the reproduction of transport system in the peak-hours, extending results to the rest of the time (daily off-peaks, weekly changes, and so on) through approximated methods.

The rapid spreading of big data in transport is changing the face of mobility [1]. In the sphere of transport planning the availability of the huge amount of FCD (Floating Car Data) allows us to add new dimensions to traditional transport models [2].

Then, this study aims to present a methodology which uses FCD data to extend the results of transport models from the morning peak hour to the rest of the day, and over,

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for a more precise estimation of inputs for assessment analysis (e.g. costs-benefits) including the estimation of external costs.

Section 2 describes the proposed methodology, while Sect. 3 reports the results of a real-size application to the city of Rome, for which a FCD dataset made of probe vehicles positions was available. Finally, Sect. 4 summarizes the conclusions and future research developments of this research.

2 Methodology

In the framework of principles of transport system engineering [3], the logical architecture of the methodology for the estimation of transport external costs by using FCD data is shown in Fig. 1.

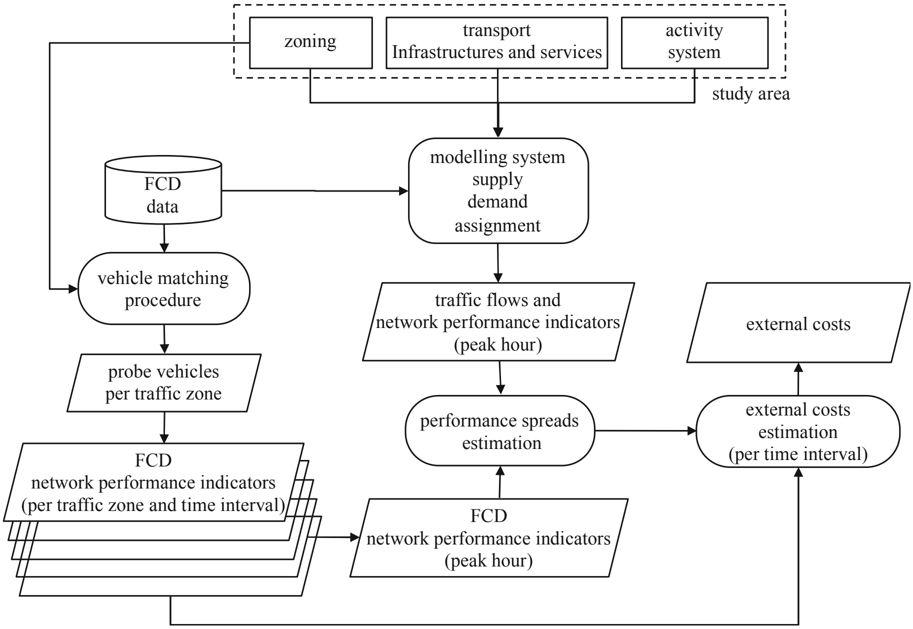

Fig. 1. Proposed methodology: logical architecture.

The proposed methodology is based on the assumption that vehicle fleet behavior captured by FCD data is a representative sample of the whole mobility in the study area for the considered time interval of the day. This assumption is also encouraged by the rapid spreading of cellular floating data availability to which this methodology can be adapted.

Then, we can use FCD data to extend the results of transport models from the morning peak hour to the rest of the day for a more precise estimation of inputs for assessment analysis by including the estimation of external costs. If paying attention to the obvious approximations, this principle can be also used to capture weekly or monthly mobility trends.

Specifically, we can relate network performance indicators coming from FCD data with those estimated by the transport network simulation obtained through transport models in the morning peak hour.

Given a portion of the study area (e.g. a traffic zone), we can define a measure of distance (performance spread factor) between information captured by FCD data and information about mobility and traffic conditions of the considered zone in the morning peak hour. Zone mobility is considered through the vehicle mileage, while traffic condition is taken into account by the average vehicle speed.

If we assume that FCD data is representative, then we can use the performance spread factor and the use of FCD data detected for each time interval of the day aiming at calculating in a more precise way variables on which transport external costs are estimated.

Features of each component of the methodology are described in the following subsections.

2.1 Study Area

The study area is defined as the territory within which we measure most of effects due to the introduction of the transport scenario under analysis. Such an area is characterized by various residential, economic and social activities, which generate transport demand flows as well as by infrastructures and services that interact with each other to produce transportation opportunities. A zoning system applies to the study area basically for modelling purposes. Zoning is the operation through which the study area is divided into a discrete number of portions (traffic zones) that are areas presenting homogeneous features in terms of land-use, accessibility and transport opportunities; they are often obtained by aggregating statistical geographical units as it allows to easily obtain statistical data (population, employees, offices, shops and so on) per traffic zone, which are used in the modelling system.

2.2 Modelling System

Transport system simulation plays a key role in transport scenario analysis and assessment. It can be carried out by using mathematical models able to reproduce traffic flows and impacts as the result of the interactions among the economic and social activities of the study area (demand) and the facilities that allow to produce transportation opportunities (supply).

Transport demand is generated by the need to complete different activities in different spaces (e.g. working in a place different from household); it can be simulated by demand models able to reproduce the trip generation, distribution and modal split both for passengers and freight, which are represented by origin-destination (O-D) trip matrices for the considered time interval (e.g. morning peak hour).

Transport supply is made of infrastructures (roads and railways), services (transit lines and timetables), regulations (road circulation scheme), and prices (road tolls and transit fares). It can be represented through a graph and cost functions, which allow to represent travel opportunities (O-D paths) and performances (Level of Service - LoS - attributes).

The interaction (assignment) between demand and supply allows to obtain traffic flows and network performances on which effects (e.g. external costs) are estimated.

Further details about transport modelling can be found in [3].

2.3 FCD Data

FCD data consists of information about position and speed of a probe vehicle. Data are characterized by a sampling frequency defined both in time and space. The space sampling is carried out mainly for data recovery in case of covering failure. Data is recorded from the start of vehicle engine to the shutdown; it usually consists of time, position and speed.

In order to be used for transport analysis, FCD data have to be geographically localized, i.e. they have to be positioned within an area or matched on a transport infrastructure according to the scope of the study. This operation is called geocoding and the process of associating the FCD data to a link of the road network is carried out by using a map matching algorithm [4]. This kind of algorithms gives a probability associated to each link of being a candidate for a matching within a feasible set of candidate links [2].

In principle, the matching procedure is complex and time consuming as the algorithm needs to compare all the FCD samples with all network links, but the proposed methodology reduces complexity and computational time because it only requires to match data within traffic zones.

2.4 Performance Spread Factors

In order to expand the information of FCD data representing the sample of detected vehicles to the whole mobility of the study area, we propose a mileage spread factor. It can be defined by considering the traffic condition detected from FCD and simulated by traffic models in the morning peak hour, that is when it is well known that traffic models reproduce faithfully the real mobility of the study area and hence the representativeness of the FCD sample can be evaluated.

Given the traffic zone Z, the mileage spread factor PSF_Z can be defined as follows:

$$PSF_Z = M_{Zh}^{FCD} / M_{Zh}^{MOD} \tag{1}$$

where M_{Zh}^{FCD} represents the mileage of vehicles travelling within traffic zone Z in the peak hour h detected by FCD, while M_{Zh}^{MOD} is the same value estimated by traffic models.

Given the traffic zone Z and time interval i, we can also use the available information on speed by averaging vehicle speeds coming from FCD, S_{Zi}^{FCD}. Referring to the morning peak hour h, such a value can be adjusted by using the average speed obtained through traffic models, S_{Zh}^{MOD}.

The performance spread factors can be used to expand to the whole mobility the information we have from FCD data per time interval of the day for a more precise calculation of input variables used to estimate external costs.

2.5 External Costs

For the assessment of transport policy strategies (e.g. benefit-cost analysis) external costs of transport usually include congestion, accidents, noise, air pollution and climate change. Most of the above costs are usually measured by using aggregate impact functions based on mileage and speed. As an example, the estimation of pollutant emissions can be cited. Specifically, they can be calculated using the results of the Corinair European research program [5] finalized in the Copert Emission Inventory Model [6] for which the emission of pollutant x for vehicles of category k in time interval i can be computed as follows

$$E_{ki}^{x} = f\left(B_{k}^{x}, S_{ki}, M_{ki}\right) \tag{2}$$

where B_k^x is the emission rate of pollutant x for vehicle category k; S_{ki} is the average speed of vehicle category k in time interval i; M_{ki} is the mileage of vehicle category k in time interval i.

Further details on methods and parameters used in Europe to estimate external costs of transport can be deepened on [7].

3 Application

The proposed methodology has been tested in Rome Metropolitan Area, where 4 million people live in about 5350 km^2.

The zoning system consists of 1339 traffic zones, which is part of the transport planning system of models used by the City Transport Agency (Roma Servizi per la Mobilità - RSM) for the assessment of transport scenarios in Rome.

Supply model consists of a road graph made of more than 42000 nodes and 97000 directional links, while the demand refers to about 350.000 origin-destination trips by car in the morning peak hour, which are assigned to the network by using a deterministic multiclass equilibrium approach that distinguish vehicles able to access the Central Restricted Traffic Area and others.

The FCD dataset was provided by RSM Transport Agency. It consists of FCD samples acquired every 30 s or 2 km for 10 consecutive days. Data is recorded from the start of vehicle engine to the shutdown according to a track record made of the following fields: vehicle ID, day, time, latitude, longitude, speed, direction, signal quality, state of motion, distance from previous data. Data are filtered on the basis of speed, coordinates and sequence of detected points, applying procedures able to capture and analyze outliers data and mis-identified trajectories. This validation allows us to consider for our application about 6 million vehicles for a total of about 26 million FCD samples in the 10 considered days. Focusing on the daily mobility of the study area during working days, such samples allow us to define an average of 3.5 daily trips per vehicle for about 27 km/day (i.e. 7.7 km/trip); the average distance per trip in the peak hour is 3.2 km.

Results obtained through the proposed methodology (FCD) are compared with those carried out by approximated methods, that is values calculated by using a peak-hour expansion rate (HP), i.e. expanding effects estimated for the morning peak hour to the whole day on the basis of historical traffic statistics.

Even if results are obtained for all the 1339 traffic zones of the study area, in the following we focus on some representative ones (see Fig. 2) which allow us to better point out the output of the methodology (FCD) and the difference with the approximated method (HP). As described in Fig. 2, such zones are descriptive of different areas ranging from the suburbs (A, D, E) to the outer (C, B, F) and inner (G, H) centre. Zone C is particular because it includes a section of one of the most important urban highway of the study area and one of the most congested exit toward the city centre.

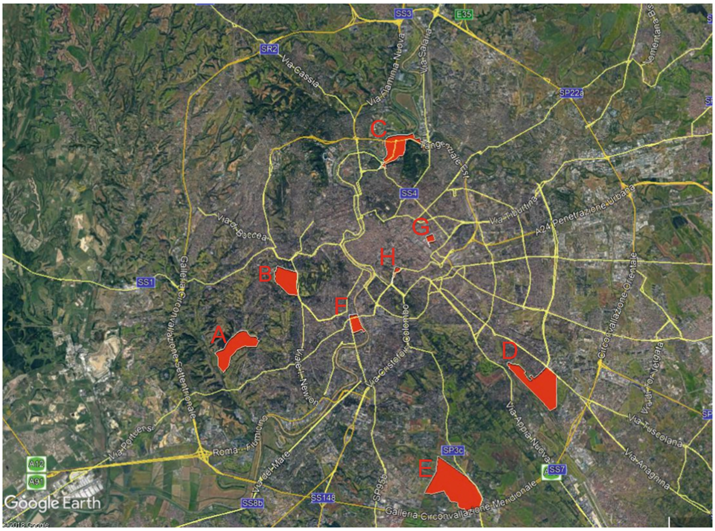

Fig. 2. Results: representative traffic zones.

Figure 3 reports the evolution of within-day average speed obtained through FCD data. The different absolute values reflect the different infrastructures that characterizes the traffic zones, while the variation over the time intervals reveals the different performances due to traffic congestion. In fact, the lowest speeds are at peak hours as well as the highest can be seen during the night.

The reverse trend can be seen in terms of evolution of vehicle mileage FCD vehicle mileage (see Fig. 4) where we can see the highest values in peak hours and the lowest in off-peaks with a minimum at 4:00 a.m.

Finally, Fig. 5 describes the difference in terms of daily vehicle mileage obtained by the application of the proposed methodology (FCD) and the use of a peak-hour expansion rate (HP) that in Rome is usually set to 0.1 (i.e. the morning peak hour is about the 10% of the daily total). As we can see we have considerable differences, especially in suburbs zones where expanding the model peak hour results seems to be too approximate to correctly reproduce the daily traffic. Most of the zones of Fig. 5 present differences greater than the 40%. Such differences greatly influence the estimation of effects resulting in a widespread underestimation of external costs that cannot

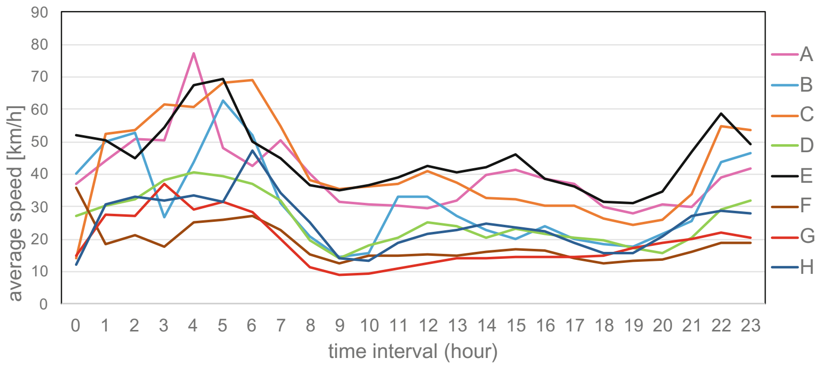

Fig. 3. Results: FCD average speeds.

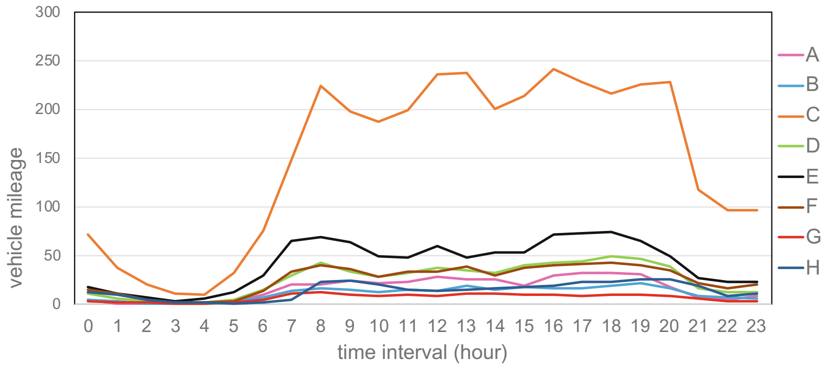

Fig. 4. Results: FCD vehicle mileage.

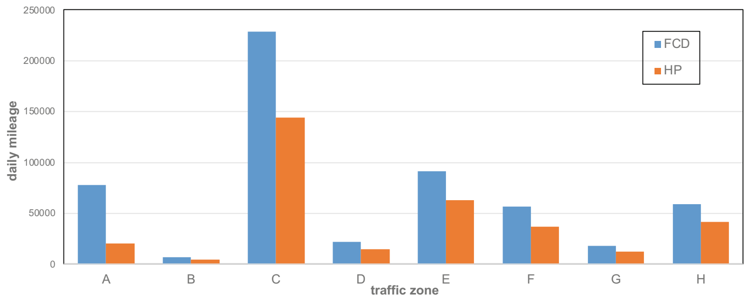

Fig. 5. Results: comparison between FCD and HP daily mileage.

be neglected for a correct assessment of the transport scenario under investigation. Moreover, if approximated methods have to be used, such results suggest an essential updating of the HP factor for a better reproduction of daily traffic and related impacts.

4 Conclusions

This paper proposed the use of FCD data for the assessment of transport policy strategies. It started from the consideration that the dissemination of cellular floating data and its availability at progressively lower costs can greatly improve the results of transport models for a more precise assessment analysis.

Even if the proposed modelling framework can be applied to all kind of floating data, it has been proposed and applied to FCD data. Such data are used to identify a representative sample of the whole mobility in the study area, which may extend the results of the morning peak hour to the whole day, and possibly over.

The test case in the city of Rome demonstrated the applicability of the proposed methodology and allowed us to identify the future advances of this research that will mainly regard efforts for greater robustness of the methodology, the introduction of other available floating data sources as well as a further validation based on the comparison with survey and field data.

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A Big Data Demand Estimation Framework for Multimodal Modelling of Urban Congested Networks

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Abstract. This paper deals with the problem of estimating daily mobility flows using different sources of data, and in particular from mobile devices, such as mobile phones and floating car data. We show how mobile phone data can be used to better estimate the structure of the demand matrix, both temporally (i.e. the daily generated flows from each zone) and spatially (i.e. distributing the flows on the different OD pairs). Then, floating car data together with traffic counts can be used to further distribute the demand on the available modes and routes. During this phase, a behavioral modelling approach is used, according to traditional dynamic user equilibrium using a joint route and departure time choice model. Floating car data information is used to estimate speed profiles at all links where information is available, and for route travel times, which feed the utility-based models. A two-step approach is then proposed to solve the problem for large scale networks, in which the total demand is first generated, and then equilibrium is calculated through a dynamic traffic assignment model. The effectiveness and reliability of the proposed modelling framework is shown on a realistic case study involving the road network of Luxembourg City and its surroundings, and is compared to the traditional bi-level formulation solved using the Generalized Least Square (GLS) Estimation. The comparison shows how the two-step approach is more robust in generating realistic daily OD flows, and in exploiting the information collected from mobile sensors.

Keywords: Dynamic OD estimation · Big mobility data · Two-Steps approach

1 Introduction

1.1 The Demand Estimation Problem

Dynamic traffic models represent essential tools for assessing properties of robustness and resilience, and for managing transportation networks. These models take as input the demand from each origin and destination and at each time period, and in turn estimate and/or predict route and link flows and travel times.

In order to generate the mobility demand, usually represented in the form of Origin-Destination (OD) matrices, traditional approaches combine survey data and mathematical tools [1]. Additionally, more recent works have done a significant progress into including new data sources, such as Call Detail Records (CDR), GSM data, sensing data

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and geospatial data [2]. Unfortunately, the estimated demand matrix is at most a coarse representation of the systematic component of the demand – such as the typical behavior during a working day. However, daily demand patterns can substantially differ from the systematic ones because of several elements, including weather conditions or road works, as well as because of the inherent stochasticity of the travelers' choices. Deviations between estimated and actual demand patterns can be mitigated by using traffic data, which can be used to update an existing (a-priori) OD matrix. This problem, which is known in the literature as the Dynamic Origin-Destination Estimation (DODE) problem, exploits a properly specified objective function for estimating the time-dependent OD flows.

While the DODE problem has been initially treated as an extension of its static counterpart [3, 4], the last decades have witnessed to a considerable effort to develop methodologies able to deal with within-day dynamics in order to apply them on (real-time) dynamic traffic management contexts. By limiting ourselves to the widely adopted bi-level optimization formulation, in the upper level, OD flows are updated by minimizing the error between simulated and observed traffic data, while in the lower level the DTA solves the combined Route Choice (RC) and Dynamic Network Loading (DNL) problems [5]. In order to overcome solution under-determinedness, Balakrishna et al. [6] suggested to use a simulation-based DTA model to generate traffic measures and to include additional information, such as link speed, within the objective function, in order to represent the congested/uncongested network conditions. Following this seminal work, many researchers developed new and more robust algorithms able to properly capture the non-linearity between link-flow propagation and time-varying OD demand [7–10]. Despite this intense effort, the resulting optimization problem remains highly non-linear and non-convex. Hence, the easiest solution is to reformulate the objective function in order to reduce the number of variables. This can be done, for instance, by using Principal Component Analysis (PCA) [11]. Alternatively, Cascetta et al. [12] introduced the so-called "quasi-dynamic assumption", which assumes that the generated demand for a certain OD pair is time dependent, while its spatial distribution remains constant. Under this assumption the DODE problem is likely to find more robust results. Nevertheless, the authors point out that the resulting matrix will be "intrinsically biased" since this assumption introduces an "intrinsic error" in the spatial distribution of the demand patterns. To partly solve this issue, Cantelmo et al. [13] proposed a generic Two-Step procedure, which separates the DODE in two sub-optimization problems. The first step searches for generation values that best fit the traffic data while keeping spatial and temporal distributions constant. In the second step, the standard bi-level procedure searches for a more reliable demand matrix.

In this paper, we show how the Two-Steps approach can be effectively applied in combination with a joint route and departure time choice model to reduce the complexity of the OD estimation problem. Furthermore, by separating the estimation process into a first step that aims at estimating the total number of trips generated by a certain zone, while the second step focuses on the spatial and temporal distribution of the OD flows, we can show how to more effectively use different (big) mobility data sources, such as mobile phone data (which is a more reliable source for capturing the temporal profile of the demand for all modes of transport) and GPS/floating car data, which is more indicated to capture the spatial and temporal variations of the supply by providing speed profiles at link at route levels. The next section will only briefly introduces the Two-Step approach. An interested reader can find more details in [13, 14].

The Two-Step approach has three characteristics that make it an ideal candidate for applications on large-scale networks. First, as pointed out by Antoniou et al. [15], the starting matrix is still a key input for all state-of-the-art DODE models. The first step of this formulation focuses on improving the historical demand matrix by performing a broad evaluation of the solution space and estimating a "better" updated seed matrix to be used in the second step. Secondly, the proposed model reduces the number of variables in the first step, increasing the overall reliability of the results [14, 16]. On this point, the idea of performing successive iterations and linearizations has been already introduced and validated in [4] for the online DODE, showing that the reliability of the results generally increases.

Driven by these considerations, the contribution of this paper is twofold. First, we show how different big mobility data can be used in a novel estimation framework. Then we apply the new approach to the real network of Luxembourg. The test-network represents most of the country of Luxembourg, including urban roads, motorways and primary roads. Mobile phone antenna density data provided by the largest operator in Luxembourg, Post, is used to create a temporal profile of the demand in and out of Luxembourg City. In addition, real traffic counts extracted from loop detectors are used within the calibration process to further update the demand. Second, as speed profiles on the counting stations were not available, we extend the objective function by including the average speeds over the analysis period, which have been calculated through Floating Car Data (FCD). We show that, when combined with a standard DODE procedure, this information leads to a poor calibration of the demand, as the DODE overfits the data within the objective function. However, as the Two-Step approach overimposes a linear relation between distribution and generation for a certain traffic zone, it is more likely to capture congestion dynamics at network level, such as the systematic overestimation or underestimating of the demand, thus to avoid this issue.

2 Methodology

2.1 The Two-Steps Approach

While for a detailed overview of this model we refer to [13, 14], in this section we briefly present its main characteristics.

In the proposed Two-Step procedure, the first step focuses on optimising the generation values of each zone in each time interval, while keeping constant the trip distributions. To achieve this goal, the objective function can be generally written as:

$$\left(\mathbf{E}_1^*, \ldots, \mathbf{E}_n^*\right) = \arg\min \begin{bmatrix} z_1(\mathbf{l}_1, \ldots, \mathbf{l}_{n'}, \widehat{\mathbf{l}}_1, \ldots, \widehat{\mathbf{l}}_{n'}) \\ +z_2(\mathbf{n}_1, \ldots, \mathbf{n}_{n'}, \widehat{\mathbf{n}}_1, \ldots, \widehat{\mathbf{n}}_{n'}) \\ +z_3(\mathbf{x}_1, \ldots, \mathbf{x}_{n'}, \widehat{\mathbf{x}}_1, \ldots, \widehat{\mathbf{x}}_{n'}) \\ +z_4(\mathbf{r}_1, \ldots, \mathbf{r}_{n'}, \widehat{\mathbf{r}}_1, \ldots, \widehat{\mathbf{r}}_{n'}) \end{bmatrix} \tag{1a}$$

$$\text{s.t.} \qquad x_n^{OD} = E_n^O d_{D|O}^{Seed,n} \qquad \forall O, \forall D, \forall n \tag{1b}$$

Where E_n^O is the generation factor of origin zone O at time interval n, $\boldsymbol{E}_n^*$ is the generation vector from all origins in time interval n, X_n^* is the number of trips originated in O with destination D in time interval n and $d_{D|O}^{Seed,n}$ is the matrix probability distribution between traffic zone D and traffic zone O in time interval n.

2.2 Including Mobile Network Data in the First Step

While the correlation between traffic demand and mobile phone data is well known [2, 17], this source of information is hard to implement within the DODE, since it provides at most the geographic position at connected antenna levels, so no direct match on the road network is possible. However, by clustering antennas located on the border of each traffic zone, it is possible to count active connections that are entering or exiting the zones (i.e. the number of *handovers*). Unfortunately, mobile network data is subject to intrinsic errors such as the split of the users between multiple network operators and the degree of activity on the network as well as the general mobile penetration rates. However, this information can be used to estimate the temporal profiles of the generated demand on a certain cluster, as shown in [18]. In [19] we proposed the following two criteria to exploit demand emission flows estimated through the mobile network data: (1) Antenna clusters need to be large enough to minimize the “ping-pong” effect, i.e. counting the same users ‘bouncing’ back and forth between two antennas, and (2) Cluster edges shall be positioned so as to maximise the difference between number of people entering and leaving the study area.

2.3 Including Floating Car Data in the Second Step

To consider the relation between the temporal characteristics of road congestion and their impact on the spatial and temporal distribution of the OD flows, a departure time choice model based on the Vickrey/Small [20] formulation has been adopted. Concerning the congestion dynamics on the supply side, traffic counts and floating car data can be used in a single estimation process to determine flows and speeds on all measured links. In practice, sensors are placed on a limited number of links, and for privacy concerns, floating car data are often aggregated and only average speeds are shared. This limits most of the application of this data for dynamic demand estimation, but we show in our case study that through the adoption of the Two-Step approach we can still reduce the estimation error systematically. Clearly, the availability of more detailed probe vehicles data such as GPS position would strongly be an asset, as shown e.g. in [21].

3 Case Study

3.1 Estimating the Generated Demand Patterns

We show the application of the Two-Step approach on the road network of Luxembourg. The network consists of 3700 links and 1469 nodes. In our case study, we created two different clusters. One cluster captures the trips generated from the city to the external zones, while the other one captures those entering Luxembourg City, as shown in Fig. 1.

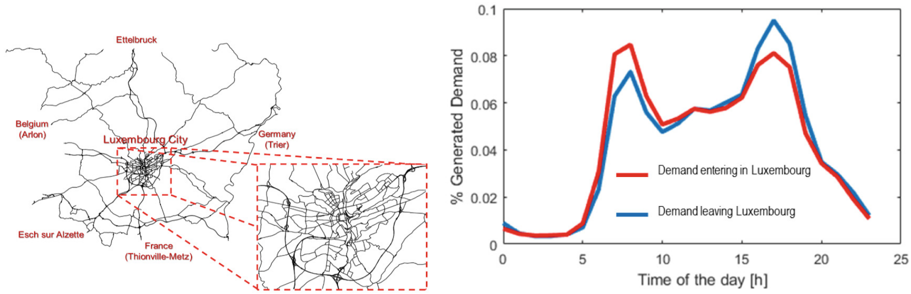

Fig. 1. Road network of Luxemborg city (left); antenna densities in and out of the city (right).

This procedure can be easily extended to any urban area, in which mobile connection handovers can be used to calculate the flows exchanged between the study area and the external centroids. Although the profile showed in Fig. 1b looks realistic, we do believe that to simply include the emission flows within the goal function may still lead to a biased estimation, since it is equivalent to over-imposing a certain time-dependent profile to the demand. Instead, we propose to use the difference between entering and exiting flows. We use then this information to calibrate the departure time choice model in Fig. 1b.

3.2 Estimating the Spatial and Temporal Distribution of OD Flows

In this part of the study, we consider the morning peak between 5 AM and noon (8 h). After some data cleaning, 54 counting stations have been retained, all located on the main arterial roads going to Luxembourg City and on the ring. Unfortunately, these data present two major limitations. The first is that, based on the publicly available data, only three detectors are located inside the ring of Luxembourg. This means that we can expect to have a realistic representation of the demand on the regional network and on the ring, but it is not possible to validate the estimated solution inside the city. The second concerns the time interval aggregation for these data, as traffic counts are aggregated on an hourly basis. This time interval is clearly too large for a network with an average free-flow travel time of 20 min since basic congestion dynamics could not be properly captured.

To deal with this lack of information, the company Motion-S provided us average speeds on the ring of Luxembourg for each time interval from Floating Car Data (FCD).

The obtained information is based on the average of all available information and does not contain specifications about time and location. Thus, the available average speed broadly captures, in this study, the congestion on the ring-way at a network level. The downside is that many possible solutions exist, which can create congestion on the ring. As a consequence, the most logical solution for the DODE should be to keep the demand as close as possible to the historical demand, while at the same time reproducing the speed profile. However, as this information is strongly aggregated, the Single-Step approach has the tendency to over-fit the average speed, while the Two-Step approach manages to provide more reliable results by exploiting the link flows as a constraint within the objective function. This claim is numerically illustrated in the next section.

3.3 Presentation of Results

To solve the DODE on the network of Luxembourg, we developed a Matlab package using PTV Visum. The package allows performing assignment-free dynamic or static OD estimation, using a deterministic and/or stochastic approximation of the gradient. While this package has been designed for Luxembourg, it can work with any network in Visum, supporting the idea that the model is ready for practical implementation.

The DODE was solved using both the classical bi-level formulation (referred to as Single-Step, SS) and with the Two-Steps (TS) approach. In both cases, the Simultaneous Perturbation Stochastic Approximation (SPSA) was adopted for the optimisation. In order to reduce the computational time, we adopted the one-sided version of this model. The interested reader can refer to [13] for more details on the solution algorithm. We performed three different sets of experiments: (1) only traffic counts are included within the OF, (2) traffic counts and mobile data are included within the OF, and (3) Using FCD and Traffic counts.

As shown in Fig. 2 (left), results confirm that, when the number of variables is large, the SS model performs a quite local adjustment of the OD demand. Specifically, to obtain a reliable estimation of the gradient, the number of stochastic perturbations should be approximately 10% of the number of variables [8]. Finally, we compare the estimation accuracy in terms of Root Mean Square Error (RMSE) on link flows, links speeds and how much the solution deviates from the OD pair when using the FCD.

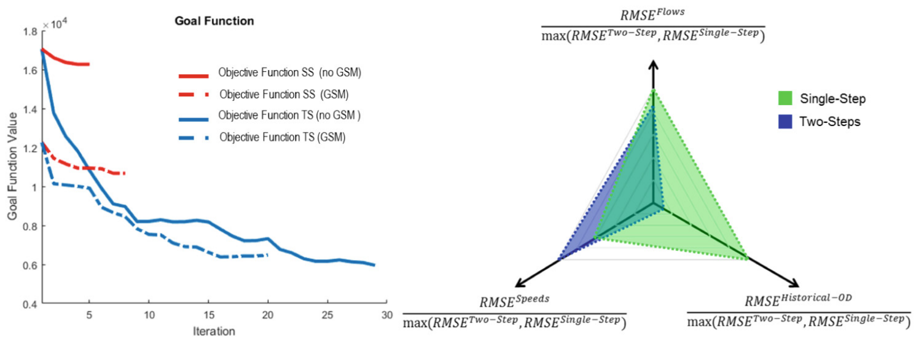

Fig. 2. Performance of the Two-Steps approach with GSM as compared to Single-Step

As shown in Fig. 2 (right), the Two-Steps approach provides a realistic fit for both traffic counts and speeds, although the error on the link flows increases with respect to the starting point. This is because constraint (2b) imposes a constant spatio-temporal structure of the demand remains during the first step of the optimisation. By contrast, the Single-Step approach over fits the data by strongly changing the original structure of the demand.

4 Conclusions

This paper showed how big mobility data such as mobile phones and probe data can be adopted into a novel Two-Steps approach on large-scale congested networks.

From a methodological point of view, the proposed approach relaxes the strong limitation of having a good starting demand matrix. As reported in [15], the capability of the DODE solution algorithm to correct the biases within the temporal and spatial structure of the demand is a strict requirement for having robust results. Mobile phone data is shown to improve the performances of the Single-Step. Then, we show that by using floating car data and link flows on the second step, the model is capable of improving the estimation results, while not affecting significantly the structure of the OD matrix.

Next step in this research will be to extend the study to multimodal networks, an in particular the utility-based model will be extended to include mode choice and transit data (in Luxembourg a real time information system using Automatic Vehicle Location data is currently being tested).

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Exploring Temporal and Spatial Structure of Urban Road Accidents: Some Empirical Evidences from Rome

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Abstract. One of the measures that can reduce the negative effects of road accidents is the quick arrive of emergency vehicles to the accident area. This measure requires an effective location in space and on time of these vehicles. This location can be decided after an analysis of the available data in order to find the spatial and temporal characteristics of road accidents.

The study presented in this paper uses time series accident data of the 15 districts of Rome Municipality, collected in four months in 2016. Results show that such analyses can be a powerful tool for identifying the temporal and spatial structure of road accidents in urban areas and that relevant differences exist in temporal patterns among different districts and types of road users. Further, such outcomes can be used as inputs to decide the optimal location on the urban area of mobile emergency units.

Keywords: Time series · Road accidents · Road safety · Accident analysis

1 Introduction

Road traffic accident is one of the main cause of mortality worldwide. According to World Health Organization [1], the total number of road fatalities worldwide remains at 1.24 million per year. In 2013, some 25,900 people were killed in the European Union because of road accidents, around 313,000 were seriously injured and many more suffered slight injuries [2]. In particular, in 2013, 9,919 people were killed in traffic accidents on urban roads in the EU, corresponding to 38% of all traffic accident fatalities in 2013 [3]. By 2050, the EU should move close to zero fatalities in road transport. In line with this goal, the EU aims at halving road fatalities by 2020 [4]. Therefore, one of the primary focus of road safety is to provide some preventive measures that can be helpful in reducing road accidents. On the other hand, the effects of road accidents can be limited if emergency vehicles quickly arrive at accident place, in particular, within urban areas. Then, it is important to have tools that, based on the analysis of spatial and temporal characteristics of road accidents, allow the best location (on time and in space) of such emergency vehicles to be identified.

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Typically, time series or regression methods were largely developed and applied for investigating *temporal dependency* [5]. The strength of time series-based methods enlightens road accident pattern dependency on time processing observed historical data [6]. The strength of time series-based methods is high computation speed due to simple formulation of the algorithm. They allow the variability structure of road accidents to be pointed out and to reveal effects along time (e.g. day hours, weekday, year period). These models, of course, are useful for identifying the main time windows and day of week when more accidents are expected to occur. If the structure of time dependency remains the same and the other variables, for example the road network characteristics or traffic flow structure and volume do not change, such analysis results can be usefully applied for the forecasting road fatalities. Otherwise, other models are, in general, to be preferred.

On the other hand, referring to spatial analysis, due to the increasing potentiality supplied by GIS (geographic information system), some researchers used mapping tools to road accident with land use factors [7, 8]. Such methods have been used by many authors because they have a relative advantage in revealing which independent variables are less or more important for reproducing/predicting road accidents. Besides, clustering, classification and association rule mining can be also used in the road accident location analysis as shown by literature [9–16]. Other authors [17, 18] use disaggregated approaches to individuate road network critical points (urban places where the frequency of accidents is higher than other or black-spots).

To accomplish research aim, a study was addressed to investigate urban road accidents and location patterns through time series methods, analyzing data collected in 2016 in Rome (Italy) classified for city district. The main objectives of the study were to analyze the road accident patterns in order to identify concentrations on time and in space useful for best locating emergency services. The results are reported in this paper, which is organized as follows. Section 2 synthetizes the data available, while Sect. 3 reports the analyses performed and the results obtained. Finally, Sect. 4 draws conclusions and further research development.

2 Data Set

The analysis described below were performed using time series data of the 15 districts of Rome Municipality, collected in March–June 2016 [19]. The data were stored according to: time, types of road users involved, type of area (e.g. junction, urban road), nature of accidents (e.g. frontal crash), light condition, number of pedestrians and number of persons involved, number and type of vehicles involved, paving state, killed and injured people. Besides, the road accidents were classified according to the types of involved users and the following classes have been identified:

- road accidents with the involvement of pedestrians;
- road accidents with the involvement of two wheel vehicles;
- road accidents with the involvement of commercial vehicles;

- road accidents with the involvement of cars:
  - only cars,
  - at least one car;
- road accidents with the involvement of transit vehicles:
  - road vehicles,
  - tram.

In total 5,225 road accidents were revealed along the four months of investigation, with the involvement of 7,592 cars, 1,683 two-wheel vehicles and 421 pedestrians. Table 1 synthetizes such info for each city districts. It emerges that the high shares of accidents with the involvement of two-wheel vehicles is in the central districts (e.g. districts 1 and 2), while in the suburbs farer from the center (i.e. district 10) it is the lowest. Similarly, there is a significant number of pedestrians involved in the inner area of the city (i.e. district 1) where the limited traffic zone is implemented, and the main historical monuments are present.

Table 1. Road accidents in the city of Rome.

Districts	Total road accidents	Involvement of					
		at least one car	*only cars*	*two-wheel vehicles*	*commercial vehicle*	*pedestrians*	*transit vehicles*
(1) Inner area	726	80%	34%	45%	12%	12%	7%
(2) Parioli/Nomentano	468	88%	45%	40%	10%	9%	2%
(3) Monte sacro	320	91%	53%	30%	13%	8%	3%
(4) Tiburtina	277	91%	53%	26%	19%	6%	3%
(5) Prenestino/Centocelle	381	93%	49%	27%	17%	8%	4%
(6) Roma delle torri	408	93%	70%	13%	13%	3%	2%
(7) San Giovanni/Cinecittà	415	92%	50%	29%	14%	9%	3%
(8) Appia antica	247	95%	52%	28%	11%	9%	3%
(9) EUR	345	91%	59%	26%	12%	3%	3%
(10) Ostia/Acilia	376	96%	72%	11%	13%	5%	1%
(11) Arvalia/Portuense	214	93%	53%	29%	12%	8%	1%
(12) Monte verde	217	91%	44%	36%	12%	10%	3%
(13) Aurelia	245	87%	40%	44%	12%	7%	6%
(14) Monte Mario	274	91%	49%	33%	9%	7%	3%
(15) Cassia/Flaminia	312	89%	51%	31%	14%	5%	3%
Total	**5,225**	**90%**	**51%**	**31%**	**13%**	**8%**	**3%**

Therefore, according to such first analysis, the time series of road accidents in two representative districts were performed: district 1 (inner area) and district 5 (spatially homogeneous – while district extends within the main road ring). In addition, for district 5, data were also available on automatic counter sections. They allowed the average speed and the number of vehicles travelling through these sections to be obtained and hence the traffic patterns to be investigated. According to these data, in the following, before time series components of road accident data are studied, hence traffic count data are analyzed to reveal how similar their patterns are.

3 Road Accident Analysis

A given time series Y_t can be considered as comprising three components: a seasonal component (S_t), a trend-cycle component (T_t, containing both trend and cycle), and a remainder component (E_t, containing anything else in the time series). Therefore, if an additive relation is assumed, follows:

$$Y_t = f(T_t, S_t, E_t) = T_t + S_t + E_t \tag{1}$$

Let Y_i denote the i^{th} observation and $\hat{Y}_i$ denote a modelled value of Y_i. The modelled error is simply:

$$e_i = Y_i - \hat{Y}_i \tag{2}$$

which is on the same scale as the data.

The decomposition of road accident time series in the months of March–June 2016 (for working days) respectively for all city and the two representative districts, was performed through the seasonality trend loess (STL) decomposition method implemented in R software [20, 21]. Trend/cycle and seasonality can be pointed out, in particular:

1. trends/cycles are quite flattened with a small difference between maximum and minimum values: less than 2 accidents for whole city, less than 1 accident for district 1 and 5;
2. the effects of daily seasonality emerge for all days in relation to the spatial case: whole city, districts 1 and 5 (Fig. 1) deriving from different level of traffic along the day and the hours of the day;
3. seasonality is quite relevant for hours of the day because of variance of traffic flows and hence of the variance of road congestion;
4. seasonality is different for the two districts (Fig. 1): inner area (district 1) and neighbor (district 5). In the inner city, high concentrations were revealed during the day from 8 am to 6 pm with peak in the morning (e.g. due to concentration of arrival constraints at work or at school); while in the district 1 high concentration is in the morning (between 10 am and 12 am) and in the afternoon between 2 am and 4 pm. The effects are quite distributed for Monday and Tuesday in the district 5, while afternoon peaks happen on Wednesday and Thursday;
5. as reported in Table 2, the contribution of remainder (E) is low and in terms of variance is about 25% for whole city, while for the two districts, it is less than 1 mainly due to the low number of accidents revealed during the days.

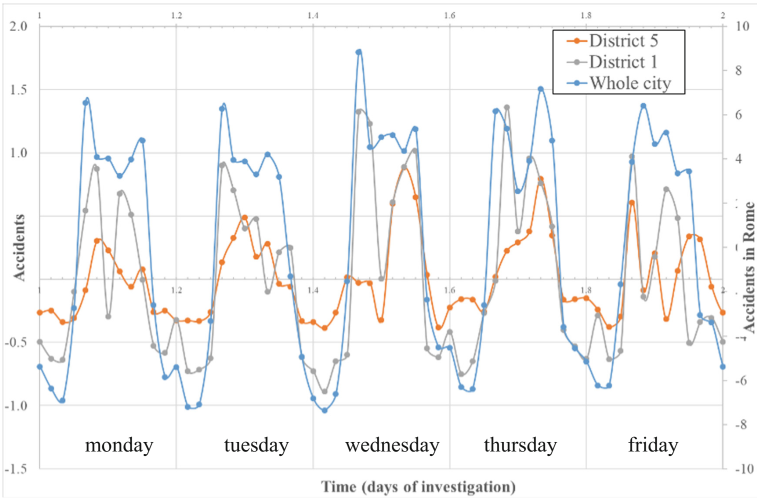

Fig. 1. Hourly fluctuation of road accidents for the investigated spatial cases.

Table 2. Variance (σ^2) and mean (μ) of observed road accidents (*Y*) and remainder (*E*).

Whole city	District 1	District 5
σ^2 [Y] = 34.05 μ [Y] = 8	σ^2 [Y] = 1.60 μ [Y] = 1	σ^2 [Y] = 0.73 μ [Y] = 1
σ^2 [E] = 8.72 μ [E] = 0	σ^2 [E] = 1.11 μ [E] = 0	σ^2 [E] = 0.61 μ [E] = 0

The above identified characteristics of road accidents and their dependences on the congestion were confirmed by the analysis of the time series of traffic counts. The analysis shows that the contribution of trend/cycle to stochasticity is low, given that its profile is quite flattened along the day, while a daily seasonality effect emerges in both directions (i.e. from and to the city center) showing similar patterns for Monday–Tuesday, Wednesday–Thursday and Friday. Comparing the seasonal components of road accidents with flows (Fig. 2), similar patterns of seasonality emerge: with flows to the city center on Monday-Tuesday and with flows from city center on Wednesday-Thursday.

Finally, the above identified spatial characteristics of road accidents were confirmed by the analysis of the time series of road accidents involving different types of users in the two representative districts. The Figs. 3 and 4 below report the trend/cycle and seasonal components of the set of road accidents when at least one car is involved.

The analysis shows that the contribution of trend/cycle to stochasticity is low, given that its profile is quite flattened along the day of the week, although a quite significant difference in terms of patterns exists. For example, in the first weeks of the investigated period in the whole city, the pattern of trend/cycle is quite constant, while in district 1

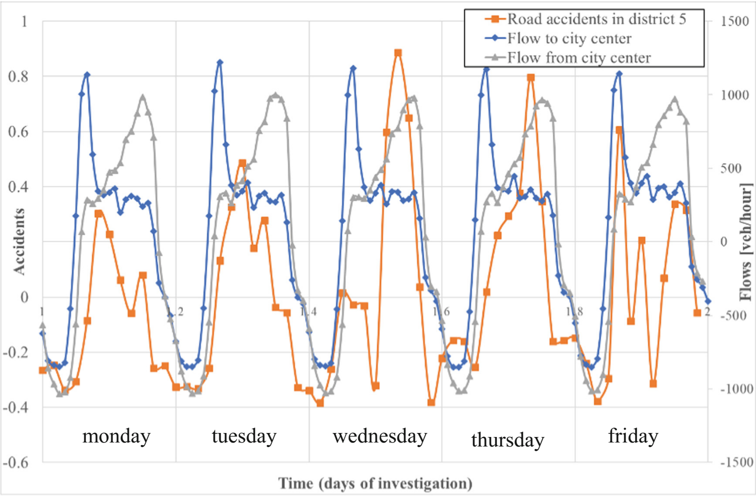

Fig. 2. Hourly fluctuation of flow for the investigated spatial cases.

Fig. 3. Trend of road accidents involving at least one car for the analyzed three spatial cases.

there is a quite constant positive slope. In the district 5, the trend quickly increases in the first days of the month after remains constant and decreases in the 4^{th} week.

A daily seasonality effect emerges in both districts showing different patterns according to the districts (spatial location). While in the district 1, the peaks are in the first days of the week and in the morning, in the district 5 the peaks are on Wednesday and on Thursday in the afternoon. Therefore, according to these first results, attention should be paid in the inner area of the city (i.e. district 1) between 10–12 am and in the afternoon between 2–4 pm. This analysis suggests therefore that it could be useful that the emergency units are more concentrate in these days and time slices.

In the district 5, the critical hours are 12–1 pm on Monday and Tuesday, while on Wednesday-Thursday-Friday such a critical stage is anticipated at 10–12 am. In district 5, the peak of accidents is expected in the afternoon on Wednesday and Thursday, while in district 1 on Wednesday and Friday in the morning. For these reasons, the emergency units should be alerted in these critical time slices. The qualitative analysis on emergency unit location provided so far will be reinforced in future developing an accident location model.

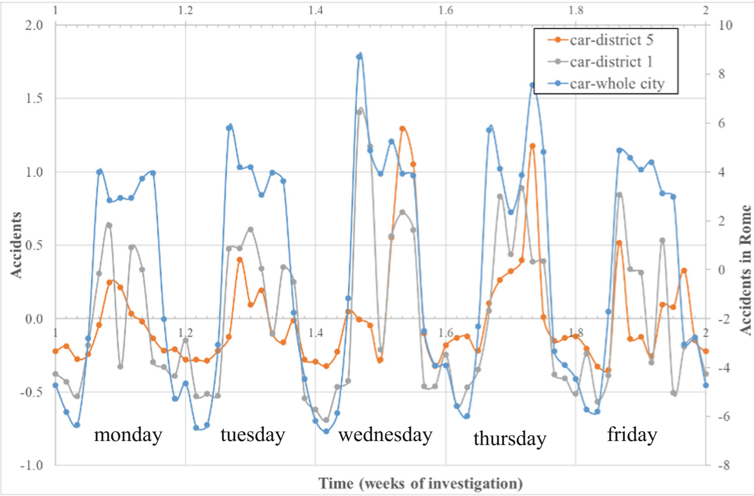

Fig. 4. Seasonal component of road accidents involving at least one car for the analyzed three spatial cases.

4 Conclusions

An analysis of road accidents, which findings can be used for designing the effective location of emergency vehicles in space and on time was presented. The analyses were performed through time series methods, which allowed to recognize temporal patterns and to point out that also day of the week (i.e. Thursday *vs* Wednesday) has significant effects on road accident stochasticity and has to be taken into account. Traditionally, such characteristics are neglected in road accident management strategies that, in general, do not take into accounts the expected temporal patterns. Besides, given that the investigated road accidents are also strictly related to build environment, a comparison between road accidents patterns in different districts of the city was performed, and the road accident patterns were confirmed as very space-dependent. Besides, the relation with the traffic pattern was also investigated through automatic traffic count data in sections within a district.

Further developments of this study are in progress. They mainly concern additional investigations on new districts and traffic counters, and further types of automated data such as floating car data for revealing local traffic patterns, analysis of residuals deriving from decomposition method applying, and finally, the development of more performing models for spatial location of road accidents depending on the infrastructural and functional characteristics of the geographic areas, through the conjoint use of time series and regression methods. Besides, a model for emergency unit location (and a related solution procedure) will be designed linking this model with the space-time location of the accidents.

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Modeling Demand for Passenger Transfers in the Bounds of Public Transport Network

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Abstract. The proposed model is based on the developed approach to perform the routing assignment stage in the classical four-stage urban planning procedure. Demand for trips is generated for each stop of a public transport system on the grounds of stochastic variable of the time interval between passengers arrival to the respective stop. After defining of the destination stop, the route for the passenger's trip is determined with the use of Dijkstra's algorithm within the frame of a public transport network which is presented as a graph model with stops for vertices and route segments for edges. Transfer nodes are defined in the model as such graph vertices which are common for at least two lines of the public transport system. The author presents a class library implemented with the use of the Python programming language. On the basis of this library, the model for simulations of demand for transfers within the given public transport system was developed. The proposed approach to the demand modeling and the developed software were used for simulations of demand for transfers within the bounds of the public transport system of Bochnia (Poland).

Keywords: Public transportation · Transfer demand · Trip simulations

1 Introduction

The passenger transfers optimization is one of the main directions to enhance the quality of public transport services. Modeling a demand for services of transfer nodes is quite a complex issue due to the stochastic nature of the transport process and the random nature of demand for trips in urban areas. However, this procedure is an essential stage for solving any problem related to optimization in transfer nodes, such as timetables scheduling for public transport lines, designing the public transport network or estimating the parameters of a given transfer node.

The main objective of transfer optimization usually is minimization of the passengers waiting time due to synchronization of public transport vehicles at the system interchanges. The existing literature considers the trade-off between passenger waiting time and operating costs [1], but multi-objective optimization approaches are also commonly used, e.g. a model for the multi-objective re-synchronizing of timetables [2]. According to the commonly used approach, the problem of the timetables' synchronization is being presented as an integer programming problem [3]. Recently, this problem was solved with respect to fluctuating demand in order to minimize both the expected total waiting time and the observed load discrepancy [4], in order to maximize

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passenger transfers and minimize bus bunching in the network [5], and with objective to achieve a maximal synchronization amongst the buses and metro [6]. Due to a big dimension of the problem, standard integer programming methods not always could be used for solving it in the real-world conditions. For this reason, to obtain some rational solution, different heuristic techniques are applied: the ant colony model in combination with fuzzy logic methods [7] or genetic-based algorithms [3].

For obtaining realistic models, randomness of public transport parameters should be considered. Stochastic disturbances appear due to the variation of vehicles intensity over time, traffic jams, weather condition, etc. The mentioned uncertainties lead to increasing the variability of the travel time and diminishing service reliability. Some published transfer models consider uncertainties of travel demand: authors of the paper [8] propose demand-oriented train timetabling models aiming to decrease passenger waiting times, authors of [9] assess the demand for an adaptive transit service on the example of Chicago region, in the paper [10], its authors have developed a predictive control scheme for a hybrid model with actuation via bus speeds, which can regularize headways and improve bus service quality, etc.

As it could be concluded from the discussed literature, the main tool for developing adequate demand model is computer simulations. Direct machine simulations are preferable, because they allow researchers to consider numerous stochastic parameters, which cannot be taken into account on the grounds of formal models. Nowadays, the commonly used tools for the transport demand simulations are PTV Visum and Aimsun, but open-source solutions [11, 12] recently become more popular due to their ability to be modified and adjusted.

The goal of this paper is to present an approach to model demand for transfers in the interchanging nodes of a public transport system based on computer simulations of the transportation process. In the framework of the described approach, a model of the public transport system is developed that allows describing the demand at the level of the system elements, which guarantees more adequate results of demand simulations in comparison with models based on the macrosystem approach.

The paper has the following structure: in the second section, the mathematical model of the public transport network is briefly described and the proposed approach to passenger transfers is presented; the third part depicts the class library developed by the author in order to simulate public transport systems; the forth section introduces a case study of transfer demand simulations for the public transport system of Bochnia city; the last part offers brief conclusions.

2 Mathematical Model for Simulations of Demand for Passenger Transfers

As far as passenger transfers are being determined in the frame of a public transport network containing public transport lines, the mathematical model aiming an implementation of these procedures should be defined in the bounds of the model of a public transport system.

2.1 Model of a Public Transport Network

At the higher level, a public transport network $\mathbf{\Omega}$ could be presented as the set containing a set $\mathbf{\Lambda}$ of lines operating within the bounds of the system and a set $\mathbf{D}$ of passengers using the public transport system to satisfy their needs in trips.

$$\mathbf{\Omega} = \{\mathbf{\Lambda},\ \mathbf{D}\}. \tag{1}$$

As elements of the i-th public transport line λ_i, $\lambda_i \in \mathbf{\Lambda}$, the following objects should be mentioned: a set $\mathbf{L}_i$ of the route segments from which the i-th line is composed, a set $\mathbf{V}_i$ of vehicles operating on the i-th line:

$$\lambda_i = \{\mathbf{L}_i,\ \mathbf{V}_i\},\ i = 1\ldots N_\Lambda, \tag{2}$$

where N_Λ – number of lines in the public transport network.

Elements of the set $\mathbf{L}_i$ characterize the end points (respective stops at the beginning and at the end of the segment) and a weight (a length of the segment):

$$l_{ij} = \left\{n_{ij},\ m_{ij},\ w_{ij}\right\},\ l_{ij} \in \mathbf{L}_i,\ j = 1\ldots N_{L(i)}, \tag{3}$$

where l_{ij} – the j-th segment of the i-th line route; n_{ij} and m_{ij} – the beginning and the end stops of the j-th route segment, $n_{ij} \in \mathbf{N}_i$, $m_{ij} \in \mathbf{N}_i$; w_{ij} – weight of the j-th route segment [km]; $N_{L(i)}$ – number of the route segment for the i-th public transport line; $\mathbf{N}_i$ – a set of all bus stops for the i-th line.

A vehicle v_{ij} as an element of the set $\mathbf{V}_i$ ($v_{ij} \in \mathbf{V}_i,\ i = 1\ldots N_{V(i)}$, where $N_{V(i)}$ is the number of vehicles servicing the i-th line) is first characterized by a capacity and the timetable on the i-th public transport line:

$$v_{ij} = \left\{c_{ij},\ s_{ij}\right\}, \tag{4}$$

where c_{ij} – capacity of the j-th vehicle [pas.]; s_{ij} – timetable of the j-th vehicle.

The proposed approach to present timetable items in the models of public transport systems is depicted in the paper [13].

2.2 Model of Demand for Public Transport Services

Demand for services of a public transport we propose to present as a set of elements that describe passengers intending to use the bus service. Each element of this set could be described on the grounds of a number of parameters:

$$\pi_i = \{\eta_i,\ \mu_i, \mathbf{P}_i,\ \tau_i\},\ \pi_i \in \mathbf{D},\ i = 1\ldots N_D, \tag{5}$$

where π_i – the i-th passenger; η_i and μ_i – origin and destination stops of the i-th passenger trip, $\eta_i \in \mathbf{N}$, $\mu_i \in \mathbf{N}$; $\mathbf{P}_i$ – a set of transfer stops where the i-th passenger changes lines within his trip; τ_i – moment of time when the i-th passenger appears at the bus stop η_i in order to perform a trip [min.]; N_D – the total number of passengers using the public transport system [pas.].

In order to simulate demand for travels, it is quite convenient to divide all the elements of the set **D** into groups according to the stops of the public transport network where the trips begin:

$$\mathbf{D} = \bigcup_{j=1}^{N_L+1} \mathbf{D}_j, \tag{6}$$

where $\mathbf{D}_j$ – a group of passengers travelling from the j-th stop of the bus line:

$$\mathbf{D}_j = \{\pi_i : \ \eta_i = j\}. \tag{7}$$

The time interval ξ_j between the moments of passengers' arrivals at the j-th stop is a random variable. Thus, for each group $\mathbf{D}_j$, the parameters τ_i for the set elements could be defined on the grounds of realization of the random variable ξ_j, which describes intervals between appearances of passengers at the j-th stop:

$$\tau_i = \begin{cases} \tilde{\xi}_j, \ i = 1, \ \eta_i = j, \\ \tau_{i-1} + \tilde{\xi}_j, \ i > 1, \ \eta_i = j, \end{cases} \tag{8}$$

where $\tilde{\xi}_j$ – realization of the random variable of an interval between the passengers' appearances at the j-th stop [min.].

2.3 Obtaining Demand for Passenger Transfers

Demand for passenger transfers in the interchanging nodes could be defined on the grounds of the set **D** in the following way:

- for each π_i, the path from origin to destination stops is being defined; different criteria and methods for the path defining could be used here; the most simple approach here is to define the path with shortest distance within the bounds of the public transport network using Dijkstra's algorithm;
- for the obtained path, a set of transfer nodes $\mathbf{P}_i$, where a passenger changes public transport lines, is being determined: the intersection of the path stops set with the set of all the network interchanges should be defined, and for the obtained result the sequences of stops depending for the same line should be eliminated;
- for elements π_i with the non-empty set $\mathbf{P}_i$, the frequency of the transfer stops appearance is being calculated.

As a result, each transfer node of the public transport network will be characterized by the number of passengers, who change the line at this stop. For more advanced simulations, each transfer node could be characterized by a set of transferring passengers, which will allow researchers to investigate a structure of the transfer demand.

3 Software Implementation of the Demand Model

To model processes of the public transport systems functioning for solving scientific problems, the specialized library of base classes was developed. The classes' implementation was performed with the use of the Python programming language; it ensures compatibility of the developed software with the most popular environments for modeling of public transport systems (including Aimsun and PTV Visum). The developed code of the mentioned base classes is available in open access and could be downloaded at [14].

As the base classes, on the grounds of which simulation models of public transport systems should be implemented, the following classes are considered:

- *Net:* is used in order to develop the software implementation of a transport network model as an oriented weighted graph;
- *Node:* allows researchers to model points of the transport network as the graph nodes; the transport net points could be considered in a simulation model as software implementation of the public transport stops (transfer passenger nodes);
- *Link:* represents a software implementation of a link in a graph; the graph link could be used in simulation models for modeling segments of the road network or spans of the public transport lines;
- *Line:* could be used in order to model a public transport line; is defined for the software implementation of a road network as an object of the *Net* class;
- *Vehicle:* allows to model a vehicle as an element of the transport system model; is used for developing simulation models of the public transport lines;
- *Passenger:* is an abstraction for implementation of passengers as transport system elements; an object of this type is a unit used for description of demand for services of the public transport within the framework of a simulation model of the transport system.

To simulate parameters which describe the external factors influence on the transport system, in the proposed library the *Stochastic* class was developed. Implementation of the *Stochastic* class objects allows to model a random variable with the defined distribution and given numerical parameters.

The main class, on the base of which implementation of the transport system simulation model could be performed, is the *Net* class. An object of this type is presented in a simulation model in a single exemplar; it is used in order to form the road network model, to define the public transport lines, to generate demand for trips in the bounds of the transport network, and to run simulations of the transport system. To run simulations, an object of the *Net* class should contain at least two objects of the *Node* type, at least one object of the *Link*, and at least one object of the *Line* class, but an empty set of the *Passenger* objects is allowed in the demand model.

In the process of simulation models implementation, the certain values are being assigned to the class fields of developed objects; to do this, the developed class methods and properties are used. Class methods are used in order to perform initialization procedures or to simulate the processes of the transport system operation. Class properties allow developers to calculate numeric characteristics of the simulated objects on the base of inner class values.

The procedures for simulations of passenger transfer nodes are implemented in the *Node* class. As far as the described library is available as an open code, additional functionality could be added to the proposed simulation tools.

4 Case Study: Modeling Demand for Passenger Transfers in Bochnia City

The described approach for transfer demand simulations was used on the example Bochnia (Lesser-Poland Voivodeship, Poland) public transport system. This case was chosen in order to illustrate the calculative abilities of the model and the respective software using a case which doesn't require many resources: Bochnia is a town of about 30 thousand inhabitants with 4 public transport lines. There are 43 bus stops at the public transport lines of the city where 8 bus stops are the interchanging nodes. More detailed characteristics of the public transport lines obtained from the official web-page www.bochnia.eu are presented in Table 1.

Table 1. Characteristics of the public transport networks of Bochnia.

Bus line ID	Route length [km]	Number of stops	Transfer stops
#1	8,1	16	sq. Pułaskiego, str. Karosek, str. Kazimierza W., str. 3 Maja, Dworzec PKP, str. św. Leonarda, str. Regis, str. Trudna
#3	9,9	22	sq. Pułaskiego, str. 3 Maja, Dworzec PKP, str. św. Leonarda, str. Regis, str. Trudna
#5a	6,6	16	str. Karosek, str. Regis
#9	17,7	38	sq. Pułaskiego, str. Kazimierza W., str. 3 Maja, Dworzec PKP, str. św. Leonarda, str. Regis, str. Trudna

Using the presented software, the model of the Bochnia's public transport network was worked out. For the obtained model, 100 runs of the demand simulation procedure were implemented, which yielded a sample for the transfers demand analysis. The obtained sample allows us to conclude that in average 53,4% of all the trips in Bochnia are performed with at least one change of a public transport line. According to simulation results, the share of transferring passengers is normally distributed random variable (Fig. 1), which was confirmed by chi-square Pearson's test.

Due to the normal distribution of the transfers share, a sufficient number of observations was calculated for the significance level of 0,05: it appeared to be much less than the sample size; thus, it could be concluded that the transfer demand parameters evaluated on the grounds of the obtained sample should be considered as statistically significant with the confidence probability equal to 0,95. The calculated

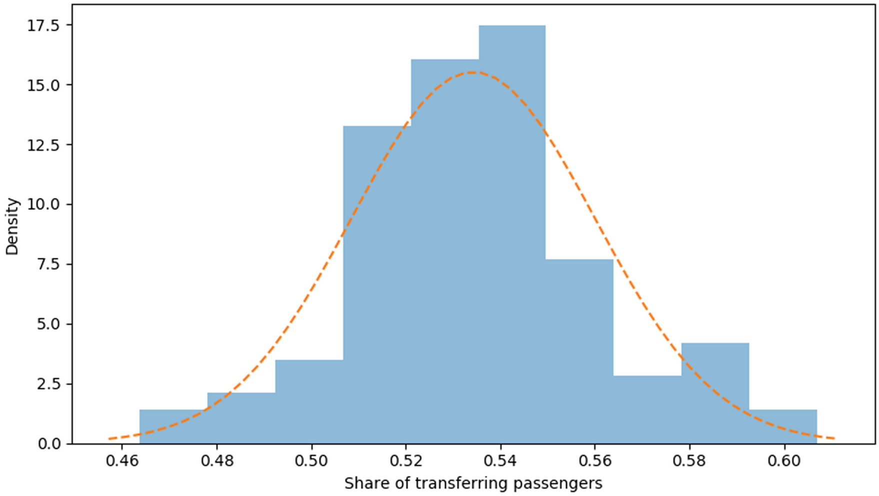

Fig. 1. Distribution of transferring passengers share in the total number of passengers.

averages for the transfer demand parameters are shown in Table 2 (on the grounds of computer simulations, only 3 of 8 transfer stops have non-zero demand).

Table 2. Average parameters of transfers demand in Bochnia: simulation results.

Demand parameter	Transfer node		
	sq. Pułaskiego	str. Kazimierza W.	str. Regis
Share of transfers in total passengers number	0,313	0,074	0,147
Share of transfers in total transfers number	0,585	0,138	0,276
Share of transferring passengers in the node	0,864	0,629	0,764

The obtained simulation results were checked on the grounds of the surveys with Bochnia public transport clients: the difference between obtained empirical and theoretical values does not exceed 10%.

5 Conclusions

The developed general mathematical model of a public transport system is a scalable tool which allows researchers to formulate a range of problems in the area of public transportation including the demand assessment tasks. The proposed software implementation of the model includes a number of methods providing simulations of the public transport operation processes.

The public transport simulations results obtained with the use of the developed tools allows researchers to estimate characteristics of demand on transfers in the public transport interchanges. This information is crucial initial data for solving a number of transportation management problems. However, it should be noted, that despite the high statistical significance of the obtained results, parameters of demand for passenger transfer must be re-checked by control surveys.

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Microsimulation Modelling of the Impacts of Double-Parking Along an Urban Axis

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Abstract. Illegal parking, particularly in urban areas, can cause severe delays and contribute significantly to traffic congestion. The main objective of the present work is to assess, using microsimulation modeling, the impacts of the phenomenon of double parking along an urban axis. A case study of an urban axis of the city of Thessaloniki, that daily serves heavy traffic, with a dedicated bus lane, is presented. Two different scenarios are modelled; one where only legal on-street parking along the axis is considered and a second one, representing the actual situation, where also a number of double-parking events are modelled; and the interaction with the traffic the axis serves is studied. Data on vehicle speed, average travel time, delay and stopped time are compared and the results show that all traffic indicators are affected by the phenomenon of double parking. Additionally, energy consumption and emissions of air pollutants are also compared to assess the impacts of double parking on the environment. The findings assist in quantifying the impacts of double parking, highlighting the importance of enforcement and measures aimed at reducing and eventually eliminating illegal parking, in order to improve traffic conditions and the quality of the atmosphere along the axis and consequently upgrade the quality of life of its residents, employers and travelers.

Keywords: Microsimulation modelling · Double-parking
Sustainable urban mobility · Traffic and environmental impacts

1 Introduction

In an urban network, illegal parking can have several major negative impacts such as traffic congestion with increased delays and travel times, unnecessary fuel consumption and increased resulting emissions, decrease of the quality of bus services, even increase of the possibility for an accident. Furthermore, illegal parking contributes in the aesthetic and environmental degradation of urban areas, making them less attractive for both vehicles and pedestrians.

Double parking is a type of illegal parking that many cities suffer from, caused either by private vehicles, stopping for a while so that passengers can serve personal activities, or freight vehicles, stopping for loading and unloading purposes.

Several case studies have been examined by researchers in order to evaluate the impacts of illegal parking but only a few of them concentrate on illegal double parking

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using a modelling approach. In 2007, Lu and Viegas analyzed how illegal double parking influences traffic flow and studied its impacts in an area of Lisbon using VISSIM software. Also in 2007 Galatioto and Bell simulated, using DRACULA framework, illegal double parking in a high-density area of Palermo, Italy, showing its significant negative impacts in traffic, in terms of length of queues, capacity, and the environment, in terms of vehicle emissions. Later, in 2013, Kladeftiras and Antoniou studied, using TransModeler microsimulation software, the traffic and environmental impacts the reduction or even elimination of illegal double parking phenomenon would have in the city of Athens, Greece. Gao and Ozbay, in 2015, used a $M/M/\infty$ queueing model and developed a microsimulation model in Paramics to estimate double parking impact on traffic in case studies in Midtown Manhattan and Downtown Brooklyn.

The present paper also uses a microsimulation traffic model to study the phenomenon of double parking along an axis of the city of Thessaloniki, Greece in order to examine the impacts it has in traffic, energy consumption and emissions. The paper is structured as follows. After this introductory part, the methodology that has been followed for the assessment of illegal double parking impact is presented, Sect. 3 presents the case that is studied from the city of Thessaloniki, Sect. 4 the results of the case study and the last section concludes the paper.

2 Methodology

The methodology of this research is based on the set-up, calibration and validation of a micro-simulation model reflecting the traffic conditions along an urban road axis. In order to explore the effects of illegal double parking along the axis, two simulation scenarios were examined:

Scenario 1: Current situation where illegal double parking that has been recorded has been simulated.

Scenario 2: An 'ideal' situation where there is complete compliance with the existing parking regulations.

In more detail, the methodological approach followed included:

- Data collection about illegal parking along the axis (time of day, location, duration).
- Set-up of a micro-simulation traffic model in AIMSUN software with detailed information about the road geometry (number/width of lanes, bus lanes, bus stop locations, traffic control, turning movements, etc.), public bus transport, traffic demand and traffic composition.
- Introduction of an approach to model in AIMSUN locations and duration of double parking phenomenon using reserved lanes plus incidents to model the burden that is caused to adjacent lanes for as long as parking maneuvers take place.
- Calibration of the model parameters to reflect the actual drivers' behavior.
- Evaluation of the outputs, making a comparison between the scenarios and assessing the impacts of the phenomenon through 4 traffic and 5 energy/environmental indicators (travel time, mean speed, stop time, delay time, fuel consumption, CO2 emissions and NOx, VOC, PM emissions).

3 Case Study

The present paper chooses to study the phenomenon of on-street illegal, double parking on an urban axis in the city of Thessaloniki, Greece.

It is a major axis with a total length of 6,2 km that daily serves heavy traffic, with direction from the east to the west of the city. It is a one-way road with 4 lanes, one of them being used as a dedicated bus lane. The axis is one of the most important of the city connecting its southeastern areas with the city center.

At the same time, it is an important commercial axis of the city, with a large number of businesses and stores located along it. Hence, it acts as a pole of attraction from adjacent areas and, in conjunction with the high density residential area located alongside, serves the needs of large numbers of people living and being active on it.

As a result there is high parking demand along the axis that is however not served by the available legal on street parking offer and this combined with the absolute lack of enforcement in the area are causing an intense phenomenon of illegal parking and double parking.

The average daily traffic of the axis is estimated at 35.000 vehicles. The peak is observed during the morning period, and in particular from 08:00 to 09:00, during which more than 11.000 journeys are served by the axis (Mitsakis et al. 2013). Of these, 523 movements (4,8% of the total) carry out a through movement along the whole axis.

A parking characteristics survey that took place in 2013 to support the planning of a controlled parking system in the Municipality of Thessaloniki (Aifantopoulou et al. 2013) - that has not been implemented in the area yet- recorded along the axis 128 parking spaces. 63% of the vehicles recorded by the survey were illegally parked, with 49% of them being double parked, and parking deficit was calculated at 854 car parks per day (Fig. 1).

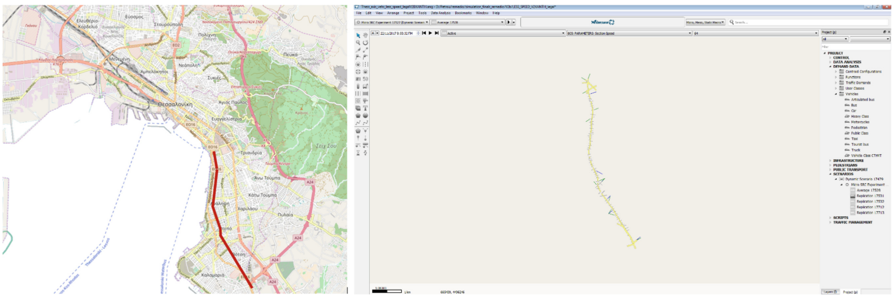

Fig. 1. The location of the study axis in the city of Thessaloniki (a) and the axis simulated in AIMSUN software (b).

The present work studies the phenomenon of on-street illegal, double parking on the axis for the typical weekday morning peak period, 08:00–09:00.

Based on the methodology described above:

Illegal double parking along the axis was quantified, in terms of location and duration. Detailed on-site observations were held in order to identify the locations where the phenomenon of illegal double parking appears. Additionally, and in order to determine how long double parking events last, data from the detailed recording of legal and illegal parking along the axis that took place in the framework of the 2013 parking characteristics survey were used.

A microsimulation traffic model was set-up in AIMSUN (Advanced Interactive Microscopic Simulator for Urban and Non-Urban Networks). (Dynamic Route Assignment Combining User Learning And microsimulation) a software of TSS (Transport Simulation Systems) company that allows mesoscopic, microscopic and hybrid simulation.

The representation of the road axis in AIMSUN software environment consists of 379 road sections, 86 intersections, 31 of which are signalized and includes information about road direction, number, width and functional use of lanes, capacity, maximum permitted speed, slope, type of vehicles using the road, bus stops locations, on street parking locations, nodes geometry allowed turns, signage, traffic control, pedestrians' crossings, and traffic signals timing.

Information about the 9 bus lines of public transport serving the axis was also included in the model. For each bus line, information about the road sections that it runs, the bus stops where it stops, the detailed timetable for the peak hour and the average bus stop duration was included.

Traffic demand was taken from the macroscopic traffic model of the metropolitan area of Thessaloniki that has been developed by the Hellenic Institute of Transport (Stamos et al. 2011). The data refer to the morning peak hour (8:00–9:00) and was given in 6 Origin/Destination matrixes, for the 6 different types of vehicles using the road (cars, taxis, motorbikes, buses, trucks and public transport buses) and used 92 centroid locations to allocate the demand on the network.

To simulate double parking, 'incidents' were used to specify where, when and how long double parking events along the axis occur based on the results of the data collection. In addition, extra 'incidents' were inserted to model the burden caused to adjacent lanes, that includes time for identifying a sufficient gap between already parked vehicles, the vehicle speed reduction and the necessary maneuvers to park. A time of 15 s (±5 s) was considered as the mean time a driver needs for this procedure.

Figure 2 presents the two simulation scenarios that were set-up, without and with illegal double parking events along the axis.

The model was then calibrated to represent the traffic conditions as accurately as possible. Data from traffic counts in 8 nodes and 2 sections along the axis were used for this purpose as well as data about average speed and travel time of taxis and public transport buses along the axis taken from their fleet monitoring centers. Comparing this actual data with simulation outputs, the model was calibrated and the figures below (Fig. 3) compare the measured vs the simulated values.

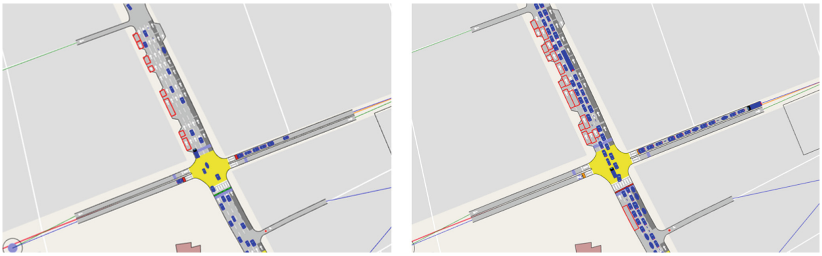

Fig. 2. Traffic conditions on the axis without (left) and with (right) illegal double parking.

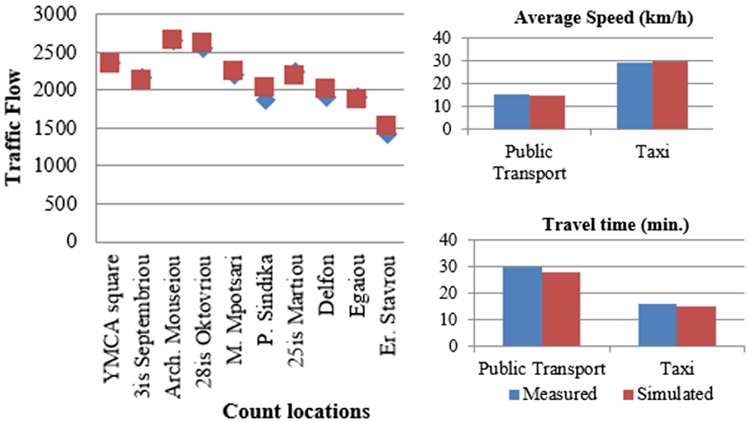

Fig. 3. Comparison of measured-simulated traffic flows (left) and PuT and taxis travel times and average speed (right).

The simulation time was set at 1 h, recording data every 15 min, that is standard time period use according to Roess et al. and 5 replications of each scenario were performed according to the software guidelines (AIMSUN 2017). For the estimation of the environmental/energy indicators, the integrated in AIMSUN software microscopic emission model, (Panis et al. 2006) has been used that relates vehicle emissions with the instantaneous speed and acceleration of the vehicle (Fig. 5).

4 Results

After the calibration and the validation of the traffic model and considering it as reliable, the two scenarios were tested in order to estimate the impacts of illegal double parking on traffic conditions of the axis, as well as the consequences on the environment.

The results of the traffic indicators (Fig. 3) show that all are heavily affected by the phenomenon of illegal double parking. More specifically, average speed of private cars is reduced by about 18 km/h, dropping from 45 to 26 km/h, average speed of taxis by

16 km/h, of public transport buses by 6 km/h, dropping to 15 km/h, and of other commercial vehicles by 14–16 km/h leading to an increase of travel time of about 10 min for private cars and motorbikes, 7 and 10 min for taxis and public transport buses respectively and 10 min for commercial vehicles. Consequently, delay time and stopped time increase for all vehicles.

The effects of illegal double parking are also assessed in terms of fuel consumption and emissions (Fig. 4). The fuel consumption indicator represents the total fuel, in liters, that all vehicles consume during the simulation time. The results show an increase of 50% on fuel consumption with the existence of illegal double parking. Regarding the emissions and more specifically carbon dioxide (CO_2), oxides of nitrogen (NOx), volatile organic compounds (VOC) and particulate matter (PM) a significant increase is also observed in the illegal double parking scenario of about 500–900%, depending on the emission type since the instantaneous speed and acceleration of the vehicle are severely affected (Fig. 5).

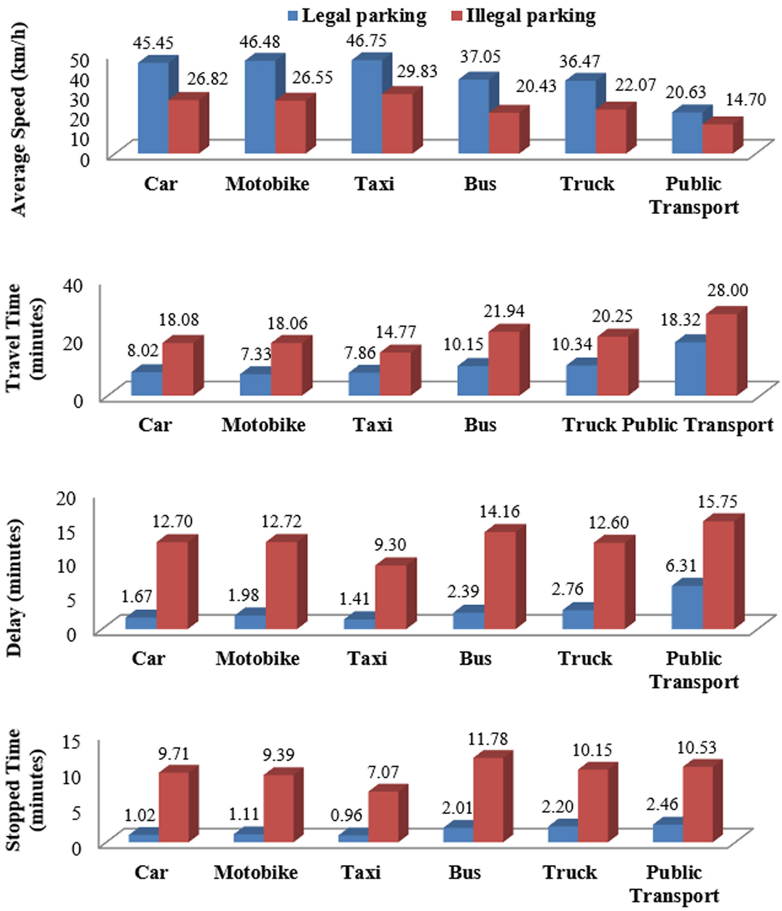

Fig. 4. Results of the case study related to the traffic indicators

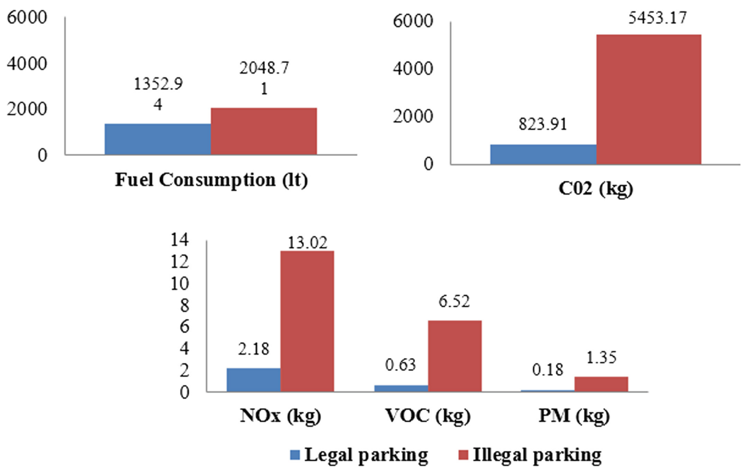

Fig. 5. Results of the case study related to the environmental/energy indicators.

5 Conclusions

The present paper analyzes the important impact of illegal double parking along an urban axis, during peak hour, not only in traffic but also in the environmental conditions. The results indicate a significant decrease of travel speed for all vehicle types using the axis and a resulting increase in travel and delay time resulting in lost productivity time of travelers. The performance of public transport bus lines is affected, with unreliable timetables and increased delay times, resulting in public transport unattractiveness.

The results make apparent that eliminating illegal double parking in the axis would result in tremendous improvement of traffic conditions as well as in the important reduction of fuel/energy consumption and the improvement of quality of the atmosphere along the axis and they quantify the benefits that would arise from a potential limitation. Therefore, the importance of enforcement and measures aimed at reducing and eventually eliminating illegal double parking by the responsible authorities is highlighted, in order to upgrade the quality of life of the areas' residents, employers and travelers.

Acknowledgement. The present work has been implemented in the framework of the co-financed by the European Regional Development Fund project REMEDIO «Regenerating mixed – use MED urban communities congested by traffic through innovative low carbon solutions» of the Interreg MED programme.

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Problems, Risks and Prospects of Ecological Safety's Increase While Transition to Green Transport

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Abstract. Improving the efficiency and environmental friendliness of transport is one of the main directions of transition to a low-carbon economy. The conducted researchers have shown that to implement the concept of transition to sustainable "green" transport, it is necessary to improve management in all subsystems of the transport system. Some of these ways are (1) the improvement of vehicles' fleet management, such as the use of low-carbon, energy-efficient vehicles, timely fleet renewal, (2) optimization of the route network, road infrastructure and (3) the full use of vehicles' capacity. We have built an original simulation models of the road **network's** sections. As the input data we have used the data received from the field observations of traffic flows. Optimization experiment allowed us to determine optimal parameters of traffic flow, configuration of the route network and road infrastructure.

Keywords: Green transport · Environmental safety · Risk Environmental standard · Simulation model

1 Introduction

Modern human civilization entered the third Millennium and faced with global challenges. Urbanization is one of the causes of most problems of our Millennium. Mobility is a key dynamic of urbanization, and the associated infrastructure invariably shapes the urban environment – the roads, transport systems, spaces, and architectural solutions. Freight movement could also rise more than threefold during the same period. Transport and road complex is a powerful source of environmental pollution. This is especially critical for the cities with a dense concentration of road transport in a small area. In the information note by Achim Steiner (Executive Director, United Nations Environment Programme) [1], it is summarized and presented the key findings and policy messages stemming from the Global Environment Outlook (GEO-6) assessments conducted for the six United Nations Environment Programme regions. The transition to an inclusive green economy should be based on viable ecosystems, cleaner production, and healthy consumer preferences. There is no doubt that achieving

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a healthy planet and healthy people requires urgent transformation of the current systems of production and consumption that most contribute to environmental degradation and inequalities in human health and well-being. Key factors, that affect atmospheric pollution from motor vehicle emissions, are the low environmental performance of the vehicles, motor fuel low quality, the raise of international and long-distance transport volumes, a large proportion of vehicles older than 10–13 years, etc.

To improve the ecological situation in cities, comprehensive solutions are needed, including measures for "greening" transport. The added value of our work is the original simulation model, built on the base of real field observations. This model allows considering and evaluating the efficiency of every suggestion aimed to reduce negative environmental impact, as well as combination of different suggestions.

2 Review of Scientific Researches on Increase of Motor Vehicles' Ecological Compatibility

According to statistical data [2], 60% of road transport's air pollution is caused by personal cars, 26,5% by freight transportation and 13,5% by bus transportation. Therefore, development of "green" transport can positively influence the solution of the problems connected with air pollution. To reduce urban emissions the managerial decisions are used both to regulate the density of traffic flow and to optimize the vehicle fleet. To solve these issues the measures of state regulation are applied and intelligent transport systems are created [3]. The author of the article [4] marks two main ways to estimate the transport efficiency: fuel efficiency and fleet efficiency.

The fuel efficiency is the form of thermal efficiency which depends on the unique parameters of the engine, aerodynamic resistance, weight and rolling resistance of vehicle, while the fleet efficiency describes the usage of fuel by a group of transport vehicles that can be increased both by improvement of an individual car characteristics and route optimization or behavior modification. Authors of the article [5] has noted that buses, as a public transport, can significantly reduce the problems associated with air pollution in large cities, in particular through the use of alternative fuels and innovative drive systems. This is due to the fact that according to statistics [4], the ecological impact of large fleets is higher than personal cars due to the high annual mileage. Personal car mileage is averaging 12,000 miles per year, while the average vehicle in a fleet passes 23,000 miles per year. Besides, the part of new vehicles in the fleet is significant because its renewal occurs more frequently than personal cars.

Conditionally, it is possible to say that the transport is environmentally friendly, if it uses alternative fuel, such as: electricity – the tram, the trackless trolley, the electric bus and vehicle; hydrogen fuel – transformation to electricity; biofuel, biogas; gas motor fuel – the use of natural gas for internal combustion engines; mechanical energy – bicycle transport. The majority of buses, as well as other vehicles use hydrocarbonic fuel (64,8% of petrol, 34,4% of diesel, 0,8% of the gas). Despite the depletion of oil reserves, its consumption continues to grow. Demand for oil already exceeds production, which inevitably leads to a deficit that will increase over time. If today unsatisfied are about 5% of demand for oil, then by 2025 the deficiency can be 12%.

According to [6], about 15–30% of global warming is due to the soot particles emission of the diesel vehicles' fleet. Soot gets to the atmosphere as a result of incomplete oxidation of carbon in the course of organic compounds burning, including, for example, during the diesel engines operation [7]. The impact of solid particles is associated with a number of diseases, namely premature death from cardiopulmonary diseases and lung cancer. In this regard, the search of alternative fuels, which, along with other requirements, would also be environmentally friendly, is especially relevant for transportation industry [8]. As it is noted in [9], the cost of purchasing hybrid bus will always be greater than the diesel fuel bus due to additional transmission components, such as traction batteries and electric motors. Similarly, the cost of buses on fuel cells will be higher than for hybrid ones, if the cost of fuel cells does not decrease to the cost of a hybrid power plant. The key question is if it is possible to compensate the higher purchasing costs by lowering operating costs to achieve a lower cost of ownership without any compromise in the provision of services. According to authors [10], the cost of owning a diesel bus is 10% lower than the hybrid one. However, hybrid buses and fuel cell buses are newer than buses on diesel fuel. To develop the market for fuel cell buses, it is necessary to use a large-scale electrolysis plant to increase the use of excess power generation; to create a bus chassis that can be used to produce a fuel cell bus, which can then be exported to world markets. The share of electric buses in the world fleet is still small, but it is continuously growing [11].

3 The Forecast and Risk Analysis of the Electric Bus Expansion

Since the fleet efficiency can be improved by timely fleet renewal by more eco-friendly vehicles, we have forecasted the change of a bus fleet structure in case of its replacement by more eco-friendly electric buses (Fig. 1a). As the initial data we have used the data on the type-age structure of the fleet mostly consisting of the buses' brand PAZ 3205 (engine capacity of 88,3 kWh). When forecasting, the method of diagonal shift [12], based on the retirement of the vehicles of the eldest age group was used. To calculate volumes of CO emissions (g/kW/h), they were given to an absolute value (in grams). For this purpose, the engine capacity of the bus was multiplied by the average time of its work and by the number of the vehicles in the fleet that correspond to the class of toxicity according to Euro standards. We have taken 12 h as the average working time of the bus per day (Fig. 1b). This measure will allow reducing emissions of harmful substances. At the same time, the use of electric buses is accompanied by certain problems, such as their dependence on the status and stability of the operation of the electrical network. Since the cost of building infrastructure is too high, without serious investments and other stimulating measures from the state, a complete transition to this type of transport is impossible. A similar situation with gas engine transport. Russia, as the second largest natural gas producer in the world, has unique opportunity to use natural gas as an alternative to diesel fuel. Gas fuel has smaller emissions of not normalized harmful substances and carbon dioxide, etc. Despite economic and environmental benefits, the implementation of projects to increase the share of the bus fleet on alternative fuel, such as natural gas or electricity, is still ineffective due to many obstacles [13]. However, these obstacles can be overcome by coordinated actions of all interested parties, including government and business.

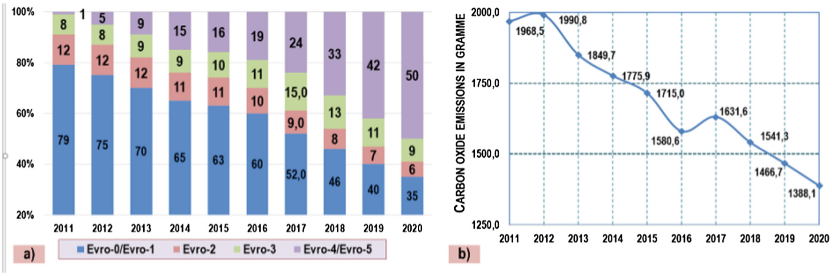


Fig. 1. (a) Forecast of change of structure of a bus fleet for standards of toxicity; (b) dependence of emissions on the electric buses' proportion in the fleet.

As the main limiting factor at the development of the "green" transport is the lack of infrastructure when using electric buses, it is necessary to assess the risks connected to implementation of the specified project. Risk, as a physical category, should be rated through two-dimensional set of indicators: risk probability and risk consequences. Then the values of indicators obtained for each risk are multiplied and entered into the matrix of risk levels. In the Fig. 2b, the figure in the center of each cell designate risk level, and the figure s in the bottom right corner is the number of risk. Risk situations in the process of infrastructure forming for electric buses can be caused by the separate causes of charging infrastructure and service network forming, and by the common for both of them.

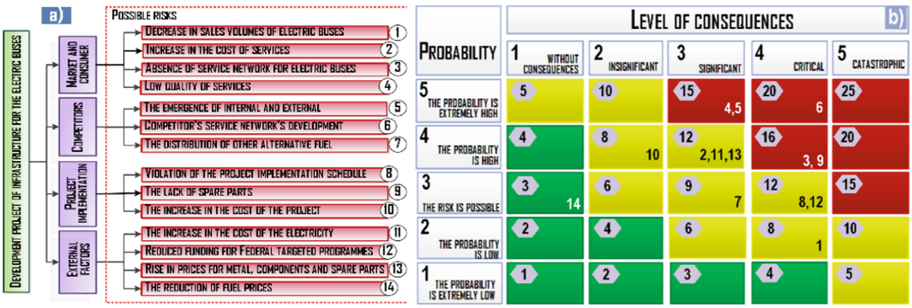


Fig. 2. (a) The risks' logical card of electric buses' infrastructure creation; (b) The risks matrix.

4 Case Study of Naberezhnye Chelny and the Forecast of Changes in the Transition to "Green" Transport

In Naberezhnye Chelny, Russia, motor vehicles are the main pollutants of the environment, all major stationary sources of pollution being located outside or along the city boundary. Spatial planning of the city was performed with respect to the natural landscape: the city faces the expanses of the Nizhnekamsk water storage basin, the Shelninsky Bay, and forests on their shores. The transport frame of the city is made up by longitudinal highways connecting the residential areas, so that the road network is rectangular. To identify the most polluted road network's segments, the maps of pollutant dispersion were built (Fig. 3). The results of the field researches and the design procedure are given in [14]. Statistics of the State Traffic Safety Inspectorate in Naberezhnye Chelny city [15] confirms that this road section is characterized by a high rate of traffic loads and accidents that cause congestions and harmful emissions.

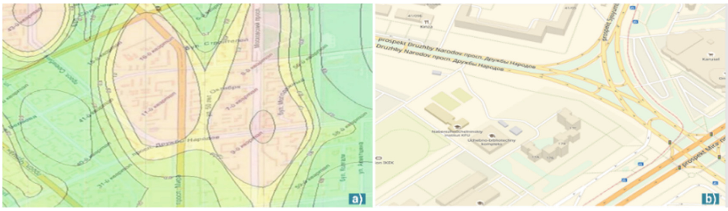


Fig. 3. (a) Map of carbon monoxide dispersion; (b) decoupling scheme simulated road network.

For a more detailed analysis of the area, we have built original simulation model with the use of special software AnyLogic. There are several factors that were taken into account: road network geometry; traffic density; intensity of pedestrian traffic; emissions of pollutants from motor vehicles and emissions quotas; modes of traffic lights on the previous and subsequent crossroad. As the limitations of the model, the emissions' quota was set that should not be exceeded. Verification of the model was performed based on the results of field observations. Traffic simulation have showed that there is an excess of carbon monoxide and nitrogen dioxide emissions on the considered section during the congestions. The first stage of optimization experiment allowed us to determine optimal parameters of the traffic flow (the density, the intensity and the speed) which ensure that the emissions do not exceed the quota.

There are a lot of public transport routes overlapping on the considered road section. Therefore, the first method is to optimize the route network in order to reduce the number of vehicles that are running on this road section at the same time. Another method is to use buses with greater capacity, which will both diminish the traffic current density and reduce emissions of harmful substances. At the second stage of optimization experiment there were determined the vehicular emissions. While preserving the original parameters, we have replaced a part of the buses with more environmentally friendly vehicles. This considerably reduced the volumes of emitted pollutants (Table 1).

Table 1. Indicators of emissions of vehicles with increased environmental friendliness of buses.

The volume of emissions	Substance name						
	CO	NO_x	CH	Soot	SO_2	Formaldehyde	Benz α piren
100% of fleet on diesel fuel	1,04	0,97	0,5	0,58	0,58	0,681	0,579
50% of gas motor fuel fleet	0,87	0,91	0,44	0,47	0,58	0,69	0,587
100% of gas motor fuel fleet	0,69	0,83	0,39	0,34	0,59	0,692	0,589

The third method is to change the configuration of the road network. Simulation results have shown that the geometry of the considered road section negatively affects traffic characteristics, because it is not corresponding to traffic flow parameters. To improve the situation, we proposed a new version of optimized configuration of the intersection. It was offered to organize a circular motion that allows reducing number of conflict points (elimination of turns) on this road section (Fig. 4). Besides, we have suggested applying at the adjacent intersection traffic light regulation with alternative number of phases, i.e. set of the main and intermediate traffic light steps.

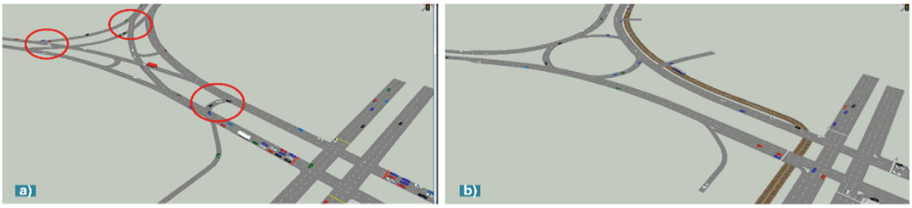


Fig. 4. Simulation model (a) before optimizations; (b) after optimizations.

Analysis of research results has shown that the most acceptable option is the organization on this road segment of a circular motion. Table 2 summarizes the traffic light stage changes with the adaptive control, depending on the traffic density. The research results of the studied crossroad are shown in Table 3. These data demonstrate that parameters of traffic of studied stretch of road could be greatly improved.

In addition, the organization of the circular motion at the site will lead to a significant reduction in pollutant emissions from road transport.

Total emission of pollutants, M, g/km, is calculated by the formula:

$$M = \sum_{1}^{n} (M_{P_1} + M_{P_2}) + \sum_{1}^{n_1} (M_{L_3} + M_{L_4}) + \sum_{1}^{m} (M_{P_3} + M_{P_4}) + \sum_{1}^{m_1} (M_{L_1} + M_{L_2}) \quad (1)$$

where M_{P_1}, M_{P_2}, M_{P_3}, M_{P_4} - emission of pollutants into the atmosphere by cars in the queue before the intersection, g/km; M_{L_1}, M_{L_2}, M_{L_3}, M_{L_4} - emission of pollutants into the atmosphere by cars moving along this road during the period under consideration, g/km. Indices 1 and 2 correspond to each of the two directions of traffic along a section

Table 2. Traffic light phase change on the crossroad depending on the traffic density.

Traffic density of the site	Total stage duration, sec.	Red signal (basic tact), sec.	Green signal (basic tact), sec.	Red and yellow signal, sec.	Yellow signal, sec.
95%	85	41	38	3	3
82%	83	37	40	3	3
74%	82	35	41	3	3
61%	81	32	43	3	3

Table 3. Calculated parameters of studied stretch of road network.

Designation of parameter	Value	
	Prior to any changes	After changes
Average speed along studied stretch of road, km/h	35	42
The number of stops per unit time, pcs.	6	2
Traffic flow density, % of road area	92	67
Average duration of travel on the stretch of road, min.	4	1,4

of the road with greater intensity, 3 and 4 for a section with a lower intensity; n, m – number of stops of the flow of vehicles before the intersection on the roads that form it for a 20-min time period; n_1, m_2 – number of periods of traffic flow of vehicles in the area of the intersection for a 20-min time period.

Emission of the i-th pollutant by the moving flow of motor vehicles on a motorway with a fixed length M_{L_i}, g/km, is calculated by formula:

$$M_{L_i} = \frac{L}{1200} \sum\nolimits_1^k M^L_{k,i} \cdot G_k \cdot r_{v_{k,i}} \quad (2)$$

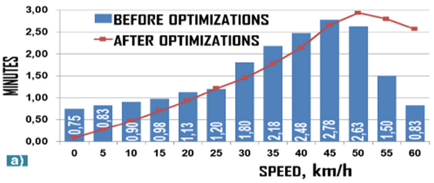
where L – length of the road, from which the length of the queue of cars before the red signal is excluded, km; $M^L_{k,i}$ – specific release of the i-th pollutant by cars of the k-th group, g/km; k – number of car groups, pcs.; G_k – the actual maximum traffic intensity, i.e., the number of vehicles of each of the k groups passing through a fixed cross-section of the selected road section per unit time in both directions across all lanes; $r_{v_{k,i}}$ – a correction coefficient that takes into account the average velocity of the flow $v_{k,i}$ (km/h).

The emission of the i-th pollutant by cars in the intersection area in the queue during the 20-min period M_{P_i}, g/km, is calculated by the formula:

$$M_{P_i} = \frac{P}{60} \sum\nolimits_1^N \sum\nolimits_1^k \left(M'_{P_i,k} \cdot G'_k \right) \quad (3)$$

where P – average stop time for 20 min, seconds; N – number of vehicle stops for a 20-min time period; $M'_{P_i,k}$ – specific emission of the i-th pollutant by cars of the k-th group that are in the queue before the intersection; $G_k^{\prime}$ – number of cars of the k-th group in the queue at the crossroad.

To determine the correction coefficient $r_{v_{k,i}}$, taking into account the average speed of movement, we used data obtained from the results of the experiment on the model (Fig. 5a). Based on the results of the experiment, the following calculated emission values were obtained at the site (Fig. 5b). Thus, the change in the configuration of the road section will result in a reduction in CO emissions by 18.6%, NO_X by 8,2%, hydrocarbons by 17,9%, SO_2 by 15,4%.



Configuration of the site	Volume of emissions, t/year			
	CO	NO_X	C_XHY	SO_2
Value prior to any changes	31.24	2.67	3.92	0.13
Value after changes	25.42	2.45	3.22	0.11

b)

Fig. 5. (a) Average duration of travel at different speeds (in terms of 20 min interval), (b) Volumes of pollutant emissions.

5 Conclusion

In our research work, we have forecasted the change of the bus structure in several years if to replace the old buses by new more environmentally friendly ones. We have also considered risks, accompanying this managerial decision. Then, we have studied the ecological situation along the main roads in Naberezhnye Chelny city (Russia), have identified the most problematic road sections and have built the simulation models of these sections. Simulation has allowed us to estimate the efficiency of suggested solutions, as well as to find their optimal combination to reduce the negative impact of road transport on the environment. As the case study proved, the use of the measures listed in the article can be realized independently of each other and receive certain insignificant results. However, their integrated implementation will provide the maximum effect and will reduce total harmful emissions.

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Short-Term Prediction of the Traffic Status in Urban Places Using Neural Network Models

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Abstract. The last decades the phenomenon of urbanisation has led to crowded and jammed areas, which makes life in cities more stressful. Thus, there is a high interest in the field of Intelligent Transportation Systems in order to prevent the traffic congestion. The most common way to prevent this phenomenon is with the use of short-term forecasting of traffic parameters, such as traffic flow and speed. Nowadays, the accuracy of the estimations has increased significantly due to the use of the latest technological advances, such as probe data in combination with machine learning techniques. Probe data is a type of crowd-sourced data collected from individuals, including vehicles, passengers, travellers or pedestrians. This paper focuses on the data processing component with the use of neural networks, for predicting traffic status in urban areas based on the relation between traffic flows and speed. As a case study is used the traffic status in the city of Thessaloniki, Greece. In this case, data is aggregated after the collection phase, which gives a better representation of the mobility patterns in the city. Two types of test were performed. The first one shows the results of the prediction of eight sequentially quarters of the time, while the second test provides the prediction four steps forward of the date time. The results of both tests provide accurate predictions.

Keywords: Neural network · Traffic prediction

1 Introduction

Transportation is one of the factors responsible for 26% of Green House Gas (GHG) emissions at European level. The percentage varies depending on the urban area, based on different activities, but mostly on Intelligent Transportation Systems as well as by Big and Open Data within the Smart Cities framework.

Even though, technological advances have been attributed to the increase of quality and quantity of mobility-related data. The challenge of producing the best possible end-products out of these big datasets is still twofold; first there is a need for developing algorithms able to fuse, filter, validate and process big amounts of data (almost) at real-time; and secondly, there is a constant need for developing new applications and

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services for providing innovative and advanced traveller information services, traffic management schemes and environmental indicators based on these data and processing capabilities.

This paper focuses on the data processing component by presenting a machine learning algorithm for predicting traffic status in urban areas based on statistical measures of traffic flows and speed. The model is applied to the city of Thessaloniki, Greece. The paper is structured as follows. A review of key contributions in the domain of predicting traffic status is provided in Sect. 2. Sections 3 and 4 deal with the methodological approach, and its application to the traffic status in Thessaloniki, which is monitored by collecting Floating Car Data from a professional fleet. Finally, conclusions are presented in Sect. 5.

2 Literature Review

The last decades cities have become more crowded and jammed, which increased the need for accurate traffic and mobility management through the development of solutions based on Intelligent Transport Systems. Therefore, the interest in the short-term forecasting of traffic parameters, such as traffic flow and speed, has been increased.

The accuracy of the estimations and predictions have risen significantly by using more granulate data sources, such as probe data. In this case, data is aggregated after the collection phase, which significantly increases the quality of the collected data and multiplies the capabilities for processing this data and having better representation of the mobility patterns in a city. The main probe data sources are based on detections or Bluetooth-enabled devices [1], mobile cell phones [2] or vehicles telemetric, such as Floating Car Data (FCD) [3]. An overview of data collection technologies is provided in [4]. These sources can be used for measuring traffic characteristics, such as speeds but it may not capture traffic flow correctly [4].

The main issue for the prediction of the traffic flow in road networks comes to the development of an algorithm that will combine computational speed and accuracy for both short and long-term problems. Many ways have been introduced to perform short-term predictions, such as Regression models [5], nearest neighbour [6], ARIMA, discretization modelling approach, as an easier solution to the complicated nonlinear models [7], and neural networks, which are considered to be the best alternative [8, 9].

3 Methodological Approach

3.1 Overview

The main scope is the development of an algorithm that will predict the traffic status in the city of Thessaloniki. This approach integrates machine learning techniques using the travel times, traffic counts and speeds as well as the skewness, kurtosis and standard deviation of the speed, to train an appropriate NN Model for efficient and robust traffic speed prediction. The considerable amount and the nature of the data and the advantage of multiple learning algorithms led us to use Artificial Neural Networks (ANN).

We want to detect all possible interactions and complex nonlinear or linear relationships, to provide better speed predictions.

For this work, we have created a package (TrafficBDE[1]) in R Software, available on Github. The user selects the road and the date time to predict the wanted variable, either the mean speed or the entries, for this road at this date time and also how many steps forward they want the predicted value to cover.

3.2 Dataset and Experimental Set up

Two main datasets are used, a dataset composed of floating car data composed of pulses generated by vehicles and a dataset composed of the road network segments.

The road network segments (Fig. 1) were extracted from the urban mobility model for Thessaloniki [10], which is composed of 47.807 intersections and 137.854 directed links, both elements bearing geometric (length, location in the network) and traffic related characteristics (number of lanes, free flow speed, capacity, direction, allowed transportation modes, existence of dedicated lanes, parking prohibition).

Fig. 1. Overview of Thessaloniki's modeled road network [10].

The floating car data in Thessaloniki is obtained from a fleet of 1200 taxis, which represent the 50% of the taxis in the city and collect location (lat, long), orientation, status (empty or occupied) and speed every 100 meters. The total amount of data varies between 500 and 2.500 datasets per minute. The data is directly collected by the Taxi association and provided for this particular research. The temporal distribution of the data presents a peak early in the morning which is reduced slowly during the day until the afternoon. It also presents a significant reduction during the weekends, as it can be observed in Fig. 2. Saturday still present a higher peak in the morning and a stable period in the afternoon, while two peaks are clearly observed on Sundays, one in the morning and one in the afternoon.

[1] TrafficBDE package imports the following packages on RStudio, caret, data.table, dplyr, graphics, grDevices, jsonlite, lubridate, RCurl, readr, reshape, stats, zoo, and it is available for the R version 3.3.1 or later. https://github.com/okgreece/TrafficBDE.

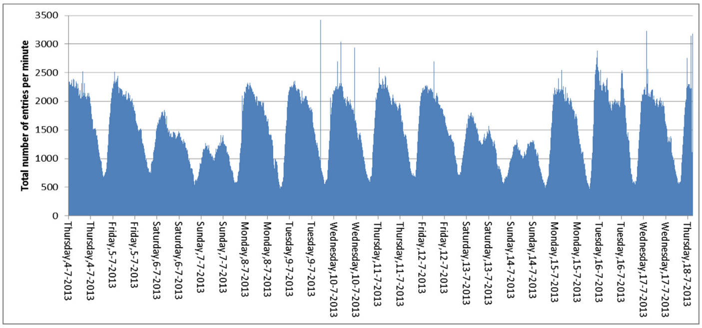

Fig. 2. Distribution of taxi pulses during the period 4/7/2013–18/7/2017 [11].

The authors decided to use only internal factors aiming at building a data-driven model, which will be able to predict the impact of rain in the network speed without knowing that it is raining, only form the drop on the speed of the taxis. This will allow for predicting non-recurrent congestion such as the one generated locally in the surroundings of a stadium twice a month, when there is a game, again without being informed about the game taking place.

3.3 Pre-processing and Data Analysis

The road, the date time, the wanted variable to be predicted and how many steps forward the prediction will be, are being selected. In Table 1 is a short description of the inputs that must be defined, to be used the TrafficBDE package.

Table 1. Short description of the inputs in the algorithm.

Input	Description
Path	The path with the historical data available
Link_id	The Link_id for the road to be predicted
Direction	The direction of the road to be predicted
Datetime	The time and date for the prediction
Steps	How many steps forward will the prediction be
Predict	The variable to be predicted. Either “Mean_speed” or “Entries”

Each road is deviated by its geographical position and length so to each part has been given a unique link id. Namely, each link id represents a specific part of a road. The roads are either one-way or two-way based on that the direction value is 1 or 2.

The path mentioned above contains the data that will be used for the prediction. The input data consists of the min, max and mean speed of the roads, the date time these speeds were observed, the entries of each road at this date time, and the unique entries, i.e. how many were the different entries. Finally, there are also provided some statistical measures of the mean speed of each Link id in a particular quarter, these measures are standard deviation, skewness and kurtosis, which are going to be used as features.

Firstly, the algorithm filters the historical data of the roads based on the selected Link id and direction, and then the algorithm keeps the data of the previous two weeks from the date time wanted and calculates the features, mentioned below, of the speed. Afterwards, the algorithm checks if all the quarters exist, this means 1344 quarters for two weeks. If there are missing quarters, they are created, and linear interpolation fills the rest data values. When the data are completed, they are split into the train set and test set, and they are processed and normalised between 0 and 1.

As mentioned above the statistical measures are going to be used as features to train a more accurate model. Namely, these features refer to standard deviation, skewness and kurtosis of each Link id in a particular quarter. The features are, also, processed and normalised between 0 and 1 (Fig. 3).

	Min_speed	Max_speed	Stdev_speed	Skewness_speed	Kurtosis_speed	Entries	UniqueEntries	Mean_speed
2017-01-16 22:15:00	0.04838710	0.4915254	0.34838094	0.5029376	0.4147874	0.154411765	0.42857143	0.34693878
2017-01-16 22:30:00	0.32258065	0.3898305	0.26030382	0.5844592	0.3162458	0.088235294	0.24489796	0.32653061
2017-01-16 22:45:00	0.11290323	0.2542373	0.23749948	0.2927972	0.6167640	0.091911765	0.28571429	0.32653061

Fig. 3. Sample of the data after being normalized.

3.4 Multilayer Perceptron Model

After the preprocessing, the data are divided into the train and the test set. In the created algorithm, the input layer consists of 7 nodes-features; min and max speed of the road skewness, kurtosis and standard deviation of the speed and entries and unique entries. The algorithm used to train the NN is Resilient back propagation (Rprop).

Rprop focuses on eliminated the influence of the size of the partial derivative on the weight step. Therefore, for the indication of the direction of the weight update, only the sigh of the derivative is considered. The size of the weight change is determined by the update-value.

The model used is Multilayer perceptron (MLP). MLP is a feedforward ANN model that is known for the simplicity and the performance of nonlinear patterns. Due to those characteristics, it is used in similar applications. MLP represents a directed graph of multi-layers of nodes, there are three types of layers the input, hidden and an output; each layer is connected to the next one.

In general, there is no restriction on the number of nodes and hidden layers to be used. We are testing in each step which combination provides the best results (cv result), and that is chosen as our final model.

3.5 Cross-Validation

Different combinations of the number of neurons in each hidden layer are checked with 10-fold cross-validation, and the model with the minimum error is used as the train model. The train set is separated into 10 datasets, which are consists of 134, original sample is divided into 10 equal subsamples (1344/10), observations each. Nine of them will be used to train the NN and will predict the other observations. This process will be repeated 10 times and according to the smallest error the NN, which provides the best predictions, will be chosen.

3.6 Neural Network Output

The output of the algorithm is the predicted value of the wanted variable, either the Mean speed or the Entries. For example, the structure of the model presented below (Fig. 4) is characterised by the 7 inputs, 4 neurons in each hidden layer and one output, the mean speed.

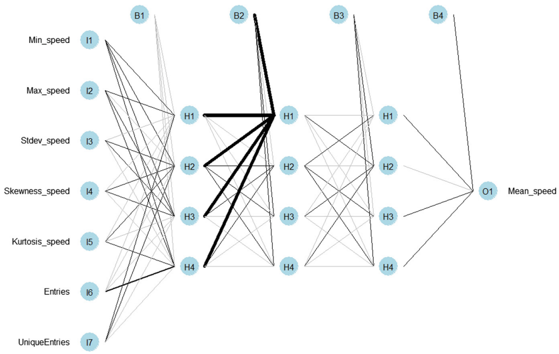

Fig. 4. Example of NN model.

4 Results and Discussion

The above methodology is applied to the FCD collected in Thessaloniki [10]. Thessaloniki is the second largest city in Greece, with a total of more than 1 million citizens in its greater area, covering a total of 1,500 km^2 with an average density of 665 inhabitants per km^2. The total number of vehicles in the city exceeds 750,000, including private cars, heavy vehicles and motorcycles.

The available data are the historical data of two random roads with links for January in 2017. The features mentioned were calculated and algorithm chose the NN model based on 10-fold cross-validation.

We perform two types of test. The first one shows the results of the prediction of eight sequentially date times. As the second type provides the prediction 4 steps forward of the date time, i.e. in the first step, the algorithm uses the historical data to predict the speed value of the first quarter. The predicted value will be used in the second step to predict the speed value of the next quarter. The same process continues until we reach the last quarter.

The following figures are the results of the first test. In both figures, the predicted values follow the pattern. It is worth noting that in cases where the pattern changed abruptly, giving a slightly increased Root Mean Square (RMSE) but still not higher than 10.5 km/h and less than 6.5 km/h in the two selected links, the algorithm recognised the changed pattern and followed it in the next predictions (Fig. 5).

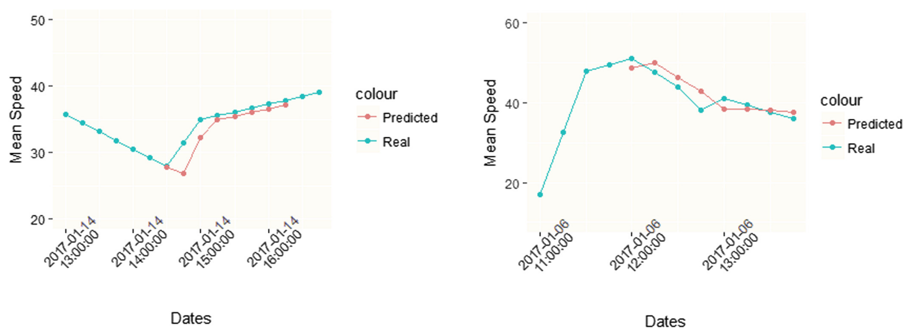

Fig. 5. Plot with the Real (blue) and the Predicted (red) values.

The following Table 2 shows the results of the 4-step forward case. Taking a look at the results, we can see the prediction value does not significantly differ from the real, and the algorithm captures the changes in mean speed.

Table 2. Results of the prediction in the two selected links.

Link	Date time	Predicted speed	Real speed	RMSE
1	2017-01-12 19:30:00	17.07	16.71	0.35
1	2017-01-12 19:45:00	16.88	16.14	0.74
1	2017-01-12 20:00:00	16.02	15.57	0.45
1	2017-01-12 20:15:00	15.69	15.00	0.69
2	2017-01-14 16:00:00	36.75	37.28	0.53
2	2017-01-14 16:15:00	37.26	37.85	0.59
2	2017-01-14 16:30:00	37.77	38.42	0.65
2	2017-01-14 16:45:00	38.31	39.00	0.68

5 Conclusions

A machine learning algorithm for predicting traffic status (speed) has been presented and applied to the city of Thessaloniki, achieving an accuracy of a few km/h. The raw data is collected by a fleet or 1.200 vehicles with a frequency of 6–10 s, generating large data sets and covering both spatially and temporally the whole city with high granularity. This allows, on the one hand having better accuracy but on the other hand increases significantly the data filtering and processing needs, especially when the predictions are made in real time to fuel mobility services.

The predictions are based on spatial relations of traffic flow in addition to the time series generated for each link, which enriches the dataset significantly due to the propagation properties of traffic flow. The increase in the reliability of the predictions will allow better traffic management in Thessaloniki as well as enhanced information to drivers.

Future research of the authors will deal with including other datasets in the analysis, such as travel time along the main routes in Thessaloniki obtained from the network of Bluetooth detectors. The aforementioned will allow combining travel times along various set of links with instantaneous speed in some of that links, and may end up with more accurate predictions. Finally, the addition of external factors, such as weather, will be evaluated by the authors.

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Social Networks and Traveller Behavior

The Walkability of Thessaloniki: Citizens' Perceptions

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Abstract. This paper aims to assess the walkability of Thessaloniki, Greece, via individuals' perceptions about the influence of the environmental factors of functionality, safety, aesthetic, and points of interest on their pedestrian behavior. The survey's participants were 117 men and 152 women, from 15 to 78 years old, who came from 12 municipalities of the greater Thessaloniki area. The participants responded to a questionnaire which was based on valid and reliable previous respective questionnaires and walkability audits. The questionnaire was formulated on an online Internet platform and the data were collected in October 2017. The results revealed a variability of the assessment results among the different municipalities of Thessaloniki. Since the data were analyzed on the detailed level of postal codes, many differences were also found even between different postal code areas. Almost all areas were found to be insufficient in terms of functional characteristics. The suburban areas suffer from lack of pedestrians' facilities, while urban areas from many obstacles on the existing facilities. In contrast, the proximity of points of interest was found to be very satisfactory. Regarding the safety of the pedestrians' environment, it was perceived as of medium level whereas it was higher in the Thessaloniki city center. The pedestrians reported dysphoria from air pollution, mostly in neighborhoods with high density and vehicle traffic. Dirty pavements, lack of greenery, and ugly buildings bother citizens while walking. The findings are discussed with respect to practical implications in urban planning and people's quality of life.

Keywords: Walkability · Thessaloniki · Perception · Questionnaire · Audit

1 Introduction

Active modes of transport benefit both society and individuals' health and prosperity [1]. Walking is the fundamental mode of mobility and the way that every route begins and ends [2]. In order to encourage walking, it is crucial to determine those factors that influence pedestrian behavior in each environment and scientifically document the current condition. Therefore, the present investigation focused on the factors that affect pedestrian behavior in a specific area.

Many researchers have developed methods on assessing the walking conditions, like e.g. the Australian Method [3]. Most of them use indices such as the Level of

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Service (LOS). The most generally approved LOS method is the Highway Capacity Manual's [4] where the approach is similar to the one for the vehicular traffic [5].

However, the last two decades another group of assessment methods has been gaining ground, those that examine the "walkability" of an area. Many definitions have been proposed for walkability and all of them have as a common base the way that the built environment encourages walking. The term "environment" is a multidimensional construct, including not only the physical elements but also the perception for the environment, the social environment, and pedestrians' safety [6]. Pedestrians' safety, specifically, is not defined merely by road safety but correlates with the sense of protection from any external factor [7]. Walkability has been defined as "the extent to which the built environment is walking friendly" [8]. The walkability index is being utilized by many scientific fields [9]. This arises the need to increase walkability as a vital step towards achieving healthy, livable, and interactive cities [10].

In the Greek environment, there are rare research examples [e.g. 11] which examine walkability. The aim of the present paper is to assess the walkability of Thessaloniki, Greece, via individuals' perceptions about the influence of the environment qualities on their pedestrian behavior.

1.1 Assessing Walkability

It is considered that three categories of factors affect people when they decide to commence a walking route. The first category includes cultural and socio-demographic characteristics [12]. The second one contains the travel characteristics, like the aim and frequency [13]. The third category refers to the attributes of the walking environment [14, 15]. Whereas it is difficult to change the first two groups of factors, the third one is not fixed [16]. This is the reason why the relevant literature, and this research, attempts to assess the pedestrians' environment. Moudon and Lee (2003) conducted an in-depth literature review and appointed many methods on assessing walkability of an area, all of which can be separated in subgroups according to the procedure of data collection [17]. Jensen et al. (2017) distinguish two groups of factors: the perceived and the objectively-assessed walkability. More specifically, perceived walkability comprises self-reported perceptions while objectively-assessed walkability is measured through audit tools and Geographic Information System (GIS) databases [18]. Other researchers, pointed out that the perception of the people on the built environment can be gathered with self-administered questionnaires and telephone interviews [19]. The most broaden used questionnaire is the Neighborhood Environment Walkability Scale (NEWS) [20] and its abbreviated version NEWSA [21]. In Europe, the ALPHA program team, developed another questionnaire which was considered to respond more precisely to the typical European context [22].

1.2 Environmental Factors of Walkability

Differentiation exists not only regarding the data collection methods but also to the selected elements of the urban environment that are thought to influence walking. Pikora et al. (2003) found four categories of such elements; (a) functional characteristics, (b) safety, (c) aesthetic, and (d) points of interest. Functional characteristics contain features of the physical environment like material and width of infrastructures and motorized traffic. Safety is divided into personal safety and protection from traffic. Air pollution, greenery and more, are important for aesthetic evaluation [14]. Lee and Moudon (2006) proposed the 3DS + R; Density, Diversity, Design, and Route, measures and encouraged the 1 km buffer for capturing neighborhood walkability [23]. The 1 km represents the distance that people are willing to walk and is supposed to be a proper distance to evaluate walkability around one point [24]. A team which developed the Systematic Pedestrian and Environmental Scan (SPACES) in Australia, used the 400 m distance from home location to determine neighborhood walkability. The same team pointed difficulty on evaluating attributes such as aesthetic, due to the entrance of subjectivity of the experts who report the conditions [25]. Moreover, many environmental features and qualities such as pedestrians' traffic lights and obstacles on pavements have been included in walkability assessment methods [26].

1.3 Aim and Hypothesis

This research aimed at assessing the walkability in the urban environment of Thessaloniki, Greece, via individuals' perceptions about the impact of the environment qualities of functional characteristics, safety, aesthetic, and points of interest on their pedestrian behavior. It is hypothesized that the higher the perceptions of the environmental qualities are the higher the pedestrian behavior is.

2 Method

This research is a primary effort to estimate the encouragement of walking in the city of Thessaloniki, Greece. Therefore, it was considered important to analyze the perspective of pedestrians towards the current situation of walkability. The main research instrument was a questionnaire developed in the frame of this research and consequently this research belongs to the perceived walkability methods, as defined by Jensen et al. (2017) [18]. The questionnaire was formed according to the literature review. The characteristics, which are under investigation, follow the categorization of Pikora et al. (2003) [14]. Thus, four categories of factors which influence pedestrians are assessed; functional characteristics, safety, aesthetic, and points of interest. The aim of the questionnaire is to record and make clear the citizens' opinion on the condition of the walking environment in their neighborhood. This could contribute to fulfill the initial target of this research; the specification and nomination of those features that could improve the walkability of the specific area. Moreover, since the research examines a broader geographical area, specifically all the municipalities of Thessaloniki, it also targets to the recognition of the most problematic areas where reformation is urgent. The questionnaire is a synthesis of numerous questions utilized in former tools, adapted to the Greek urban and suburban environment, in coherence with the characteristics of the study area. It is mainly based on NEWS and ALPHA questionnaires due to the high accuracy and development in a European environment, respectively. It was developed using Google Forms and it consists of three sections.

The first section contains questions on the personal and demographic characteristics of the participants. In this section the participants specify their home location in the detail level of postal codes. The answers are either in form of multiple choice (gender, walking disability, and usage of supporting equipment), or numerical text (age and postal code) and short text (municipality of residence). In the last question (frequency of 30 min' walk) the answer is given in a Likert scale.

The second section is the core body of the research, and within 25 questions, it examines the perspective of the individual towards the walkability of his or her home neighborhood. Answers are only possible in a Likert scale, with distinguished grades from 1 to 5, like in other walkability questionnaires [20–22]. All questions are formed in a way that 1 is the least and 5 the most positive evaluation. The first seven questions examine the functional characteristics such as adequacy of pavement's width, existence of incline, and the degree it bothers pedestrians. The following 10 questions refer to the sense of safety while walking. It provides questions in which the residents describe how safe they feel during day and night. The questionnaire continues with the assessment of aesthetics asking the pedestrians about the dysphoria level from air pollution, the beauty of the buildings, the disturbance from stray animals, and more. Finally, the participants describe the proximity of points of interests within a 1 km distance, as proposed by Oliver, Schuurman, and Hall (2007) [24]. The total score from the answers in this section is the assessment of each postal code area. The final grade is the average of the rates of the people who inhabit in the same postal code area.

In the third section, residents name the problems and dangers that they rate as the most significant.

Overall, there were no weights used and the metric for Walkability was the average score of the following factors: "Functional characteristics", "Safety", "Aesthetics", and "Points of Interest".

3 Procedure

The collection of the answers was realized through the Internet. This method was preferred due to the possibility it provides for simultaneous multiple answers at the same time from various locations. The questionnaire was published and disseminated through social media (viz. Facebook and LinkedIn) and remained open for answers from Saturday 7th October 2017 12.30 p.m. until Wednesday 11th October 12.30 p.m. In addition, to ensure the participation of elderly people, on-site interviews took place on Sunday 8th and Monday 9th October between 9 a.m. and 3 p.m. in the main square of Thessaloniki, the Aristotelous Square. A tablet device was used for these interviews.

In total 300 people filled the form. Analyzing the validity of the homes' location and postal codes that were recorded, 31 answers were characterized as invalid. An answer was considered to be invalid when the postal code was not found in the Hellenic Post database or there was no agreement between the postal code and the municipality in which the home was reported to be located. Aiming to achieve a comprehensible view of the results it was decided to utilize a map depiction. This map was constructed by the authors as a file in QGIS and the postal code areas were formulated as polygons.

4 Results

There were partial imbalanced responds from men and women, 45.3% and 54.7% respectively. Most of the participants were either 15–28 or 34–47 years old (150 answers). However, there were people that responded up to 78 years old. Only eight people revealed that they face mobility difficulties during walking. Apropos the walking habits, only 0.05% of the sample never walks for 30 min whereas, 106 people said that they walk daily. The participants reported their home location in 58 different postal codes and almost 2/3 were residents of the Municipality of Thessaloniki. Eleven more municipalities were covered by the sample.

The results regarding the functional characteristics showed that the participants mostly graded the pavement infrastructures as adequate (>3), in terms of cover of the area and width. However, they seem disappointed from the number of pedestrian ramps on them. In seven areas people said there are no ramps at all. Additionally, the inhabitants who responded to the survey declared that most of the times it is impossible to use the existing pedestrian ramps. Participants reported that in most of the neighborhoods there are obstacles across the pavements. The residents of the Municipality of Oraiokastro reported the least barriers on the pavements. The incline of the ground bothers residents from some postal codes areas. All the inhabitants of the Municipality of Neapoli-Sykeon reported that face difficulties during walking because of gradient. For these characteristics the Municipality of Kalamaria gathered an average grade over 3 which is a good one. On the contrary, the surrounding eastern areas received the most negative evaluation; around 1.9. Close rates were also received by two suburban municipalities on the west site of the survey area, specifically, the Municipalities of Oraiokastro and Pylaia-Chortiatis.

Moving on to the safety at the pedestrians' environment, none of the postal codes received the maximum 5 for the velocity of the vehicular traffic. However, 14 codes received an average score close to 4, which means that the pedestrians judge that the vehicles run relatively slow across these neighborhoods. The results were similar for the disturbance from the traffic volume. During the day the average grade of all participants is high ($\approx$4). In contrast, the pedestrians reported that they feel less safe at night and the road lighting was reported as insufficient in many suburban areas. Only the 5% of the participants feel fully protected from the vehicles. Simultaneously, around 40 people considered the frequency of pedestrian crossings and those with pedestrian traffic lights as inadequate.

The participants reported that they do not see beautiful buildings while walking in their neighborhood. Moreover, almost half of them think that the pavements are at least dirty. The postal code areas at the periphery of the city center obtained higher rate. Referring to the green spaces, the residents from the western areas stated that they are insufficient. A positive graduation is highlighted while moving from the west to the east side of the city. Furthermore, participants reported that air pollution is medium to significantly sensed for pedestrians in their neighborhood. Only in the Municipalities of Thermaikos and Thermi, the pedestrians said that they do not feel much discomfort from the air pollution. Most participants (63%) answered that stray animals do not repel them from walking.

In the Thessaloniki city center, residents stated that their points of interest and connection with the public transportation are within a walkable distance

The grade for each postal code area that was evaluated is depicted in Fig. 1. This final grade is the average sum of the individual questions and it is the rate for each area according to the method of assessment of the walkability of the urban and suburban environment which was developed in the frame of this research. On this map the darker the color the more positive the evaluation is.

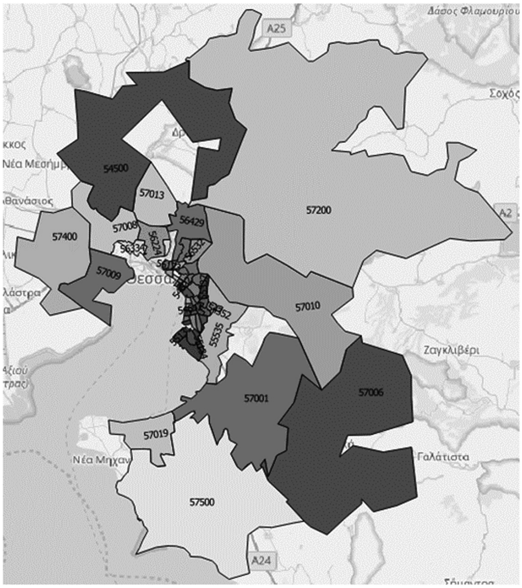

Fig. 1. Spatial depiction of the assessment of walkability in Thessaloniki, Greece.

5 Discussion

The present research aimed to examine the citizens' perceived influential urban environment factors on their walking and pedestrian behavior.

Although, different people provide different evaluation of the same condition, probably depending on their personal needs and personality, trends appear among habitants of the same or close neighborhoods. The present research shows interesting results by considering the average rate of the answers. Comparing the assessment of the four groups of factors which were investigated, the functional characteristics received the lowest evaluation. This contrasts with results from previous surveys, in the European environment [27], where the functional characteristics were rated almost excellent. In contrast, in the investigated area of this research, the proximity of points of interest received the highest evaluation. In the city of Thessaloniki, the pedestrian facilities are often inaccessible and useless because of obstacles or damages, whereas most peripheral areas lack in infrastructures. The incline of the ground influences the pedestrians in the city of Thessaloniki and this should be taken into consideration in urban design. The sense of safety was the characteristic with the higher agreement between residents of close neighborhoods. This paces with the fact that pedestrians care about the environment of their whole route and not only about the points of origin and destination, as the drivers and passengers do. In addition, discomfort from air pollution and low aesthetics of the surrounding environment are mentioned by most residents in Thessaloniki. Surveillance, cleanliness, and maintenance of infrastructures together with adequate urban planning, which protects pedestrians from vehicles, could significantly improve the walkability. Since multiple factors have proved to interact in pedestrian behavior and encouragement of walking, a multidisciplinary cooperation is essential to achieve a proper walkability level in Thessaloniki.

This research faces some limitations that future investigation needs to overcome. For instance, the number of participants and the participation among the postal code areas is imbalanced. However, despite this limitation, the present findings underline the role of all four categories of factors towards enhancing walkability in an urban environment and stress the necessity of considering citizens' opinion during urban planning.

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Perception of Smartphone Applications About Transportation Among University Students

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Abstract. This paper aims to examine the extent to which student population of the Aristotle University of Thessaloniki (AUTh) is familiar and uses smartphone applications for the facilitation of their trips. To reach the final results and draw the respective conclusions, three main methodological steps were followed.

The first step includes the literature review, where a number of reports and papers were thoroughly examined for the better research's topic understanding.

The second step was the design of the questionnaire and the conduction of the survey. Based on the studied bibliography, a questionnaire which consisted of three main sections was designed in such way for drawing as much useful information as possible. Afterwards, the questionnaires were distributed and answered by AUTh students.

The final step was the statistical analysis of the results of the survey. The extracted data from 300 questionnaires were encoded and imported in the IBM SPSS Statistics software for descriptive statistical analysis. In the framework of this research, it was possible to identify the extent to which university students use the smartphone applications about transportation. In addition, the frequency of use of the applications as well as the usefulness of these applications was examined. Moreover, the results revealed the smartphones applications' prospect to change and shape mobility behavior. The findings suggest the great extent to which mobile applications on transportation are used and the role they play to make university students' trips easier and more efficient.

Keywords: Smartphone applications in transport · University students
Mobile applications in transport · Smartphone usage
Mobility of university students

1 Introduction

Since 2000 a growth is observed in the new technologies such as internet, mobile phones and smartphones. According to a study conducted in the United States by Dutzik et al. [1] an increase of 36% in the internet, an increase of 35% in the use of

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mobile phones and an increase of 46% in the use of smartphones are observed during the period 2000–2012.

A report on the EMarketer [2] indicates that there were 4.55 billion mobile phone users worldwide in 2014, of whom 1.75 billion were smartphone users The projection for 2017 is that the number of smartphone users will be 2.50 billion - a 9.7% increase (the smartphones' users represent the 48.8% of total number of mobile phone users). The actual number of smartphone users in 2017 is 2.32 million and it is expected to pass the 5 billion mark by 2019 [3].

A study conducted by Aljomaa et al. [4] about smartphone addiction among university students led to the conclusion that 48% of the participants (200 out of 416) were categorized as smartphone addicts. This finding indicates that students spend considerable time using their smartphone and a dependence on the several technological applications they provide. It is also worth noticed that students depend on a smartphone to carry out all of their daily tasks, even the simplest ones.

The overall increase in the use of smartphones leads in the increase of the use of smartphones' applications. Those applications can be found in the dedicated markets/stores of the technological companies (e.g. App Store [5], Google Play [6]). Siuhi and Mwakalonge [7] indicate in their study that smartphone applications play a leading role in different aspects of a citizens' everyday life (e.g. communication, entertainment, transportation etc.). Nevertheless, Shaheen et al. [8] mention that the irrational use of smartphones' applications may have negative results in the mental health of the users.

In terms of transportation, a significant factor is the provision of information to the users of the transport systems through the use of Intelligent Transport Systems (ITS) [9]. It is also of high significance that younger persons use applications in order to be informed for, or during, their trip. Anderson and Smith [10] and Khoo and Asitha [11] indicate through their studies, that these people are likely to use transport-related smartphone applications (respectively, 80% and 69% of young people use turn-by-turn navigation applications).

Transport-related smartphone applications cover a variety of fields. The main fields covered by such applications [1, 7, 12] are:

- Trip and route planning
- Ridesharing, carpooling, vanpooling
- Real-time parking information
- Travel information

According to studies [7, 8, 11, 13] the use of transport-related smartphone applications can be beneficiary to the users of such applications. The main benefits stated in the relevant studies [7, 8, 11, 13] are:

- Increased efficiency in terms of mobility
- Improved safety and security
- Control of the transportation process by the users
- Information throughout the day

The current study examines the interaction between the users and the transport – related applications. The main objective of this survey is to identify the extent to which university students use transport-related smartphone applications as well as the usefulness of these applications. The impact of the transport-related applications to the mobility habits is also examined, as well as the extent to which transport-related smartphone applications make university students' trips easier and more efficient.

2 The Questionnaire-Based Survey

The questionnaire-based survey, which was addressed to the students, took place in the campus of the Aristotle University of Thessaloniki (AUTh) during the period November – December 2016 [14]. A number of 300 valid questionnaires were collected through face-to-face procedure. The questionnaire used in the survey consisted of three main sections which examine the interaction between the applications (especially their content and the provided information) and the users.

3 Descriptive Statistics

The software used for the statistical analysis was the IBM SPSS Statistics [15] Version 23. Data were properly checked, encoded and imported in the specific software. The results of the descriptive statistical analysis are presented hereinafter.

The frequency of the use of the main smartphone application about transportation, as stated by the respondents, is presented in the Table 1.

Table 1. Use of the main smartphone application about transportation.

Use per month/day	Respondents	Percent	Valid percent	Cumulative percent
1–3 times per month	31	10.3	10.5	10.5
1 per day	65	21.7	22.1	32.6
2 per day	72	24.0	24.5	57.1
3 per day	46	15.3	15.6	72.7
4 per day	42	14.0	14.3	87.0
5 per day	21	7.0	7.1	94.1
6 per day	9	3.0	3.1	97.2
7 per day	2	0.7	0.7	97.9
8 per day	2	0.7	0.7	98.6
>8 per day	4	1.3	1.4	100.0
Total	294	98.0	100.0	–
Missing	6	2.0	–	–
Total	300	100.0	–	–

It is interesting to notice that 3 out of 4 students use their main application for transportation 1–4 times per day. This number shows the diffusion of the specific technology. The average number of trips made during a typical work day is presented in Table 2.

Table 2. Average number of trips made during a typical work day.

Daily trips	Respondents	Percent	Valid percent	Cumulative percent
0	4	1.3	1.3	1.3
1–2	107	35.7	36.0	37.4
3–4	135	45.0	45.5	82.8
5–6	30	10.0	10.1	92.9
>6	21	7.0	7.1	100.0
Total	297	99.0	100.0	–
Missing	3	1.0	–	–
Total	300	100.0	–	–

Almost half of the students make 3–4 trips during a typical work day. This finding justifies, to some extent (applications referred to Public Transport, taxi), the daily use of smartphone applications by the students for the organization of their trips. The use of smartphone applications for choosing a specific transport mode in order to save some time is presented in Table 3.

Table 3. Decision to use an application in order to choose a transport mode, in terms of time savings.

Answers	Respondents	Percent	Cumulative percent
Not at all	5	1.7	1.7
Slightly	14	4.7	6.3
Moderately	34	11.3	17.7
Very	126	42.0	59.7
Extremely	121	40.3	100.0
Total	300	100.0	–

As shown in Table 3, a large percentage (82.3%) of the respondents considers that the use of mobility applications can considerably help them in their decision to choose a transport mode, in terms of time savings. The use of smartphone applications for choosing a specific transport mode in terms of improved safety level is presented in Table 4.

Table 4. Decision to use an application in order to choose a transport mode in terms of safety level.

Answers	Respondents	Percent	Cumulative percent
Not at all	99	33.0	33.0
Slightly	74	24.7	57.7
Moderately	62	20.7	78.4
Very	50	16.6	95.0
Extremely	15	5.0	100.0
Total	300	100.0	–

As shown in Table 4, safety seems to play a less important role in students' decision to use an application for choosing a transport mode (at least when it is compared to time savings). The lack of sufficient knowledge for the safety level of each transport mode may be the reason for this finding. The influence from the use of an application to the daily use of a specific transport mode is presented in Table 5.

Table 5. Decision to use an application in order to change transport mode for the main trip, during the typical work day.

Answers	Respondents	Percent	Cumulative percent
Not at all	47	15.7	15.7
Slightly	40	13.3	29.0
Moderately	70	23.3	52.3
Very	92	30.7	83.0
Extremely	51	17.0	100.0
Total	300	100.0	–

In regards to changing transport mode for their main daily trips, almost half of the students have stated that the use of applications has influenced them to change transport mode. The main factors for such a decision are presented in Table 6.

Table 6. Main factor for changing transport mode for the main daily trip.

Factors	Respondents	Percent	Valid percent	Cumulative percent
Time	213	71.0	82.9	82.9
Cost	26	8.7	10.1	93.0
Comfort	8	2.7	3.1	96.1
Alternative transport modes	1	0.3	0.4	96.5
Alternative routes	5	1.7	1.9	98.4
Environment	4	1.3	1.6	100.0
Total	257	85.7	100.0	–
Missing	43	14.3	–	–
Total	300	100.0	–	–

It is clear, from the content of Table 6, that time is the most important factor for the students in order to choose another transport mode for their main daily trips. This decision is based on the information provided by the application used. It is interesting to notice that factors like comfort, alternative routes and environmental impacts do not significantly affect the decision of the students (which is based on the use of an application) concerning another transport mode for their main daily trips.

It is worth mentioned that the term "alternative transport modes" refer to all the modes that were identified via the use of smartphone applications about transportation, and are used as a new mode of transport by the students.

The findings concerning the perceived security of the transactions made through the use of smartphones are presented in Table 7.

Table 7. Perceived security, by the students, when making transactions via smartphone.

Answers	Respondents	Percent	Cumulative percent
Not at all	13	4.3	4.3
Slightly	56	18.7	23.0
Moderately	75	25.0	48.0
Very	91	30.3	78.3
Extremely	65	21.7	100.0
Total	300	100.0	–

As shown in Table 7, the perceived security by the students during the use of smartphones' applications about transactions is considered a rather important factor for the assimilation of applications to their daily routine and for their afterwards extended use and exploitation of all of the capabilities and facilities that these applications can offer. The perceived security, as far as the proper use of personal data is concerned, is presented in Table 8.

Table 8. Perceived security about the proper use of personal data in transport-related applications.

Answers	Respondents	Percent	Cumulative percent
Not at all	38	12.7	12.7
Slightly	67	22.3	35.0
Moderately	71	23.7	58.7
Very	75	25.0	83.7
Extremely	49	16.3	100.0
Total	300	100.0	–

The perceived security, as far as the proper use of the "location of the smartphone" is concerned, is presented in Table 9.

Table 9. Perceived security about the proper use of the "location of the smartphone" in transport-related applications.

Answers	Respondents	Percent	Cumulative percent
Not at all	57	19.0	19.0
Slightly	58	19.3	38.3
Moderately	99	33.0	71.3
Very	50	16.7	88.0
Extremely	36	12.0	100.0
Total	300	100.0	–

It is noticeable from Tables 8 and 9 that students express a significant concern about the proper use of their personal data and also about the proper use of the information about the "location of their smartphones". In order to deal with this hesitation, a provision of better information about the security aspects of mobility applications (and applications in general) is a good option.

The need for a new portal-type application which will explore all the existing transport-related smartphone applications and suggest the best options according to the users' mobility needs is presented in Table 10.

Table 10. Need for a new portal-type application which explores and suggests the best options according to the users' mobility needs.

Answers	Respondents	Percent	Cumulative percent
Not at all	16	5.3	5.3
Slightly	25	8.4	13.7
Moderately	36	12.0	25.7
Very	96	32.0	57.7
Extremely	127	42.3	100.0
Total	300	100.0	–

As shown in Table 10 it is worth to mention that there is strong need for an application that will explore all the existing transport-related smartphone applications and, at the same time, it will suggest the best options that satisfy the needs and priorities of the students (and the citizens in general).

4 Concluding Remarks

It is evident from the findings of this research that smartphones' applications about transportation consist an important part of the daily routine of the university students in the case of the AUTh. Time savings is a crucial factor for the university students when they consider the use of smartphone applications for their mobility needs. On the contrary, safety seems to play a less important role in students' decision to use an application for choosing a transport mode. Almost half of the students have stated that the use of applications has influenced them to change transport mode for their main daily trip during a typical work day because of time saving. Students express a significant concern about the proper use of their personal data and also about the proper use of the information concerning the "location of their smartphones". This finding imposes the need for the provision of better information about these issues to the smartphone users.

It is recommended to develop new portal-type application which will explore all the existing transport-related smartphone applications and suggest the best options according to the users' mobility needs. In addition, information campaigns towards the benefits arising from the use of smartphone applications about transportation should be carried out by the respective authorities on a constant basis

University students are generally characterized by high mobility rates and convenience to use new technologies. This can explain quite a lot of the research findings. It is essential to know the perception and impact of such applications in the general population in order to maximize their usefulness.

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Social Networking and Driving. A Study About Young Greeks

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Abstract. Though mobile phone use is considered a risky behavior while driving and it is even illegal in most countries, it is still very common to see drivers talking or texting, ignoring the fact that they are behind the wheel. According to literature, more than 80% of mobile users under the age of 30 are members of at least one social network and questions arise on whether and how social media affect driving behavior.

In this paper, questionnaire answers from 113 Greek drivers are analyzed in order to estimate if young people use social media when driving. Participants provided demographic information, such as sex, age and income, driving characteristics, such as years of driving experience and kilometers traveled per day and information related to smartphone use and social networking activities while performing driving tasks, such as status update, photo uploading or texting. Participants were also asked about their opinion on how phone use affects their driving skills, as well as their willingness to use an application that would turn off their phone while being behind the wheel.

Results show that although the majority of them think that their driving performance is affected by smartphone use, less than half were willing to use a "phone-off" application and more than 50% tend to interact through social media, more or less frequently. Results are also statistically analyzed, with regard to differences between men and women, group ages and other personal characteristics.

Keywords: Young drivers · Smartphone · Distracted driving Social networking

1 Introduction

Distraction occurs when drivers divert their attention from their primary task in order to focus on any other secondary activity NHTSA [12]. Young et al. [22] describe driver distraction as "any secondary task performed while driving that distracts the driver's attention visually, audibly, physically or cognitively from the primary task of driving. The driver's inattention is provoked by stimuli derived from either inside or outside the vehicle such as talking or texting on a smartphone, eating and drinking, talking to passengers in the vehicle, adjusting music devices while driving, programming navigation systems, etc. [18, 20]. Among the above mentioned sources of distraction, cell phone use while driving distracts the driver both visually, audibly, physically and

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cognitively [22]. A research by Highway Traffic Safety Administration (2013) indicated that by the end of 2010, there were 24,000 accidents/crashes that lead to injuries and 2,912 fatal crashes respectively, that involved cell phone use. Although cell phone use while driving is considered a risky behavior and is even illegal in the majority of the countries globally, 660,000 drivers talk on their cell phone at any given time. The use of cell phones while driving, as well as its impact [17, 20] on driving safety has long been researched by the scientific community and therefore is recognized as a threat to road safety [2, 6, 7, 19]. Hand-held phones, especially those providing internet access, may cause eye glances off the forward roadway due to secondary tasks, increase crash and near crash risk [20]. In addition, waiting periods at urban intersections' traffic lights, seem to evoke phone use, both texting and calling [10]. Even though the majority of the drivers are aware of the ban of hand-held phone use while driving and that such a behavior degrades their driving skills, a noticeable proportion of them continue to engage with phone related activities [16]. More specifically, drivers engaging in multiple tasks (e.g. conversation, texting) besides driving tend to reduce speed in order to compensate for their risky behavior. Especially, when speed alternation does not occur, both conversation and texting are linked with even higher accident risk [18]. Zhao et al. [23] found that age contributes significantly to phone use while driving and also that drivers who use their smartphone while driving are inclined to an aggressive driving behavior (frequent change of lane, driving above speed limit, speed variations). Walsh et al. [21] indicated that besides age, the driving purpose (personal or professional) affects smart phone use and that drivers are more likely to reply than initiate a text message.

A recent study of cellular use indicated that more than half of young drivers texted at least once while driving [3]. According to Parnell et al. [15] young drivers (up the age of 30) were more likely to engage in tasks related to their smartphone while driving such as reading a text, using social media applications, checking email, especially when stopped at a traffic light. Simons-Morton et al. [20] examined crash or near crash risks among novice licensed drivers caused by visual distraction involving phone use. Independently of the source of the distraction, eye glances with duration >1 s and >3 s increase the risk up to 1.7 and 6 times respectively. Harisson [9] analyzed self-reports from college students that were frequent drivers, indicating that 30% of them admitted to text while driving "fairly often" even though they declared that it constitutes a risky driving behavior. Texting while driving is a main activity for social networking as well. Young people's tendency to be more familiarized with technology featured items is considered as a contributing factor to internet-based applications usage while driving [15]. Moreover, a number of smartphone applications with vast popularity involve texting. An internet survey conducted in Israel [11] investigating sex and age related differences regarding adult drivers, concluded that young drivers below 30 are liable to respond to smart-phone texting. Recent researches showed an imminent association between social networking and smartphone use while driving [14]. A remarkable proportion of 48% of drivers have texted at least once while driving and an alarming 22% has read messages derived from social media applications [8].

2 Method

The purpose of this study is to examine the attitude of young Greek drivers, aged up to 30, towards their smartphone, especially when it concerns social networking engagement. An anonymous 35- question survey was administrated, both online and via personal interviews. All of the responders owned a smartphone, driving license and were active members of at least one social network. The first part of the questionnaire revealed the drivers' information about their sex, age, education, income, frequency of vehicle driving, weekly travel in kilometers and car possession. In the second part of the questionnaire participants responded to several questions concerning their attitude towards cell phone use while driving using a five Likert-scale response options (i.e. Never, Rarely, Neutral, Often, Very often), Finally, the drivers had to answer questions regarding their willingness to use a web-based application that is going to turn off their smartphone while driving. The questionnaire's reliability and validity towards internal coherence were checked particularly as far as questions about social media were concerned. The Cronbach-alpha coefficient was 0.79 (7 questions involved), that is an acceptable value.

3 Results

3.1 General Characteristics, Driving Attitude and Perceived Risk

The sample consisted of 113 participants, 30 females (26.5%) and 83 males (73.5%) whom age ranged from 18 to 30. A percentage of 75.2% had some college training or even further education owning a bachelor or a master degree and almost half of them (54.9%) were college students. The vast majority (98.2%) reported they drive for personal reasons and nearly 1.8% for commuting. Almost half of the participants (46%) owned a car, a percentage of 44.2% use their vehicle on a daily basis, while 37.9% and 16.8% a few times or less per week, respectively.

Interestingly, 36.3% of the drivers appeared to feel intense emotions of addiction towards their cell phones as they answered 4 and 5 in a 5-point scale (Match and Very match addicted) whereas 39.8% admitted to feel slightly the same (answer 3 in a 5-point scale: Neutral). In addition, only 8.8% of the sample uses Bluetooth devices (answers 4 and 5 in a 5-point scale: often and very often) whereas the most part (84.1%) talks via his hand-held cell phone while driving (answers 1 and 2 in a 5-point scale: Never and Seldom). No part of the sample self-evaluated as a Not Capable ("bad") driver. According to the answer 2 (Low skilled driver), 4 and 5 (Skilled and Excellent), in a 5-point scale, more than half of the participants (59.3%) self-evaluated as excellent or skilled drivers and only a percentage of 4.4% described themselves as low skilled. Among the participants who self-evaluated as skilled drivers, 63.8% of them were males and 46.6% females, 74% of them very frequent drivers. Based on answers 4 and 5 on a 5-point scale, the secondary task with the highest perceived distraction (Fig. 1) was texting for the 80.6% of the responders, followed by internet surfing (69%), taking or uploading photos (64.6%), reading incoming messages (67.3%) and lastly responding to phone calls (30%). On the other hand, 11.5% and

18.5% of the respondents reported that texting and taking or uploading photos while driving respectively does not distract the and 16.8% admitted that surfing on the internet during driving does not affect their concentration. Overall, none of the participants answered that they reply very often to notifications received from social networking applications whereas 15.1% of them usually do reply (Neutral, Often, Very often). However, the vast majority (94.6%) never takes/uploads a photo while driving (answer 1: Never) while, as for texting, 18.6% of the respondents selected answers 4 and 5 admitting that they reply often and very often to incoming messages or notifications during driving.

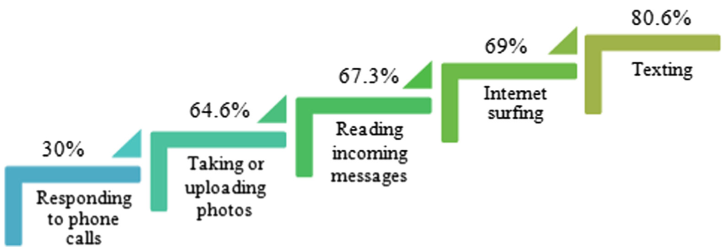

Fig. 1. Perceived driving distraction (answers: very distractive and absolute distractive).

3.2 Social Networking and Driving

Five critical questions of the whole answers data set, are analyzed in the following part. At the question *"Do you remain connected to the internet while driving",* 55.8% are used to driving having their cell phone connected to the internet. More females (66.7%) than males (51.8%) reported to remain connected but with an insignificant difference (x2 = 1.97, p-value = 0.373). Almost six out of ten of the drivers (59.5%) with 500–1,000 followers and of those without a car crash experience (58.8%) reported that they remain connected to the internet. None of the differences in personal characteristics such as sex, car crash experience, followers etc., are statistically significant in 95% level.

Regarding the question Q_2 (Table 1), only 8.9% of the drivers reported an increase in their communication while driving due to networking apps (based on answers 3, 4 and 5). Most of the categories are close to this percentage and no significant difference is recorded between subcategories of driver's characteristics except the drivers who are "on line" vs those with no connection to the internet that reported a significant increase in their communication through social networking apps (x^2 = 5.21, p-value = 0.022). At the question Q_3 (Table 1), 20.5% of men and 13.3% of the women they read often and very often read social networking's notifications while driving. Additionally, 27% of drivers who are "on line", 25% of those with 1000–2000 followers and 18.8% of those without a car crash experience, read this kind of messages simultaneously. Concerning the question Q_4 (Table 1), 94.6% responded that they do not upload (never and rarely) a photo while driving. On the other hand, often and very often answered 3.6% of male, 3.3% of female, 4.8% of those who remain connected to internet, 8.6% of drivers with more than 2,000 followers and 3.6% of the drivers without a previous crash. Again, there are no significant differences between these categories. At the question Q_5 (Table 1), a percentage of 21.5% will may use an application that turns off cell phone while driving. Of them 21.7% are males, 30% females and 28% the "disconnect" participants.

Table 1. Results for several Questions regarding critical characteristics (scale 1Q No/None/Not often, to 5: Yes/Always).

Question	Categories		Answers in scale 1 to 5						x^{2*}	p-value
			1–2	3	4–5	1–2 (%)	3 (%)	4–5 (%)		
Q_2: "*Has social networking apps affected to an increased communication while driving?*"	Sex	Male	75	5	3	90.4	6.0	3.6	0.24	0.6
		Female	28	1	1	93.3	3.3	3.3		
	Connected to internet	No	49		1	98.0	0.0	2.0	5.21	0.02
		Yes	54	6	3	85.7	9.5	4.8		
	Followers	150	7	1	0	87.5	12.5	0.0		
		150–500	34	2	0	94.4	5.6	0.0		
		500–1000	33	1	3	89.2	2.7	8.1		
		1000–2000	19	1	0	95.0	5.0	0.0		
		> 2000	10	1	1	83.3	8.3	8.3		
	Car crash experience	No	76	5	4	89.5	5.9	4.7	1.28	0.2
		Yes	27	1	0	96.4	3.6	0.0		
	Sub-Total		**103**	**6**	**4**	**91.1**	**5.3**	**3.6**		
Q_3: "*How often do you read notifications derived from social media while driving*?"	Sex	Male	52	14	17	62.6	16.9	20.5	0.00	0.9
		Female	19	7	4	63.3	23.3	13.3		
	Connected to internet	No	39	7	4	78	14	8	2.18	0.1
		Yes	32	14	17	50.8	22.2	27		
	Followers	150	6	1	1	75	12.5	12.5		
		150–500	26	4	6	72.2	11.1	16.7		
		500–1000	18	11	8	48.6	29.7	21.6		
		1000–2000	12	3	5	60	15	25		
		> 2000	9	2	1	75	16.7	8.3		
	Car crash experience	No	52	17	16	61.1	20	18.8	0.402	0.5
		Yes	19	4	5	67.9	14.3	17.8		
	Sub-Total		**71**	**21**	**21**	**62.8**	**18.6**	**18.6**		
Q4: "How often to you take/upload a photo while driving?"	Sex	Male	80	0	3	96,4	0	3.6	1.787	0.181
		Female	27	2	1	90	6.7	3.3		
	Connected to internet	No	49	0	1	98	0	2	1.954	0.162
		Yes	58	2	3	92.1	3.2	4.8		
	Followers	150	8	0	0	100	0	0		
		150–500	35	0	1	97.2	0	2.8		
		500–1000	34	2	1	91.9	5.4	2.7		
		1000–2000	19	0	1	95	0	5		
		> 2000	11	0	1	91,6	0	8.3		
	Car crash experience	No	80	2	3	94.1	2.4	3.6	0.224	0.636
		Yes	27	0	1	96.5	0	3.6		

(*continued*)

Table 1. (*continued*)

Question	Categories		Answers in scale 1 to 5						x^{2*}	p-value
			1–2	3	4–5	1–2 (%)	3 (%)	4–5 (%)		
	Sub-Total		**80**		**3**		**0**	**3.6**		
Q5: "Are you willing to use an application that turns off your cell phone while driving?	Sex	Male	54	11	18	65	13.3	21.7	1.28	0.256
		Female	16	5	9	53,3	16,7	30		
	Connected to internet	No	27	9	14	54	18	28	2.40	0.121
		Yes	43	7	13	68.3	11.1	20.7		
	Followers	150	6	1	1	75	12.5	12.5	2.50	0.643
		150–500	19	8	9	52.8	22.2	25		
		500–1000	25	4	8	67.5	10.8	21,6		
		1000–2000	13	2	5	65	10	25		
		> 2000	7	1	4	58.4	8.3	33.4		
	Car crash experience	No	54	11	20	63.5	12.9	23.5	0.364	0.546
		Yes	16	5	7	57.2	17.9	25		
	Sub-Total		**70**	**16**	**27**	**61.9**	**14.2**	**23.9**		

*comparison of 1–2 and 3–4–5.

Based on the results, only few statistically significant differences appeared, mainly in the category of participants who remain "online" while driving. This homogeneous behavior that resulted from the responses was further investigated by interpreting statistical tests using the average responses of the 5-level and the t-student test. The results showed similarities. The Tables 2 and 3 present the significance (p value) of the average values of the male-female response score as well as those who have previously participated or not in an accident.

Table 2. t-student statistical analysis for sex variation across several driving conditions.

Questions	Sex	N	Average score	SD	t	p-value
Increase in cell phone use due to social networking	0	83	1.47	0.86	0.2	0.842
	1	30	1.43	0.86		
Read notifications/messages	0	83	2.29	1.25	0.34	0.733
	1	30	2.2	1.13		
Replying to notifications/messages	0	83	1.73	0.91	0.01	0.933
	1	30	1.73	0.91		
Uploading photos/posts the last 7 days	0	83	1.43	0.74	0.4	0.678
	1	30	1.37	0.89		
Bluetooth use	0	83	1.7	1.2	1	0.318
	1	30	1.47	0.68		
Self-evaluation	0	83	3.87	0.85	1.86	0.066
	1	30	3.53	0.82		
Turn-off application use	0	83	2.3	1.3	0.71	0.481
	1	30	2.5	1.36		

Table 3. t-student statistical analysis for cars crash experience across several driving conditions.

Questions	Crash experience	N	Average score	SD	t	p-value
Increase in cell phone use due to social networking	0	85	2,28	1,18	0,26	0.799
	1	28	2,21	1,34		
Read notifications/messages	0	85	1,73	0,86	0,1	0.918
	1	28	1,75	1,04		
Replying to notifications/messages	0	85	1.42	0.81	0.18	0.857
	1	28	1.39	0.69		
Uploading photos/posts the last 7 days	0	85	1.26	0.8	0.92	0.357
	1	28	1.11	0.57		
Bluetooth use	0	85	1.58	1.03	1.04	0.303
	1	28	1.82	1.25		
Self-evaluating	0	85	3.76	0.84	0.3	0.762
	1	28	3.82	0.9		
Turn-off application use	0	85	2.28	1.35	1.01	0.315
	1	28	2.57	1.2		

4 Conclusions

Given that the majority of the drivers answered that they make infrequent use of social media while driving, some of the answers imply an increased risk. For example, more than half of the drivers remain connected to the internet while driving and, consequently, receive various types of notifications and also have access to several web-based applications. However, 15.1% of the sample reads and answers to incoming notifications on their smart phone. Almost one out of four (18.6%) admitted reading incoming notifications and 27% of those who remain connected on the internet act the same. Interestingly, 36.3% of the drivers said they had an intense feeling of dependence by their cell phone while at the same time, Greek young drivers “overestimate” their skills as no one had been self-evaluated as an inadequate driver and 72.6% consider having excellent driving skills. Simultaneously, the sample indicated a negative predisposition towards the use of an application that would disable their mobile phone while driving as only 23.9% of the sample said they would use it. Another interesting conclusion is that the answers among the young drivers do not differ statistically in categories such as sex, accident experience, followers etc. That means a homogeneous behavior and attitude regarding social media and driving. To either confirm or reject that result, further research and surveys based on a greater number of questionnaires are needed.

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Crowdsourcing and Visual Research Methodologies to Promote Data Collection for Sustainable Mobility Planning

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Abstract. This paper aims to present and compare two methodologies in order to gather data from residents and visitors about their mobility behavior in the urban environment: crowdsourcing and visual research. These methodologies were used in two Sustainable Urban Mobility Plans (SUMPs) in the medium-sized cities Kozani and Drama in Greece. Public input proves to be efficient in recognizing problems, proposing priorities and describing detailed proposals towards achieving desired aims. Results show that the issues that were recorded through the applications of visual research were also perceived by the inhabitants, through the ideas they proposed. It was also found that residents are focusing on concrete proposals, mostly realistic, sometimes presenting a specific spatial reference. On the other hand, public participation in the crowdsourcing platform was low. Combining the two methodologies proves to be effective towards raising public input validity.

Keywords: Crowdsourcing · On-line platform · Visual research
Sustainable Urban Mobility Plan · Medium-sized cities

1 Traditional and Innovative Methods for Studying the Urban Environment

In recent years, the use of modern tools, such as electronic applications and crowdsourcing, is at the forefront of understanding the city's environment in a quick and cost-effective manner, since the collection of the data is performed by citizens who act as "sensors", as pointed out by Pödör, et al. [1], with the use of their smarthphones [2, 3]. The development of such practices is rapid, resulting in a new type of geography called "Neogeography", which demonstrates a new approach of the city by its residents, as they do not just live in it but are becoming active members in the city's planning process, contributing to the gathering of data as well as to traditional consultation meetings [4].

There are two elements that should be pointed out. The first relates to the importance of photography in Neogeography, as most users consider they recognize the space better through pictures, which are then uploaded to social media platforms or Flickr. Besides, photography provides an easy and tangible description of areas or situations that can be imprinted over time, which can not be done with the same ease with other forms of communication [5].

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The second concerns the way that the public becomes active so that the necessary data is available when needed. New technologies, like smartphone applications, can be at the core of such methodologies that provide enough data in a series of plans, such as SUMPs, which are strategic and integrated urban and transportation/mobility plans. However, due to the fact that not all population uses such tools, public engagement and involvement are not applied in overall following these methods. Indeed, as claimed by See et al. [6], the type of used tools results to a different degree of social participation in various plans.

Traditional visual techniques based on scientists' observation haven proven to be useful for understanding behaviors in public spaces as well as the development of cities and do not require participation of users. Indeed, according to Abbott [7], the Chicago School of Sociology was largely based on the observation of public spaces. Reiss [8] has accordingly systemized such approaches, arguing that systematic social observation can be a key strategy for measuring and understanding social phenomena. Finally, Whyte [9], in his research on small public spaces in New York, was a strong supporter of observations with the help of videos and photography, in order to reassess spaces with clear mind. Tools used include photo assessment (monitoring photography/time lapse phtography, re-photography of old pictures), as well as innovative and participative ways such as photo elicitation/auto driven photo elicitation and photovoice, where contact is immediate and face-to-face.

Based on the above, the topic of this particular research paper is to compare two techniques in terms of performance and effectiveness to record data useful for a Sustainable Urban Mobility Plan. At first it analyzes the success of a crowdsourcing platform to activate the public for city planning. The quality of the data collected is evaluated. On the other hand, the paper examines the success of visual research as a key methodology in implementing a SUMP. The paper deals with two study areas, Kozani and Drama, which are two typical medium sized Greek cities.

2 Case Studies Research

2.1 Aim and Objectives

The work presented is part of the SUMPs that are currently under implementation in the cities of Kozani and Drama by the research team of the Sustainable Mobility Unit at NTUA. The presentation of these specific case studies constitutes a way to increase the understanding of two specific research methodologies, namely crowdsourcing data and visual techniques, in the context of implementing SUMPs, which is allowed through the assessment of case studies, as a methodological tool [10].

2.2 Methodology

The two methodologies presented are part of a greater methodological framework organized under the implemented SUMPs for the two case study cities. The two assessed cities are Kozani and Drama. They are two medium-sized cities, which, aside of the similar population size, exhibit a variety of other common characteristics: their central districts have been developed without strict city plans over the centuries; arterial roads are passing through their central districts; their central districts display analogous land use dispersion and clustering; SUMPs are implemented. The aforementioned factors were considered for the selection of these two cities as comparable case studies [11], within the framework of the research. More details about the urban characteristics of the two cities can be found on Table 1.

Table 1. Cities examined.

City	Kozani	Drama
Population (Dense Urban Core)	41,066	44,823
Population (Including Areas of Urban Expansion) (approximately)	47,000	51,500
Area (Including Urban Expansion) (approximately) (km2)	20	27
Bicycle Infrastructure Length (km)	2.5	3.3
Size of pedestrianized or traffic-calmed areas (hectares)	12.4	17.4

Indeed, in both Kozani and Drama, a series of methods formed the basis for the design of the designated policy to inform the public and its activation towards the successful planning of the SUMP. Tools utilized for the implementation of the specific action are both innovative, such as web applications, crowd sensing and crowdsourcing techniques, mainly through mobile appliances like smartphones and pads [12] and traditional, such as workshops [13]. In the context of this particular research, interest is mainly focused at the mechanics of the online platform, where citizens were invited to present their ideas on how they envisage their city.

Moving on to the next level, research is on the pursue of relating the ideas embedded on electronic platform, in connection to the outcomes that arose from inspection and examination of video and photographic material, obtained from non-participatory observation. Research took place under good weather conditions. More specifically, in Drama it was carried out on July and in Kozani on March, for a time period of one week per city. This observation was made at consecutive intervals between 7 am–10 pm and 8 am–12 pm, in proportion to their respective research work [14–16]. Photos were examined qualitatively and behavioral patterns were noted, particularly regarding the issue of mobility, both for pedestrians and drivers.

As it is obvious, the two procedures that were conducted simultaneously, aimed at answering three different types of questions. Visual research corresponds to “how the city has changed through time” and “how people behave in the public space” and the e-platform crowdsourcing research corresponds to “how people want to make/alter their cities”. These two methodologies function within the context of implementing a SUMP like complementary studies in order for the planners to collect data. These questions in fact are not independent. People have a view about the future having in mind how the city has changed through time and what problems they face when moving in the public space. These consistencies allow the comparison of the methods in regard to their effectiveness to provide feedback to planners.

2.3 Looking for New Ideas: Participatory Planning Through an On-Line Platform

In the context of the implementation of the two SUMPs, ideas were solicited in order to discover concepts of how inhabitants envisage their cities. The necessity for the aforementioned was based at the intention to raise the voice of citizens, who fully know their city and extended equally to the mobilization of the public towards the successful implementation of the derived SUMP. On these grounds, additionally to the traditional engagement methods, the research group decided to design an on-line platform where residents and visitors would be able to present their own ideas for the city.

In Kozani forty-two (42) ideas were submitted while the platform counted seventy-six (76) registered users. In Drama twenty-two (22) ideas were accrued, while the platform counted nineteen (19) users, meaning that there were some users submitting more than one ideas.

As to the substance of the interventions, with the exception of some general statements, which in the case of Kozani were higher than in Drama (e.g. A focus on changing attitudes/education residents, to make the city more calm), most of the ideas were specific and some were clearly documented. This is also met on the photo selected by each user to support his/her idea. Indeed, 58.2% of the e-platform users in Kozani, opted to post a photo. From this proportion, 11.9% reflected the idea very precisely. In Drama, 77.8% of the ideas posted on the e-platform were accompanied by a picture. Moreover, a percentage accounting for 22.7% of the images, are perfectly targeted demonstrating accuracy, particularly regarding the idea or the area of the proposed intervention.

In both cities, it was obvious to the public that a critical part of the city's problem was related to the strong presence of the car at their center. Indeed, this is evident in both cities, although travels within the city are short. This fact as identified from the proposed ideas, is directly linked to the perception of the researchers for the SUMP about the shift of motorized traffic from city centers and the overall SUMP objectives [17–21].

Participation of volunteers, in the case of e-platform was relatively small compared to the population of the two cities so far, as was the case for participation to environmental data collection [11].

The online crowdsourcing platform, additional to providing space to develop future ideas, provided a link to an online survey questionnaire. In particular, 1,829 questionnaires were completed for the city of Kozani and 528 for the city of Drama. For the city of Kozani, the profile of those responded to the survey can be described as follows: male 18–30-year-old, student or freelancer with an average income less than 1,000 Euros/month, who owns a bicycle and/or a private car, and he identifies himself also as a pedestrian. Accordingly, in Drama, the profile of the average respondent can be described as follows: male employee aged 31–45, with an average income less than 1000 Euros/month, owning a private car and using it to travel around the city. The questions varied and were related generally to the traffic and urban problems presented in the two cities, as well as to the people's behavior in terms of city traffic and their intention to use more sustainable means of transport. Focusing on the problematic issues of commuting, it is worth noting that the main issue recorded in the case of Drama was the lack of parking spaces in the city center. The same problem was categorized as the third priority in the case of Kozani, with the cost of transportation and pollution, occupying the first and second place of identified priorities. In overall, it was appraised that the quality of transport is assessed as being on an average level, as well as the state of the public spaces. A typical such case is the Aghia Varvara Park in Drama, which is believed to present places that need to be improved and maintained so that pedestrians' presence will be increased in the future.

In overall, the results of the questionnaire are analogous to those of e-platform research, with some discrepancies relying on the small size of the sample participating in the e-platform. In any case, this participatory method is assessed as an important step in activating the public, through the provision of an official state for filing in the citizens' opinion, which will be later re-evaluated after the completion of the research programs.

2.4 Visual Research

As previously stated, observation, video capture and taking photos took place in the framework of the research in order to understand the behavior of drivers and pedestrians. Besides, observation is an important methodological tool that can respond to "what's happening", but cannot answer to "Why" discovering an objective opinion [22], which is being explored through interviews or questionnaire research.

The most basic conclusions that emerged from reading the pictures and video snapshots support the conclusions that emerged during the observation. These could be summarized as follows:

- Connections between pedestrians and the public space: Pedestrians' behavior is influenced by the form of the built environment, the traffic load and the overall attitude and habits of the inhabitants. The above is confirmed by the observation of pedestrians using the road at places where the pavements were of small width or of poor quality. At the same time, another important point is the issue of road crossings. In both Kozani and Drama the crossing of streets was observed at points without zebra-crossings or at points with zebra-crossings but at the time when the traffic light was red for the pedestrians.
- Drivers' relations to public space: Drivers' behavior was observed to mostly comply with the rules of the Road Traffic Code. In both cities drivers seemed to respect the traffic lights and the horizontal signaling, giving space and time to pedestrians to cross the roads. However, severe illegal parking issues have been encountered, concerning unregulated and illegally parked vehicles, without respect for public space.
- Drivers' relations to pedestrians: Observing the behavior of the two categories, there was a clear difference. Drivers respect pedestrians in most cases and stop before zebra-crossings, so that there is adequate space for pedestrians to move/cross. At the same time, most of them slow down or stop in cases where pedestrians use the road without warning. On the contrary, pedestrians do not respect the road rules, as they were observed to cross the roads while the traffic light was red for them. They also move from one side of the road to the other at points without zebra-crossings, resulting in conflicts with the vehicles, especially in urban areas, where the traffic flows are high.

- Infrastructure and the use of it: Most traffic lights and other traffic-related infrastructure work well in both cities. However, improvements could be made at bottlenecks. With regard to horizontal signaling and especially zebra-crossings, there is room for improvement. Regarding pavements' condition there is also room for improvements although there are several provisions for children and disabled people.

3 Conclusions

In order to check the level of understanding of the city's problems by its citizens as well as the response of the proposed ideas to the existing issues, two methodologies were compared in regard to their effectiveness to provide input to planners, namely visual research (observation) and public participation through a crowdsourcing platform. The methodologies were conducted at the same stage of research but were independent. The aim of both was to collect information, especially qualitative, which would present a geographical reference. Through crowdsourcing, citizens were asked to step in and actively showcase the issues and participate in city planning by providing ideas on how to address some of them.

The issues that were recorded through the applications of visual research were also perceived by the inhabitants, through the ideas they proposed. The lack of parking spaces and high speed driving within the urban fabric, as well as the improper and sometimes illegal behavior in public spaces were observed and mentioned by the citizens in both Kozani and Drama. Indeed, there was an important need to regain public space and elements of the natural environment, through pedestrianized roads and more green areas. In fact, the demand for green spaces was greater in Drama, although a large lung of urban green is located at the center of the city. Realizing the "occupation" of several city areas by motorized traffic, was also reflected to the existence of several proposals for limiting car through traffic and promoting public transportation. Proposals were in favor of public transportation, cycling and vehicle sharing options along with the limitation of motorized traffic, recognizing the importance of pedestrianized surfaces for the promotion of urban sociability and social cohesion.

Through the research that emerged by applying this methodology, it was also found that residents are focusing on concrete proposals, mostly realistic, sometimes presenting a specific spatial reference. The suggested ideas have been applied abroad, hence researchers assume citizens have seen what they propose on one of their or their friends' journeys or on websites, TV etc.

From the above it is clear that the public input proves to be efficient in recognizing problems, proposing priorities and describing detailed proposals towards achieving desired aims. But as public participation proves to be a difficult task, combining the two methodologies (visual research and crowdsourcing) could contribute to a more complete analysis of the urban phenomena (Table 2). Their operation is complementary since the information collected, is checked and evaluated by the study group, resulting in reliable data to be used within the SUMP planning process.

Table 2. Topics recognized by the two methodologies.

Topics	Visual research	Crowdsourcing platform
Illegal/Excessive on-street parking	Yes	Yes
Poor Quality of Pedestrian Infrastructure	Yes	Yes
Behaviour of Drivers/Pedestrians	Yes	No
Concrete/Realistic Proposals	No	Yes
Recognize Social Priorities	No	Yes

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Megatrends, a Way to Identify the Future Transport Challenges

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Abstract. In the last ten years, huge advances in detecting trends methodology have been spotted in particular in Europe. Trend represents a fundamental change over an extended period, i.e. associations that are defined by crossing contextual borders. They are phenomena that are always complex and whose lifespans can only be measured inaccurately. Trends, whose implications are reflected on the whole or almost entire society, are called megatrends. The objective of this paper is to define the key megatrends affecting the future passenger and freight transportation system through review and analysis of the transport reports and studies on the global level. Megatrends commonly elaborated in the majority of literature sources will be identified. It indicates a convergence to those that are most important for the future development of transportation processes.

Keywords: Key megatrends · Passenger and freight transportation Reaching consensus

1 Introduction

Based on the existing knowledge and understanding, it is obvious that megatrends lead to serious challenges for the transportation systems. Therefore, there is a need for the transportation practice to adjust its developing routine to the current and future megatrends. However, different economic, social and environmental characteristics of various regions all over Europe cause different impacts of these megatrends on corresponding transportation systems.

The process of identifying megatrends affecting the future transport system will be based on the review of existing literature dealing with the megatrends and their implications on transport. Therefore, our goal is to reach consensus on the key megatrends for both passenger and freight transportation systems.

This paper presents initial results of the H2020 project INTEND - Identify future Transport Research Needs (grant agreement No 769638). The overall objective of the INTEND project is to deliver an elaborated study of the research needs and priorities in

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the transport sector utilising a systematic data collection method. INTEND will develop a transport agenda that would pave the way to an innovative and competitive European Transport sector.

Rest of the paper is organized as follows. Section 2 elaborates concepts of trends and megatrends. Analyzed literature sources for both passenger and freight transportation are listed in the Sect. 3 of this paper. Section 4 defines the criteria for reaching consensus on the most important megatrends for each transport sector and identifies them. Section 5 concludes the paper.

2 Weak Signals, Trends and Megatrends

Trend management, as a research discipline, arose from the concept of weak signals, introduced by [3, 4]. According to [4], weak signals are "*warnings (external or internal), events and developments that are still too incomplete to permit an accurate estimation of their impact and/or to determine their full-fledged responses*." Over the years, Ansoff's concept of weak signals has been accepted for what is now called a trend ([38]). Studying trends implies research of something new, with the aim of understanding them and correctly perceiving the possible consequences in certain areas ([38]). Liebl and Schwartz [22], point out that innovation and diffusion are two perspectives from which trends should be observed in order to understand them. Innovation clearly points out the need for something new in every trend, while diffusion enables us to see to what level a certain trend influences the development of different areas, such as transport.

If the importance of certain transformation processes is to be emphasized, such changes are often called megatrends. Therefore, megatrends are one of the research disciplines in trend management. Vejlgaard [37], points out two the most significant characteristics of megatrends:

- megatrends represent cultural, economic, political and technological changes that have not yet happened;
- the effects or implications of megatrends are reflected on the whole or almost entire society.

The same author indicates the following differences between trends and megatrends:

- Megatrends last longer;
- Megatrends have a more pronounced impact on many areas;
- It is significantly easier to predict development patterns of certain trends in comparison with the prediction of future development of megatrends.

It is known that many internal and external factors influence both freight and passenger transportation system. This paper deals with general external factors or megatrends i.e. "*those variables, which are not specific to the transport system, but have impacts on it and contribute to shape its development*" [5]. These external factors or megatrends interact with policy actions within both freight and passenger transportation processes. It means that any policy action affects not just transportation systems but also development patterns of the megatrends.

3 Reviewed Literature

The aim of this paper is to identify megatrends that may affect both passenger (PT) and freight transportation (FT). The applied approach is based on a literature review of transport studies, projects and papers. We took into account relevant studies that consider megatrends with time perspective of up to 2050. The analysis of studies was performed particularly for passenger and particularly for freight transport. Passenger and freight transport related studies that we reviewed for the purpose of identification of relevant megatrends are given in Table 1.

4 Reaching a Consensus

Reaching a consensus, in this case, means defining the criteria that will allow for the identification of megatrends that have the most significant impact on the future development of passenger and freight transport. In this respect, in our approach, we have adopted and used a standard for the Delphi method. Literature usually recommends that consensus should represent 50 to 70% agreements. Numerous exercises, performed so far, required an agreement among 70% of the sources, experts or panelist to reach the consensus (Ashton Acton, 2013, Kleynen et al., 2014; Kelly et al., 2016). Therefore, in order to select any megatrend as the most important, it is necessary that at least 70% of the identified literature sources elaborate and describe the impact of that megatrend on passenger or freight transportation.

4.1 Matrix of Megatrends Over Sources

In order to perform the required analysis, we prepared the matrix, shown in Tables 2 and 3, listing sources against the megatrends identified in the reviewed literature. As it can be seen, a total of 22 megatrends from all sources, which are related to both passenger and freight transportation, are separated and included in our analysis. The goal of this matrix analysis is to determine the megatrends that are processed in most of the reviewed sources, indicating a certain level of consensus or convergence to those that are most important for the future development of transportation processes. Some of the megatrends, given in Tables 2 and 3, are in the same way labeled and described in a number of sources, while in certain cases, there are differences in that respect. For this reason, the labels and descriptions of the megatrends applied in various studies, projects, papers and reports have been harmonized herewith. Similar approach for identification of key global megatrends and their implication for environmental assessment practice was applied in [27].

Table 1. Reviewed passenger and freight transport related studies.

	[13]	[18]	[26]	[32]	[40]	[10]	[14]	[31]	[34]	[15]	[2]	[9]	[12]	[28]	[29]	[8]	[30]	[33]	[5]	[10]	[16]	[19]	[24]	[39]	[1]	[17]	[25]	[35]	[36]	[23]
PT	+	–	+	+	+	+	+	+	+	+	–	–	+	+	+	+	+	+	+	–	+	+	+	+	+	+	+	+	+	+
FT	–	+	–	+	–	–	–	–	–	–	+	+	+	–	–	–	–	–	–	+	+	+	+	+	+	+	–	–	+	+

Table 2. Key global megatrends in passenger transportation.

	[13]	[26]	[32]	[40]	[10]	[14]	[31]	[34]	[15]	[12]	[28]	[29]	[8]	[30]	[33]	[5]	[16]	[19]	[24]	[39]	[1]	[17]	[25]	[35]	[36]	[23]	Total
Population growth	–	+	–	–	–	–	–	+	–	–	+	+	–	–	–	–	–	–	–	+	–	–	–	+	+	–	7
Ageing society	+	+	–	+	–	–	+	–	+	+	+	–	+	–	–	+	+	+	+	–	+	–	+	–	+	+	16
GDP, income, economy growth	–	–	+	+	+	–	–	–	–	–	+	–	+	–	–	–	–	–	+	+	–	+	–	–	+	–	9
Economic pressures and crisis	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	2
Increase of Inter–/Intra–national social disparities	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Urbanization and megacities	**+**	**+**	**–**	**+**	**+**	**+**	**+**	**+**	**+**	**+**	**+**	**+**	**+**	**–**	**+**	**+**	**–**	**+**	**+**	**+**	**+**	**–**	**+**	**+**	**+**	**+**	**22**
Changing lifestyles	–	+	–	+	+	–	+	–	+	+	+	–	+	–	–	–	+	+	+	–	+	+	–	+	+	–	15
Changing mobility behaviours	–	+	–	–	–	+	+	–	–	+	+	+	+	+	+	–	+	–	+	–	–	–	–	+	+	–	13
Climate change	**+**	**+**	**–**	**+**	**+**	**+**	**+**	**+**	**–**	**+**	**+**	**+**	**+**	**–**	**+**	**+**	**+**	**–**	**+**	**+**	**+**	**+**	**+**	**+**	**+**	**+**	**22**
Energy demand/sources	–	–	–	+	+	+	–	–	–	–	+	+	+	–	+	+	–	+	+	+	–	+	–	+	+	+	15
Key resources scarcity	+	+	+	–	+	+	–	–	–	–	–	+	+	–	–	–	+	+	+	+	–	+	+	+	+	–	15
Globalization 2.0	–	+	–	–	+	–	–	–	+	–	–	–	+	–	+	+	+	+	+	–	+	–	–	–	+	–	11
Migration and internal mobility	+	–	–	–	–	–	–	–	+	–	–		+	–	–	–	–	–	+	–	–	–	–	–	–	–	4
European market regulation	–	+	–	–	+	–	–	–	–	+	–	–	+	–	+	+	–	–	+	–	–	+	–	–	+	–	9
Knowledge society and knowledge economy	–	+	–	–	–	+	+	–	+	–	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	5
Trade growth	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	+	–	+	–	+	–	–	+	–	5
Land availability	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	2
Natural disasters, safety and security issues	–	–	–	+	–	–	–	+	–	–	–	–	–	–	–	–	–	+	–	+	+	+	–	–	+	–	7
Increased food and water demand	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–	–	1
Becoming customer–oriented employers	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	1
Infectious disease and pandemics	–	–	–	–	–	–	–		–	–	–	–	–	–		–	–	–	–	–	–	+	–	–	–	–	1
Geopolitical (in)stability	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–	1

Table 3. Key global megatrends in freight transportation.

	[18]	[32]	[2]	[9]	[12]	[11]	[16]	[19]	[24]	[39]	[1]	[17]	[23]	[36]	Total
Population growth	–	–	–	–	–	–	–	–	–	+	–	–	–	+	2
Ageing society	–	–	+	+	+	–	+	+	+	–	+	–	+	+	9
GDP, economy growth	+	–	–	–	–	–	+	–	–	+	–	+	–	+	5
Urbanization/megacities	–	–	+	–	+	–	+	–	+	+	+	–	+	+	8
Changing lifestyles	–	–	+	–	+	–	+	+	+	–	+	+	–	+	8
Changing mobility behaviours	–	–	+	–	–	–	+	+	–	–	–	–	–	+	4
Climate change	**–**	**+**	**+**	**+**	**+**	**–**	**+**	**+**	**–**	**+**	**+**	**+**	**+**	**+**	**11**
Energy demand/sources	–	–	–	+	+	+	+	–	+	+	–	+	+	+	9
Key resources scarcity	**+**	**+**	**–**	**+**	**+**	**+**	**+**	**+**	**+**	**+**	**–**	**+**	**–**	**+**	**11**
Globalization 2.0	–	+	–	–	+	–	+	+	+	–	+	–	–	+	7
Migration and internal mobility	–	–	–	–	–	–	+	–	–	–	–	–	–	–	1
Market regulation	–	+	+	–	–	–	+	–	–	–	–	+	–	+	5
Trade growth	–	–	–	–	–	–	–	–	+	+	–	+	–	+	4
Security issues	–	–	–	+	–	+	–	–	+	+	+	+	–	+	7
Food and water demand	–	–	–	–	–	–	–	–	–	+	–	–	–	–	1
Infectious disease and pandemics	–	–	–	–	–	–	–	–	–	–	–	+	–	–	1
Geopolitical (in)stability	–	–	–	–	–	–	–	–	–	–	–	+	–	–	1

4.2 Key Global Megatrends in Passenger Transportation

Table 2 gives a matrix of megatrends over sources for passenger transportation. In order to select a megatrend as the key it should be elaborated in at least 19 out of 26 reviewed sources (> 70%). Our approach has enabled us to identify the following megatrends as the most important for the development of passenger transport:

- **urbanization and megacities** (higher population densities; improvements in cities infrastructure; environmental and health risks; PPP models; more sustainable cities);
- **environmental challenges – climate change** (decrease in carbon emissions; global temperature increase; sea level arise; increased risk of flooding from melting glaciers; adaptation and mitigation policies; development of carbon markets).

4.3 Key Global Megatrends in Freight Transportation

Table 3 presents our matrix of megatrends over sources for freight transportation. In this case, consensus is reached if a megatrend is elaborated in at least 10 out of 14 identified sources (> 70%). By applying the described approach, the following megatrends can be selected as the megatrends with the most significant influence on the future development of freight transportation:

- **environmental challenges – climate change**;
- **key resources scarcity – shortages and consumption** (more constraints on consumptions – resource management; greater demands on scarce resources – fossil fuels; development of substitute materials; global privatization of resources; changes in ecosystems use).

5 Conclusion

This paper lists the global megatrends affecting passenger and freight transportation. After thorough review of relevant and available literature, a consensus on the selection of the key global megatrends that impact on freight and passenger transport was agreed and defined across the source literature. In that context, a matrix giving megatrends over sources was prepared. By doing so, megatrends commonly elaborated in the majority of literature sources were identified suggesting some level of consensus.

As megatrends are expected to change the whole sector in a fundamental way, they should be further validated in order to estimate their impact on defining the future transport research priorities. INTEND project, in its further steps, will validate the megatrends by using the Analytical Network Process (ANP). The aim of the validation process is to determine the prioritized megatrends (as well as technological advances and political imperatives) for successful implementation and realization of key transport concepts of the future. This task will include review of non-only transport related studies i.e. general foresight studies or studies not exclusively related to the future of transportation. In order to validate the obtained results, we will also apply an approach of selection of the key megatrends based on the experts' opinions. For that purpose, we will use a lower limit of 50% agreement for selecting certain megatrends for further analysis and elaboration through the application of the ANP methodology.

In order to define streams of needed future researches in the fields of transport technologies, mobility concepts and research systems, INTEND project will also identify the gaps between technological advances in the transport sector and development prospects of the transport and mobility systems. The Gap analysis will be based on the perception of different technological advances and megatrends impacts on specific characteristics of the future transport system. Impact of megatrends on transport research needs will be visually presented by using the Transport Synopsis Tool.

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Unveiling the Potential of ITS: Market Research Analysis

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Abstract. The ITS market is changing rapidly shaping the near future of a brand new world. This paper aims to provide an understanding of this ever-changing world, analysing current markets, trends and initiatives which will eventually contribute in developing new business models and incentives in order to accelerate the ITS deployment in Europe.

The paper provides a general ITS market watch including an overview of the market and it identifies the current needs and trends of ITS solutions. In addition to this, the research is based on four case studies both in terms of market analysis and stakeholders' analysis.

Keywords: Intelligent Transport Systems · Market research

1 Introduction

According to the EC ITS can play a significant role in delivering safe, efficient, sustainable and seamless transport of goods and people in Europe as well as to safeguard the competitiveness of European industry. [1] The Innovation Union flagship initiative [2] and Digital Agenda for Europe [3] underline the need for a strategic approach to innovation where innovative technologies need to be deployed quickly to maintain the European transport industry at the forefront of international competitiveness whilst preserving jobs in Europe and supporting economic growth.

A prerequisite for effective deployment is a better understanding of the market conditions surrounding the ITS arena [4]. This paper provides a definition and assessment of the current ITS market environment based on four *ITS case studies*.

A vast range of ITS definitions currently exist [4–7], however, for the purposes of this paper, we adopted the definition applied at the ITS Handbook [8] *ITS - Intelligent Transport Systems - is a generic term for the integrated application of communications, control and information processing technologies to the transportation* system.

The selection and configuration of the case studies has taken into consideration several key factors such as the technology employed, market segmentation, market

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viability, transferability, innovation level and involvement of a network of stakeholders. This led to the selection of cases selected representative of the ITS ecosystem, covering several transport modes (road, maritime and rail transport), all the market segments and with a Technology Readiness Level (TRL) of 7 or above, as follows:

- Case study 1 is a carpooling service deployed in the campus of the Universitat Autonoma de Barcelona.
- Case study 2 is a traffic light infrastructure integrated in the Urban Traffic Control and an Energy Efficient Intersection Service (EEIS) deployed in the Municipality of Verona.
- Case study 3 is a synchromodal track-and-trace solution including a forecasting of container arrival service located in the corridor Rotterdam-Limburg.
- Case study 4 is a predictive maintenance solution deployed in the London North Western route from London to Carlisle.

2 Overview of the ITS Market (Status Quo)

Grand View Research, Inc forecasts the global ITS Market will reach USD38.68 Billion by 2020 [9]. In 2017, BIS Research provided a report stating that the global ITS market is estimated to reach $72.32 billion in 2022 and will grow at a compound annual growth rate (CAGR) of 7.9% over the period 2017–2022. North America leads the global ITS market and Asia-Pacific (APAC) is expected to grow at the highest rate in comparison to other regions [10].

Despite the high growth of the ITS market, there are certain factors hindering faster advancements. One of them being the slow growth of intelligent infrastructure owing to high installation cost for monitoring and controlling devices [11]. Another key barrier restricting the global ITS operation is the lack of standardisation but also the relevant legislation and policies which have not so far been harmonised [12]. There is an imperative need for governments to develop their strategic plans towards ITS including legislation and measures in a transparent manner in order to also rise the interest of private parties to invest in the sector [13].

Amongst the major trends, the introduction of smart vehicles are at rise, aiming at responding the demand for an increased public safety [14]. However, while Connected and autonomous cars are “hot topics”, according to the GSMA report (2015), mobile communications are crucial [15]. To this end, Mobile Network Operators (MNO) are in an advantageous position where they have an important role to play. However, due to the disruptive nature of the future ITS market, which will be a culmination of converged ICT and automotive industries, MNOs have to adjust their business model to be able to respond to the rapid needs of the advancements [16].

3 Methodology

The objective of this paper is to provide a description of the market conditions in order to enable the exploitation potential of ITS solutions. To better understand the significant market drivers in context, a case study approach was adapted. A holistic market-demand-supply intelligence process was applied which resulted into a value chain analysis.

Two main phases of data collection and analysis were performed: a market research and a stakeholder analysis. The first phase included data collection based on secondary research. The objective of the first phase of the desk research was to collect information from different sources about market definition, sizing; products analysis; competitors assessment; market segmentation and customers definition; market information, trends and barriers (considering technological, business, social, policy and organizational factors).

For the market analysis, the following tools were applied:

- Political, Economic, Social, Technological, Environmental, Legal analysis (PESTEL) on the ITS sector on the whole but also on Case Study level
- SWOT analysis, evaluating the strengths, weaknesses, opportunities and threats of the case studies
- An overview of the current and potential market
- Competitors' assessment.

The second phase of the market study involved a stakeholder analysis. In this, qualitative information was collected, making use of stakeholder structured interviews, in order to determine influences and interests. More specifically, the stakeholder analysis included the following steps:

- Identification of the case studies' main stakeholders and key characteristics
- Assessment of the stakeholders considering their importance and influences
- Mapping and characterizing relations and dependences between stakeholders
- Value Chain analysis

4 Results

4.1 Case Study 1 (CS1): University VaoPoint Mobility

Car-sharing market potential has increased recently as a result of expansive sharing economy [17]. For the specific case study, the demand curve is elastic and flexible – students, admin and academic staff work with different work schedules – which could allow a high degree of utilisation of the carpooling services. The supply curve, however, for parking seats is inelastic and totally vertical, fixed at a specific size.

With regards to the macro environmental analysis of CS1, the technological developments seem to be in a good stage of development to support the solution while social acceptance is gaining ground. Opportunities to expand to other markets is very significant, however, incentives must be offered to achieve high occupancy of the scheme.

For the implementation of the project, a range of stakeholders were involved. However, the primary stakeholders in order of importance and influence are UAB MU (transport authority within the university campus), Aslogic (ITS service provider), and UAB (academia). They can be considered the project initiators as they can influence positively the rest of the stakeholders.

Finally, from a value chain analysis perspective, it can be concluded that the main costs for the primary activities are located in the operations. The bigger the demand, the more computational power the platform will require. The inbound logistics and the outbound logistics parts (data gathering and service delivery) are web based and usually operated by the end-users from their smartphones, so there are not big costs involved.

4.2 Case Study 2 (CS2): Traffic Management System in Verona

The current market demand for EEIS is significant. The global traffic lights market is deemed to grow steadily during the period 2017-2021 at a Compound Annual Growth Rate (CAGR) of about 6% [18].

The demand side of the project involves two major groups, the first group being road transport operators and drivers and the second group value-added services implemented by third parties. The supply side is composed by traffic control systems manufacturers and ICT service providers along with the municipalities. Both demand and supply are growing very slow, with demand being totally ‘inelastic’ since the solution is offered free of charge. Provision of add-on fee-based services would cause the supply demand equilibrium to balance at a different point depending on the services provided and associated costs.

From a macro-environmental perspective, the political problems in multi-stakeholder involvement might be one of the most important barriers. However, there is potential for expansion of the service beyond city or country boarders as the challenges (pollution, safety etc.) that the application addresses, are common to many cities.

The stakeholder analysis revealed that the Municipality of Verona, Swarco Mizar (ITS service provider), AUDI (automotive supplier) and Telecom Italia (ICT service provider) were considered to be of utmost importance as providers of essential hardware and know-how for the realization of the project itself.

The conclusions of the value chain are that a big part of the costs for the primary activities are in the acquisition and deployment of the infrastructures needed in order to provide the services, which could be located in the inbound logistic operations. These costs are also proportional of the size of the place where allocated, since they will require more infrastructure the bigger (or complex) the place is.

4.3 Case Study 3 (CS3): Synchro-Modal Corridor

According to recent studies the global freight management market has great potential 20 21. The Netherlands holds a strong position in terms of logistics; this is reflected by the position of Rotterdam as the largest seaport in Europe. The container throughput in Rotterdam amounted 12.4 million TEU in 2016 and is forecasted at 18 million TEU in 2035 [19, 20].

Currently, the case study is in pilot phase and the services are provided for free, so the supply is inelastic. In the market phase, services could be offered as a fee-for-service, switching to an elastic supply curve. The demand is elastic based in the amount of the containers' volume managed by the actors in the demand side (shippers, inland terminals and warehouse operators).

CS3 offers a sustainable transport solution influenced by political, economic, environmental and social elements. Another element that is affected by external factors is the use of an open source data model by CS3 that allows better combining of various data flows from several stakeholders. This ICT solution is influenced by several external factors including technical and legal issues with data security and privacy.

TNO (research institute) is coordinating the development of the technology, therefore TNO is of high importance and high influence. The shipper, ITO and Warehouse L are the main users of the service in the pilot phase. The planning data (from the logistic companies) and knowledge of the system requirements (from TNO) are key for the service development, which makes them stakeholders with high importance.

Finally, the value chain analysis demonstrated that the major costs for the primary activities are located in the operations. The more customers of the solutions, the more computational power the platform will require and the more software & hardware infrastructure (servers, cloud services) will be needed. There is a big opportunity of creating added value in the outbound logistic, offering personalised services to the customers depending on their specific necessities.

4.4 Case Study 4 (CS4): Keep Safe

According to UNIFE WRMS the world rail market volume hit a record level of nearly €160 billion in 2015 and in the coming years the market volume will grow 2.6 percent per year on average worldwide and reach €185 billion in 2021 [21].

The demand of Keep Safe is elastic based on the contract of the franchise with Network Rail for the routes where the franchise is operating and the total variable usage charge, which will constitute variable maintenance expenditures for the franchise. In the current model for Virgin, the predictive maintenance services are provided for free, causing the demand to be inelastic.

According to the SWOT and PESTEL analysis, this case study has extremely important and innovative technological components, a crucial social aspect, a potentially high economic benefit for a relatively low cost, some interesting political implications, and potentially important benefits in the long term future for the legal and environmental aspects.

With regards to the stakeholders involved for the implementation of this project, the three key stakeholders of this case study in terms of both influence and importance are Network Rail (owners of the trains and the infrastructure being monitored), Virgin Trains (trains operators) and Coventry University as the custodians and analysts of the infrastructure data. Other stakeholders (Alstom Transport and Serco) played a key role during early stages of the project in the fitting and calibration of the sensors.

In the value chain analysis of Keep Safe, it is foreseen that the major cost for the primary activities are located in the operations. The sensors, cameras and infrastructure are not really a high costs overall compared with the potential savings the solution offers. The inbound and outbound logistics does not seem to be or experiment a raise in the costs actually. Marketing can highly benefit of the intervention of Network Rail promoting the solution to other operators. This could be reinforced with a travellers advertising campaign in order to further raise the social aspects of the solution.

5 Conclusions

The ITS market is changing rapidly and it's affected by several inherent factors along with other external factors in close relation with the ITS landscape. Topics like urbanisation, energy and a digital single market are changing the parameters of our surroundings and are shaping the near future into a brand new world.

The European Union is taking several initiatives in order to tackle the rapid evolution of the general mobility and transport situation (Transport White Paper, Urban Mobility Package, EU smart cities initiatives, strategy for a Digital Single Market, among others) and developing new regulations and action plans for the specific deployment of Intelligent Transport Systems in Europe.

As result of the market analysis, the factors influencing each case study have been identified along with the segmented definition of the market (supply and demand) and the selection of the target market and main competition.

The stakeholders' analysis provides information about their characteristics, influence and importance. The value chain analysis offers insights about primary activities and support activities.

CS1 and CS2 are business to customer (B2C) solutions with drivers as main end-users and sharing one of the main barriers: the "freedom of driving feeling". Both have strong influence from public entities (such as municipalities) although CS1 could potentially target other markets such as industrial zones.

CS3 and CS4 are business to business (B2B) solutions, with CS3 focusing road/fluvial freight transport and targeting mainly the private sector. CS4 is focusing rail transport, both for passengers and freight and targeting the public sector in the UK. All case studies are in close relation with the Mobility-as-a-Service transport paradigm, which is an important trend influencing both the public sector (smart-cities) and the private sector (producing an increase in merger and acquisition activities in the auto industry of US$74.4 billion in 2015 and 2016, three times the annual average of the last ten years).

The results of this research can be used as a good baseline providing insights of how the ITS market is evolving and as a reference for other initiatives or policy makers in the development of ITS strategies.

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Tactical Urbanism: Reclaiming the Right to Use Public Spaces in Thessaloniki, Greece

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Abstract. During the past four decades, there has been an increasing body of knowledge examining the positive effects of pedestrian mobility on individual health, sustainable development and social inclusion. In parallel, tactical urbanism, referring to an approach to neighborhood building using short-term, low-cost, and scalable interventions and policies has been manifested since 2010 an emergent trend in large cities across the world. Tactical urbanism is 'tactical' because it is driven by deliberate and organized processes; it is a form of 'urbanism' because it assigns uses to the urban space. Inspired by this trend, the purpose of this paper is to explore the processes and undertakings behind the tactical urbanism activities of the "Union for the Rights of Pedestrians" (PRU), a Non-Governmental-Organisation (NGO) in Thessaloniki. The method followed includes the following steps: i. Literature review about the role of tactical urbanism and pedestrian mobility for urban development ii. Case study analysis by means of five structured interviews with members of the PRU that organize and participate in the organisation's tactical urbanism initiatives, and iii. Development of conclusions and policy recommendations for improving the effectiveness of tactical urbanism in Thessaloniki.

Keywords: Urban development · Community · Accessibility · Temporary Land use

1 Introduction

During the past four decades, there has been an increasing body of knowledge examining the positive effects of pedestrian mobility on individual health, sustainable development and social inclusion. Many cities across the world develop and implement sustainable mobility and public space renovation strategies and plans, with the purpose to increase the quality of services offered to citizens. The case of the city of Thessaloniki, Greece, is an especially difficult one when it comes to pedestrian mobility issues. For decades the city has been striving to increase the availability of public spaces and encourage active and sustainable mobility, but a number of limiting factors impede this process. Such factors include an environment that is highly degraded in the first place (public spaces have been violated in Greek cities for years), a long-lasting

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individual motorized vehicle culture, a limited public transport coverage, the existence of private interests in land ownership and the presence of strong employee unions (e.g. unions of Taxi drivers).

The "Union for the Rights of Pedestrians" (PRU) is a Non-Governmental Organisation (NGO) based in Thessaloniki, Greece, created in 2007 and today counting over 400 registered members and 3.000 followers on common social media. The mission of the PRU is to promote and advocate pedestrian rights, and further to propose public works, regulations and activities that safeguard and facilitate pedestrian mobility throughout the city. Among other activities, the PRU has gained large popularity in Thessaloniki for its tactical urbanism initiatives over the past 10 years.

Inspired by the above situation, the purpose of this paper is to explore the processes and undertakings behind the tactical urbanism activities of the PRU, and further examine the broader implications of the existence of this movement for socioeconomic development and policy making for sustainable mobility in Thessaloniki.

The structure of this paper is as follows. The next section presents current trends and published literature on the topic of the paper. The following section presents the research methodology used to conduct the presented research. After that, the analytical research findings of the performed research are presented. The last section offers the major conclusions stemming from the performed research.

2 Literature Review

2.1 Tactical Urbanism

Harvey [1], in his widely cited paper 'The Right to the City', highlights the inherent need to shape the environment in which we reside; the need to actively imagine and pursue better living conditions; and the need to pursue social justice. Yet, cities operate on the basis of capitalistic economies, which are driven by free market forces and as such inevitably create conditions of social segregation, lack of ubiquitous accessibility, ghettoization and uneven property markets. In the author's words, these conditions create *'worlds of inequality, alienation and injustice'*. He argues that a paradigm shift in the *'right to the city'* is needed; one where derivative rights are treated as fundamental, where citizens are empowered to make their cities better, and where democratic participation and 'urban commons' are consciously and constantly nurtured.

At the same time, the cost of making improvements in a top down manner in cities appears to be daunting in the current times of austerity. An increasing number of forward looking governance authorities and urban planners welcome temporary, low cost, bottom-up interventions in the public space that are aimed at improving the quality and usage of public spaces [2]. This trend, which emerged as a trend across US cities around 2010, soon came to European grounds as well, with urban planners and city makers embracing the concept by developing guides and providing suggestions as to how it can be implemented in an organized and impactful way [2–6]. More particularly, tactical urbanism has been defined as '*an approach to neighborhood building and activation using short-term, low-cost, and scalable interventions and policies'* [5]. It is 'tactical' because it is driven by deliberate and organized processes. It is a form of urbanism because it assigns uses to the urban space. Other notions close to the one of tactical urbanism are Do-It-Yourself (DIY) urbanism, participatory urbanism, open-source urbanism, pop-up urbanism, guerrilla urbanism, city repair, although subtle differences exist among them [5, 7].

Citizens and their communities self-organise and pursue tactical urbanism for a number of reasons. These include [2, 4, 5, 8, 9]:

- the inherent need to actively respond to pressing situations and to participate in community action in the face of those situations
- the demonstrated incapability, inflexibility and bureaucracy of the state to provide solutions to well-known public problems of the urban realm or provide qualitative public services to citizens on a continuing basis
- the realization that innovative and drastic solutions are needed in order to solve problems of the urban realm, while also demonstrating that these solutions are viable
- emergent spatial and social phenomena in environments of austerity, such as the increasing number of vacant commercial properties, the diminishing quality of public spaces and workforce mobility

2.2 Promoting Pedestrian Mobility and Accessibility to Public Spaces in Cities

Current thinking about transportation planning emphases accessibility, rather than mobility, and embraces multimodal transport, including walking, cycling, public transport and automobile [10]. During the past 20 years major improvements have taken place in cities all over the world to improve neighbourhood walkability [11].

Current transport planning practice tends to undervalue the positive effects of reduced vehicle travel and transport system diversity, especially when it comes to assessing safety, pollution and public health [10]. More particularly, active transport (walking and cycling) appears to be advantageous in the following ways [11–15]:

- it results in a documented net reduction of traffic causalities
- it can lead to significant air pollution emission reductions
- it increases physical health through activity and basic access
- it increases real estate value in walkable neighbourhoods
- it increases social interaction and a sense of community among citizens

The reviews of existing cost-benefit analyses of cycling and walking infrastructure by Cavill, Kahlmeier [16] and Mueller, Rojas-Rueda [17] found that most of them produce positive benefit-cost ratios with an impressive magnitude. In practice, this means that public administration can save large amounts of financial resources by investing in the development of cycling and walking infrastructure, rather that dealing with the costs of motorized mobility on the environment and public health.

Cho and Rodriguez [18]'s research demonstrated that residents in neighbourhoods of high land use mix and density are more likely to walk. Middleton [19] identified walking as one's way of reading and getting to know urban space and engage with the city. In other words, they proved that lively and safe urban environments are more inviting to walking.

3 Research Methodology

After the above analysis, the following research questions emerge: How is tactical urbanism reclaiming the right to use public spaces in the city of Thessaloniki, Greece? Further, which are the socio-economic development and policy making implications of this movement for sustainable mobility in Thessaloniki?

The method followed includes the following steps: i. literature review about the role of tactical urbanism and pedestrian mobility for urban development ii. case study analysis by means of five structured interviews with members of the PRU that organize and participate in the organisation's tactical urbanism initiatives, and iii. development of conclusions and policy recommendations for improving the effectiveness and potential of tactical urbanism for public spaces' accessibility in Thessaloniki.

More particularly, three cases of tactical urbanism induced in the city of Thessaloniki by members of the PRU were studied. These cases were selected due their high impact and publicity.

In terms of analysis of findings, a comparative case study methodological approach was used [20, 21], which allows to horizontally analyse and synthesize research findings across cases, with the ultimate purpose to identify trends, patterns and causal effects. Each case was researched with regards to the following components: i. Drive/need addressed, ii. Aim with regards to pedestrian mobility, iii. Temporary Land Use, iv. Obstacles/Challenges and v. Results.

4 Research Findings

4.1 Tactical Urbanism Cases

Typical actions of the PRU include events on pedestrian ways, pedestrian crossings, and ramps to serve persons with restricted mobility (Fig. 1).

Fig. 1. Photos from the NGO's campaigns and activist actions with the purpose of raising awareness, organised by the Union for the Rights of Pedestrians (NGO's archives).

The first tactical urbanism case that was studied in the context of this research is the pedestrianisation of one of Thessaloniki's most central commercial roads, Ag. Sofias street. The initiative for the temporary pedestrianisation was taken by members of the PRU and it was welcomed with enthusiasm from the public. Activist actions, group gatherings and other NGOs followed in supporting the initiative. Eventually Ag. Sofias street was permanently pedestrianised in 2013 and the experiment exceeded every expectation in terms of success. Today the street is a major meeting point of citizens, tourists and shoppers, full of life and commercial activity and a formal urban and architectural plan had been designed for the pedestrian road and its surroundings.

The second tactical urbanism case is the temporary pedestrianisation of the city's central business district. Until recently (circa 2008–2014), every year the PRU supported very actively the municipality of Thessaloniki in organising the "European mobility week", including the "Day without car". It acquired a very central role in the implementation of the included programme, activities and events. Nevertheless, during the most recent years, and as the crisis began deepening, local authorities and organisations (mainly the Municipality of Thessaloniki and the city's Public Transport Authority and Public Transport Operator) have been downplaying the extent and importance of these events. Hence the temporary pedestrianisation of Thessaloniki's center has been covering fewer areas and lasting for a smaller number of days, producing a much lower impact compared to previous years.

The third tactical urbanism case study is one of the more recent actions of the PRU, which was about re-painting and decorating pedestrian crossings in road network positions where pedestrian priority is not respected by motorized vehicle drivers. In this action, members of the PRU painted a major pedestrian crossing on the road between the Aristotle University of Thessaloniki Campus and the adjoining commercial and residential neighbourhood (Tritis Septembriou Street). This pedestrian crossing is primarily used by students of the university as they come or leave the university campus, but motorized vehicle drivers customarily do not stop to allow pedestrians to cross it. The action was concentrated both on highlighting the colors of the pedestrian crossing to make them more visible to drivers, and on being present and stopping vehicles in order to allow students to cross over the street for an entire morning.

4.2 Temporary Land Uses

In the first two cases, the temporary land use assigned was that of a pedestrian walkway (first case) or an entire pedestrian urban area (second case). In the third one, the temporary use (pedestrian crossing) was actually the same as the one it was initially designed for, but had not been respected by drivers of motorized vehicles to begin with. The durations of the initiatives ranged from several hours to several days. However, the first case demonstrated that tactical urbanism for active mobility can lead to permanent results; the temporary pedestrianisation of Ag. Sofias street was enthusiastically embraced by thousands of citizens, leading the establishment of the initiative as permanent.

4.3 Driver/Need Addressed

The major driver behind the tactical urbanism activities of the PRU is to demonstrate that pedestrian mobility can produce more inclusive, livable, viable and safe urban environments. This is achieved by the temporary assignment of pedestrian land uses and the reclamation of public spaces throughout the city in general, which is followed by enriched humane activity and interaction in those spaces.

The second driver of tactical urbanism initiatives is a feeling of need to react to the demonstrated incapability, inflexibility and bureaucracy of the state to provide solutions to well-known public problems. Thessaloniki, the interviewees report, is conquered by private motorised vehicles, many of them illegally parked in places that were originally designed for pedestrians. The Municipality of Thessaloniki is unable to enforce the related legislative provisions, while it also suffers due to low human and financial resources and lack of political will.

Another driver reported by the interviewees is to act through community action in the face of the NGO's tactical urbanism pursuits. The interviewees reported that it is easier to organize activities collectively; each member brings new ideas and capabilities to the table. Some of the NGO's members always acquire the same roles, for example the 'organizer', the 'communicator', the 'carrier', and so on. Also, they feel safer when they act all together.

The fourth driver is the need to demonstrate that innovative and drastic solutions are indeed feasible and needed in order to solve problems of the urban realm. Again this is combined with the feeling of safety and sense of collective achievement when they act as part of a group.

The last driver reported is the will to draw more citizens into embracing the sustainable and active mobility paradigm and, if they wish, join and support the PRU.

4.4 Aim with Regards to Pedestrian Mobility

The foremost aim pursued by the tactical urbanism activities of the PRU is to induce a culture shift through society, by informing citizens about their right access and used public spaces and sensitizing pedestrians and drivers about the benefits of active mobility.

The NGO also wishes to demonstrate that pedestrianisation is feasible and viable in specific parts of the city, despite the adverse claims by public authorities. The interviewees believe that major improvements can be achieved, simply by enforcing the protection of current pedestrian and cycling ways against illegally parked vehicles and improving the quality and coverage of public transport services across the city.

The interviewees also demonstrated an increased commitment to providing increased support to people with disabilities, low mobility or increased safety requirements, such as elderly people, school children, and mothers with baby carriers.

The NGO also aims to highlight the importance of pedestrian mobility in social, economic and environmental terms.

4.5 Obstacles/Challenges

The most important challenge faced by the PRU regards awareness about the benefits of active walking and pedestrian rights to begin with. Pedestrian rights in Greece have been violated for so many decades, that many view the current situation as ‘normal’. There is broad indifference about the quality and quantity of public spaces, accessibility rights and the overall quality of public services.

The second very important challenge is community engagement, referring to the volunteers that participate in the organisation and champion the activities of the NGO. More specifically, the NGO representatives discussed that although a well-organised activity can generate huge impact, they have a small number of volunteers to plan and execute the task in hand. Generally, many citizens support the activities of the NGO, but only after a flagship activity has taken place.

This brings us to the third and very important challenge faced by the NGO, which regards its organisational structure. The current spontaneous volunteer and initiative driven function of the NGO does not allow it to pursue a constant flow of activities and focus on specific tasks and issues.

Surprisingly, the interviewees did not mention strict legal frameworks and obtaining the necessary permits from governance authorities in order to engage in tactical urbanism activities as an obstacle. When asked, they reported that usually the Municipality of Thessaloniki is flexible with tactical urbanism activities.

5 Conclusions

Thessaloniki faces many problems related to the urban realm, and the Municipality of Thessaloniki maintains a rather indifferent position with regards to tactical urbanism. As such, the city (unfortunately) can be considered as a fertile ground for tactical urbanism initiatives.

The reported challenges are predominantly related with maximizing the impact of the tactical urbanism activities, which can happen by bringing in new members that wish to improve public space and ensuring a more constant flow of activities. Since financing sources are scarce and activities are implemented by volunteers, this cannot be achieved through financial investment in strategy, organization and marketing. Rather, to achieve a higher impact, it is imperative for tactical urbanism to demonstrate that it can produce measurable impacts and concrete outputs. The NGO can also unite with other citizen groups and opinion leaders with an interest in public spaces and enforce their position in the public debate.

Considering that have been cases where tactical urbanism activities generated large impact in Thessaloniki, it would be beneficial for the Municipality of Thessaloniki to embrace and support tactical urbanism initiatives across the city. In fact, tactical urbanism has shown that it can lead to constructive dialogue with and within the city, and audaciously experiment with solutions that the administration could not have proceeded with legitimately. Given the current financial restrictions, the city could devise alternative support measures. For example, it could focus on increasing awareness about the potential contributions of the civil sector or provide tangible assets (e.g. Municipal offices) that can be used as meeting spaces for those organisations.

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How Big Data Affects the Design of Urban Furniture: An Approach from the Perspective of Industrial Design

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Abstract. Urban designs and sciences are always in contact with the industrial design with urban furniture being an embodiment of this relation. Due to the changing dynamics of design and technology, there is an invisible relation shift between those disciplines. Industrial design is expanding to interaction, interface and service design, and urban design changing as the management of data created by the city. As a result, two areas are crossing again as data-generating city and data-processing industrial design and at the middle of that: the new urban furniture.

Observing and estimating tendencies on that re-formation and dissolution, require research on progresses of both urban and product design disciplines. This paper shall describe an approach to the relation of information systems and industrial design through urban furniture.

Keywords: Urban design · Industrial design · Interaction design Information systems · Urban furniture · Interdisciplinarity · Traffic lights

1 Introduction

Systems of information technology that enable people, organizations and objects to access and create digital content are named as Information Systems. In another saying, information systems are steam machines of today's world. One of the most important tools of information systems is ubiquitous computing. Third phase of computational power described as using computers in everyday objects, called "ubiquitous computing" by Weiser [1]. Start of ubiquitous computing phase brings us to the point of that future progresses in industrial design and information systems cannot be taken separately.

Furthermore, when we look at the point where cities are today, the concept of "data" is becoming increasingly important for cities and urban design. The correct processing of the resulting data of the citizen and city interaction has become a necessity to define and solve the urban problems today. Innovation departments have begun to be established to create pilot solutions that will enhance the quality of city life with effective use of data in many cities.

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To sum up, observing the effects of information systems on urban object, both necessary to examine the effects on product design and urban design. Ubiquitous computing is a tool in the multidisciplinary relationship with other design disciplines, mostly industrial design. One of the main reasons of changing definitions in design disciplines and advances on interdisciplinary studies are the widespread use of increased processor power and information systems.

All reasons above, reveals through which disciplines, information systems influence on urban furniture. To analyse the effect correctly, it is necessary to observe these effects in the field, especially after investigating the ones created by the information systems on these two disciplines. But before all else, the concept of "interdisciplinarity" should be referred to in such a study.

2 Interdisciplinarity and Industrial Design as an Transdisciplinary Profession

As our needs evolve and get complicated to push disciplines bring together, the definition of the relationship between disciplines and the definition of design, is changing. Working on problems involving more than one disciplines crate the term of interdisciplinarity. Interdisciplinarity described in three main groups today: multidisciplinary, interdisciplinary and transdisciplinary. Multidisciplinary works occurs when multiple disciplines come together without integration to solve a problem related only one of those disciplines [2]. Gibbons have described interdisciplinary studies as a way of bringing disciplines together on a common framework in a variety of themes [3]. Transdisciplinary works are involving the solution of complex problems that cannot be covered by a single discipline [2].

Previously, the advantages of interdisciplinary against single disciplinary approaches were discussed, and now interdisciplinary studies are preferred on many fields. Emerging technology and accordingly shaped user needs, resulting in the adoption of user-based, experiential and interactive approaches [4]. Approaches emerged that involve multiple disciplines at every stage of the design process, like whole systems design. These emerging trends have created new sub-fields of design as well as some of them have been removed and some have adopted new definitions [5].

Industrial Design is one of the redefined disciplines owing to World Design Organization's (WDO, formerly known as ICSID) definition unveiled at 29th General Assembly, Gwangju (South Korea), held on 17–18 October 2015. According to the new definition, industrial design has been a transdisciplinary profession that produces solutions to problems using creativity. In addition, approaches such as interaction design, experience design, and system design have turned into new disciplines [6]. In Dan Saffer's scheme (Fig. 1) it is possible to observe the relationship between design disciplines and the evolution of trans-disciplinarity of industrial design.

It is important to emphasize that at many points of these scheme (Fig. 1), information systems are seen to directly or indirectly related with design disciplines. To define this relationship next section will examine the impact of information systems on industrial design in more detail.

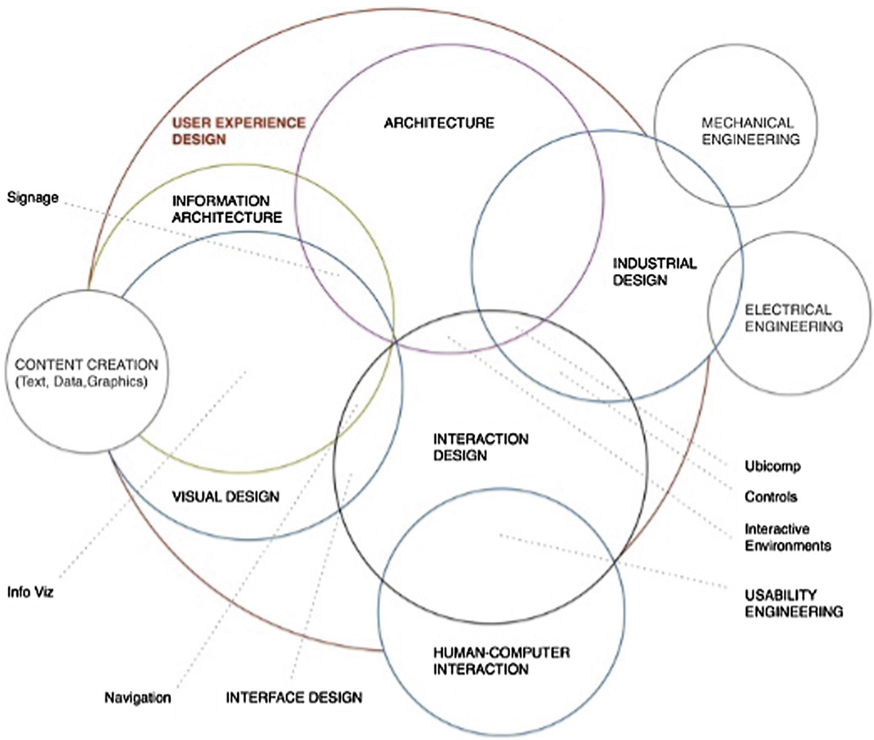

Fig. 1. Relationship between design disciplines according to Dan Saffer [7].

3 Relationship Between Information Systems and Industrial Design

Just as we invented machines that do the work we did with agricultural tools, now we have become people who design finance, marketing, and promotion of products from being the person who runs the machines that make the products [8]. The question of whether these functions will be handed over to machines in the near future, has begun to be discussed and researched already.

Edeholt validates ubiquitous computing phase by emphasizing the increase in the number of computers is more than the number of users [6]. This progress points out that the transformation in computer and information technologies can no longer be distinguished from industrial design.

One of the other impacts of information systems that makes industrial design transdisciplinary is the new disciplines incorporated into design process. Such as interaction design that we can relate closely in the city furniture; leaving being a part of the system development and has become part of the process of product design & development by the influence of ubiquitous computing, the internet of things and the developments in mobile devices [9].

The next step will be the effects on urban design discipline to finish background analysis of urban furniture and information systems relation.

4 Relationship Between Information Systems, City and Urban Design

Communication technologies have been promoting the current mobility of cities in a virtual space with the rapidly developing internet access network and mobile vehicle technology alternative to the urban space since 2000's. Since these technologies are added to the urban life, the physical space needs of various urban functions and the usage of public spaces are changing [8]. Developments in information systems caused many tools and services used in urban design to change. Technology can force objects (traffic lights, lights, bus stops) not only to change but to recreate the entire system to which it is connected or even completely remove problematic systems. Same rules are valid for public spaces. Every day, more and more people adapt to new forms of communication ad creates traffic between spaces. Many daily needs can be met by traveling in unlimited virtual spaces without physically moving, and individuals can be in more than one place. Therefore, the development of communication technologies is reducing the rational needs of public spaces, thereby removing people from the lifestyle of physical effects [8].

Beyond defining digital products as singular objects, digital technologies are now beginning to appear as an invisible layer on the points of interactions at spaces we are living. This viewpoint is causing public and private organizations to renew themselves to survive. Obviously, this change also applies to public institutions of cities. On the contrary, it can be predicted that the change will be much slower when we are talking about cities. Cities are exploring the best use of technology at this point, but it takes a very long time to react because they are formed by the interaction of many different disciplines. As a result, a significant conceptual change emerges that defines the relationship between urban and information systems. Cities sometimes abandoned their "service provider" duties and began to take on the role of "data provider". Moreover, they have started to use data generated by the city in an effective manner to ensure service management. Some examples about these transformations are discussed below. One of the good examples is Department of New Urban Mechanics at Boston, Massachusetts which is one of the first innovation offices in World. It has a team consists of different disciplines, developing research and design projects that generate solutions to urban problems by thinking how to make urban life more meaningful [10]. Another example is from Netherlands and related to data providing. The REISinformatiegroep (TRAVEL information group) study has been established with agreements between government and public transport companies to share unprocessed transport data via the open data model [11]. The Boston municipality has been started an application that they have partnered with a team from Boston University to get rid of the increasing road quality problems. Application called "Street Bump" used by volunteers to improve the quality of nearby roads [12]. With the help of above examples, it's clear that the task of providing services or data can undertake by private companies, academic projects, initiatives or NGOs which is more efficient and sustainable way for governments [13].

Up to this point, the relation between information systems and disciplines that have co-create urban furniture have been mentioned. Behind all of them is the driving force of the information systems, depending on the development of the processor power. From now on, it would be beneficial to conduct a research on an urban product to verify the effectiveness of information systems.

5 An Urban Furniture at the Intersection of Information Systems and Industrial Design Disciplines

In 1868s London, traffic lights, firstly used to control horse-drawn traffic, continue to be used till today in much the same way as before, despite several minor improvements. Traffic lights are defined as a controlled intersection traffic regulation tools in urban design and used in cities that has rules defined by transportation engineering. This city furniture is developed by many professions like product designers and electrical engineers, so that it can fulfil its function properly.

Traffic lights, however it contains physical differences from geographical and social differences, can be described as a universal object. That object, developed by more than one discipline, has begun to cause some problems in addition to the ones it solves today. This induces some design and systematic improvements to the traffic lights nowadays. For the same reason, there are also studies for adaptation with information systems intensively but the fact that more than one discipline intervenes makes it difficult to reshape that urban furniture.

One of these studies is the SURTRAC (The Scalable Urban TRAffic Control), which was developed in Pittsburgh in 2012. SURTRAC system was originally developed in the Intelligent Coordination and Logistics Laboratory at the Robotics Institute at Carnegie Mellon University as part of the Traffic21 research initiative [14]. It is an easily extensible sensors and processors system that provides real-time traffic signaling using artificial intelligence and distributed calculation principle in determinations (Fig. 2). According to information given its website SURTRAC reduced travel times more than 25% on average, and wait times were reduced an average of 40%. The project, which was used in the first step at 9 junctions, is now being used at 50 junctions [15].

The traffic lights are undergoing serious infrastructure changes with projects like SURTRAC. In addition, sensors on the roads and on the traffic lights are integrated to the system. Information systems apply pressure to change the design of conventional traffic lights. In some cases, these technological developments integrated into the existing systems are solutions that single disciplined or do not deal with the whole system. According to way of whole system thinking, these traffic systems can only be completed after physical urban furniture is redesigned.

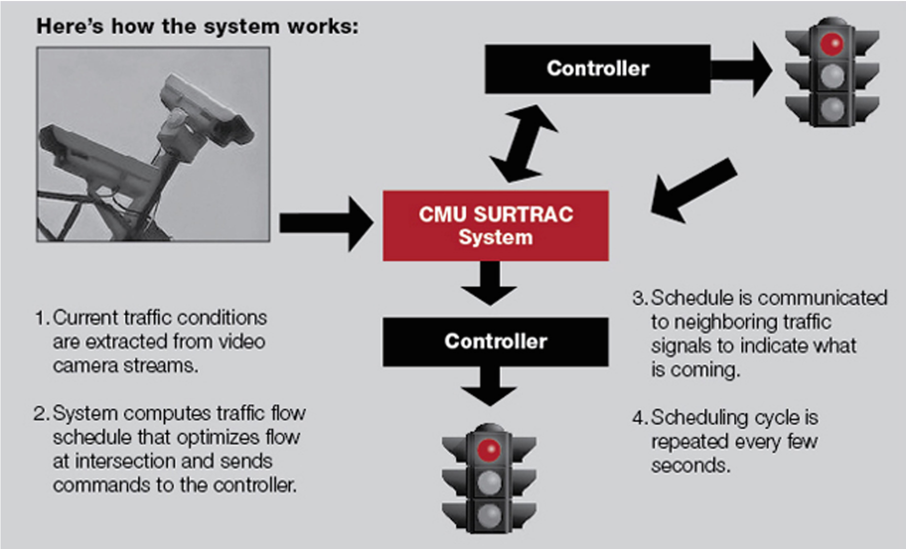

Fig. 2. SURTRAC converts the data from camera, sensor and nearby traffic lights into information that will adjust the traffic light phases [16].

6 Future Outlook

The situation in traffic lights is applicable to many urban objects today. The complexity of the today problems necessitated that the solutions should be complex and multidisciplinary.

In many cases, municipalities are using systems that regulate traffic lights by taking advantage of traffic information with the help of sensors located in traffic lights. Those systems; sensors, computers that process the data, and other devices are easily getting old and new systems are taking their places. This situation causes cities to have difficulty to solve the problems with technology-based methods. Instead the user can access this information by downloading an application to his phone, their navigation device uses this information to warn them. Users can change, update or delete the application when the technology developed or defunct. We can clearly see that in futuristic approaches. An urban furniture that has changed a little since its first design, may soon become an application reflected in dashboards of our vehicles [17].

Developments show us that the usual objects can be transformed into services or interfaces. Though it is not possible to generalize the concept, this progress is also taking place in urban furniture which used to provide services to the city.

Our researches show that the use of transdisciplinarity and information systems as a new tool in solving complex problems with the renewed definition of industrial design and can be used to develop many urban objects, especially traffic lights. In the ongoing research, the existing traffic light projects will be examined and the effect of industrial design and information systems on multidisciplinary studies on traffic lights will be revealed.

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Investigating the Role and Potential Impact of Social Media on Mobility Behavior

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Abstract. Social media are considered as a major communications channel for information exchange, opinion statement, social network enabling, decisions influencing and business promotion. New activities can be triggered by web friends and followers, as a mutual trust on choices is developed during peoples' interactions on social media. Visited places, attended events, bought merchandise that are disseminated on the web turn into possible attractors for others to visit, attend and buy, thus affecting individual's travel preferences and behavior. The impact of social media in travel/mobility decisions is the main objective of this paper. A digital questionnaire was formulated to investigate the degree of social media usage in terms of type of information searched, reached and shared, time of information and purpose for which the information was created. The final sample size comprised 237 users and was grouped according to gender (women-men) and occupation (students - full-time job). In addition, statistical analysis results that were based on this grouping are included and further described in this paper.

Keywords: Travel choices · Travel behavior · Questionnaire survey

1 Introduction

The explosive growth of social media use and the amount of time being spent on them has resulted in huge volumes of available and active data. Users share publicly information, ideas, opinions and experiences on platforms such as Twitter, Facebook, Instagram, LinkedIn rendering them powerful tools, suitable for transport data collection. Their wide spread encourages the users to share their location more often, leading to an exponential increase of their volume day by day [1].

Due to their high availability and obtaining low cost, data from social media create potential for mobility behavior analysis. Moreover, profiles of social media users offer useful social-economic and demographic information of travelers, creating potential for investigating relationships between activity patterns and the characteristics of the users [2].

The increasing use of social media and the interactions with the web friends and followers, have changed dramatically the way that users perceive social relationships. Social networking undoubtedly plays an important role not only in broadening social connections but also affecting users' decisions [3]. Social media are being used in ways

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that shape the users' travelling, entertainment and shopping preferences, creating the need for them to participate in activities shared by their web friends or by people they follow. Despite the fact that social media allow a communication in which the physical presence is not necessary, reviews, photos, videos, posts, stories shared on them motivate users to visit a place, attend an event or buy a product. The instantaneous and real-time access to relevant tips and guides, travelling instructions, specific offers and discounts or inspirational photos/videos has ultimately changed the way users plan an activity [4].

User-generated content is a vital source of inspiration and often affects the initial decision of the activity planning. Social media users influenced by the content shared online, execute an activity. The present survey investigates user preferences in sharing photos/videos or posts during or upon a positive experience and how this new user-generated content triggers new activities of other users, creating a circle of influence among web friends.

2 Methodology

In this section the design of the digital survey as well as the data collection and analysis are thoroughly described.

2.1 Survey Design and Data Collection

An on-line questionnaire survey was carried out to understand the potential impact of social media use on travel behavior. The questionnaire was internet-based and in English language aiming at reaching a wide range of users. The survey was built on SurveyMonkey [5], owing to its integrated and simple environment and the high number of features that the software offers. The questionnaire was mainly disseminated via the social media Facebook and Instagram.

The survey consists of five parts. The first part recorded the socio-economic characteristics of the respondents, by collecting personal information such as gender, age, education level, employment status, etc. The second part referred to the use of social media, in which data regarding the most preferable social media, the time, frequency and duration of social media use were collected. The next three parts aimed to investigate the role and potential impact of social media on mobility behavior; in parallel, information regarding the social media use before, during and after an activity was collected. The research in this paper gives emphasis to the effect of social media in planning an activity, and for this reason, data regarding the use of social media before an activity was analyzed.

2.2 Data Analysis

The analysis of the data was done through descriptive and inferential statistics. In the first case, a number of the sample characteristics, such as age, gender and occupation were addressed by estimating the frequency distribution per characteristic, as well as the mean values and standard deviations. In the second case, the statistical analysis of the responses was carried out using non-parametric tests. Specifically, in order to estimate whether there were any differences in the average rating of respondents, hypothesis testing was used. Mann-Whitney two-sample U-testing were performed to assess differences among and between the samples in characteristics measured on the 5-point scale (Never 1, Seldom 2, Sometimes 3, Often 4, Always 5) respectively [6]. A confidence level of 95% and confidence interval of 5% were assumed.

3 Results

The sample characteristics as well as the results of the statistical analysis are presented in the following sections.

3.1 Sample Characteristics

The final sample size comprised 237 users, who fully completed the questionnaire. The women are 59% and the rest 41% are men. Regarding age, 40% of the respondents are between 18–25 years old, 52% of them between 26–35, 6% between 36–45, 1% of them younger than 18, and 1% older than 45 years old. In addition, 37% of the participants are students, 47% have a full-time job, while 7% a part-time job, 7% are unemployed and the rest 2% answered other. The 80% of the respondents live in Greece and the rest 20% lives currently abroad. This last distribution is owing to the nationality of the researchers which reflects also the nationality distributions of their social networks, through which the survey was disseminated.

3.2 Results

Results of the survey showed that 97% of the participants use social media. The sample was grouped according to gender (women-men) and occupation (students - full-time job) and the analysis was based on this grouping. Since the occupation-based grouping in the category students includes the participants that are between 18–24 and the participants with full-time job are between 26–35, age was not used as a separate parameter for grouping participants.

According to users' statements, Facebook and Instagram are the most used social media for both women (55% use both media) and men (38% use Facebook while 27% Instagram) as well as for students (42% use Facebook, 38% use Instagram) and participants with full-time job (51% use Facebook, 42% use Instagram). 21% of men and 27% of participants with full-time job are also interested in job-related social media such as LinkedIn, while 27% of women are more interested in inspirational image-based platforms such as Pinterest. The participants were also asked about the time of the day that they most frequently use social media. The majority of men (69%) and women (61%) as well as the highest percentage of students (60%) and full-time job participants (68%) use social media between 17:00-00:00. In addition, most of the respondents stated that they use social media before an activity for travel arrangements (67%), entertainment (80%) and shopping (55%).

Eleven parameters that are related to the frequency of public transport use, the share of fake information, the impact of social media use and of shared reviews on activity planning, the share of information regarding an activity before its execution and the help of social media use in participant's activity planning are further examined. Tables 1 and 2 present an overview of the average rating and standard deviation of the eleven variables and the test results of the comparisons between men and women, and students and full-time employees, respectively. Results are described through the z-statistic, the calculated effect size ($r = z/\sqrt{N}$, where N is the total number of observations) and p-value, indicating the strength of the respective evidence.

Table 1. Social medial parameters' rating between women and men.

Parameters	Groups						
	Women		Men		W vs. M		
	M	SD	M	SD	z-statistic	Effect size (r)	p-value
Use of public transport	3.61	1.11	3.13	1.27	−2.67	−0.18	0.008*
Share of fake information	1.24	0.54	1.22	0.56	−0.65	−0.04	0.515
Purchase of products seen on social media	2.56	0.87	2.19	0.8	−3.08	−0.21	0.002*
Impact of reviews on buying decisions	3.69	0.91	3.53	1.11	−0.85	−0.06	0.395
Visit of a place seen on social media	3.01	0.69	2.86	0.81	−1.69	−0.11	0.09
Impacts of reviews on a place visit	3.64	0.87	3.42	0.87	−1.83	−0.12	0.067
Impact of photos/videos shared on social media on a place visit	3.93	0.81	3.58	0.87	−2.94	−0.20	0.003*
Importance of the proposed transport mode on final decision	2.9	0.97	2.93	1.05	−0.31	−0.02	0.76
Impact of social media use on activity plans	2.71	0.79	2.57	0.9	−0.94	−0.06	0.35
Share of activity's information on social media before its occurrence	2.22	0.74	2.3	0.8	−0.56	−0.04	0.59
Help of social media in activity planning	3.4	0.99	3.27	0.91	−1.34	−0.09	0.22

M: average rating, SD: Standard Deviation, *statistically significant ($p\text{-value} < 0.05$)

66% of the participants responded that they never share fake information on social media, results showed that both women ($M = 1.24$, $SD = 0.54$) and men ($M = 1.22$, $SD = 0.56$) rarely share fake information with the difference between them not being statistically significant ($r = -0.04$, $p\text{-value} > 0.05$). 38% of the respondents are often affected by photos/videos shared on social media regarding a place visit/activity and according to Table 1 both women ($M = 3.93$, $SD = 0.81$) and men ($M = 3.58$, $SD = 0.87$) are often affected, the differences between the two groups of comparison were statistically significant ($p\text{-value} < 0.05$). All the results of the eleven variables when comparing gender differences are included in Table 1.

Table 2. Social media parameters' rating between student and full-timer employees.

Parameters	Groups						
	Students		Full-time job		S vs. F		
	M	SD	M	SD	z-statistic	Effect size (r)	p-value
Use of public transport	3.8	0.89	3.2	1.33	−3.07	−0.22	0.002*
Share of fake information	1.2	0.5	1.2	0.56	−0.07	−0.01	0.95
Purchase of products seen on social media	2.5	0.97	2.4	0.79	−0.58	−0.04	0.56
Impact of reviews on buying decisions	3.8	0.92	3.5	0.99	−2.66	−0.19	0.008*
Visit of a place seen on social media	3.0	0.68	2.9	0.81	−1.23	−0.09	0.22
Impacts of reviews on a place visit	3.7	0.88	3.5	0.87	−1.73	−0.13	0.08
Impact of photos/videos shared on social media on a place visit	4	0.79	3.6	0.87	−3.15	−0.23	0.002*
Importance of the proposed transport mode on final decision	3	0.98	2.8	1.02	−1.17	−0.09	0.24
Impact of social media use on activity plans	2.7	0.85	2.6	0.79	−0.91	−0.07	0.36
Share of activity's information on social media before its occurrence	2.2	0.7	2.3	0.82	−0.58	−0.04	0.56
Help of social media in activity planning	3.4	0.93	3.3	1	−1.23	−0.09	0.22

M: average rating, SD: Standard Deviation, *statistically significant (p-value < 0.05)

Only 10% of the respondents answered that they never use public transport while 53% of them responded that they always use it. Table 2 shows that students (M = 3.8, SD = 0.89) use more often public transport compared to full-time job employees (M = 3.2, SD = 1.33), with statistically significant differences between them (p-value < 0.05). The frequency of fake information share by students (M = 1.2, SD = 0.5) and full-time job employees (M = 1.2, SD = 0.56) is also low, but with no significant differences between them (p-value < 0.05). Regarding the impact of photos/videos shared on social media, students are more often affected by them (M = 4, SD = 0.89) compared to full-time job participants (M = 3.6, SD = 0.87) with statistical significant differences between them (p-value < 0.05).

In addition, hypothesis testing was used to assess differences in the mean values of the frequency of changing destination, transport mode or both of them after social media use, between men and women and between students and full-time job employees. Two-way ANOVA was used to examine these differences, and results are presented in Figs. 1 and 2.

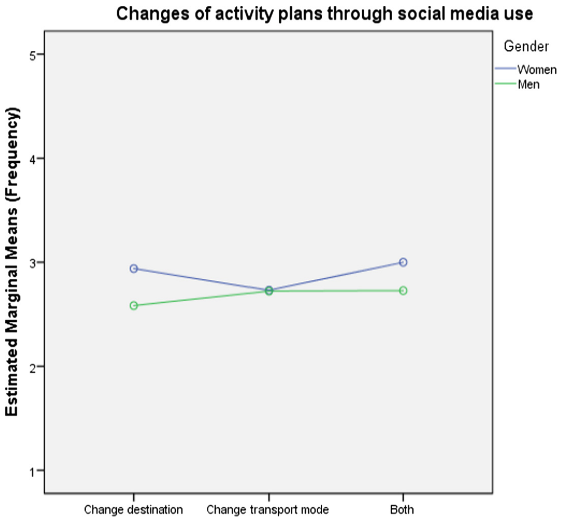

Fig. 1. Changes of activity plans after using social media (women-men).

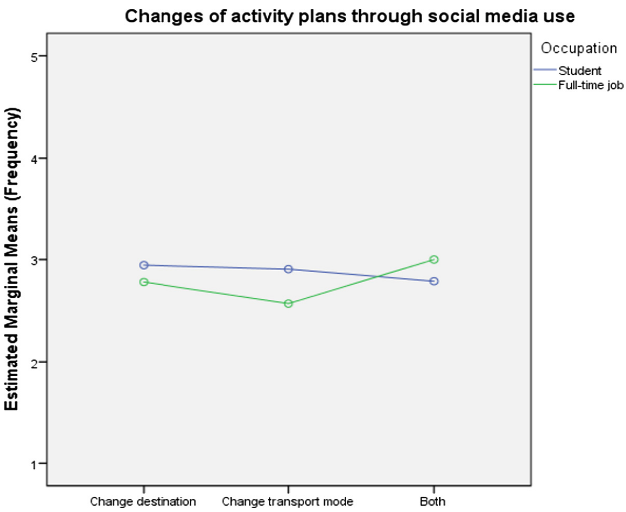

Fig. 2. Changes of activity plans after using social media (student - full-time job).

The changes of activity plans through the use of social media were tested for women and men and it is observed that a destination change is more often for women compared to men while both of them change transport mode after use of social media with the same frequency. The testing also revealed that women change both destination and transport mode more frequently than men. However, a change in activity plans is not relatively significant either with the gender (p-value = 0.197) and the type of change (destination/mode or both) (p-value = 0.690) or the combination of them (p-value = 0.538).

By testing the changes after the use of social media for the occupation groups, it was revealed that students change more often transport mode compared to full-time job employees who change both mode and destination more frequently. However, there were no significant differences between students and participants with full-time job (p-value = 0.578), between the type of change (p-value = 0.689) or the combinations of these two parameters (p-value = 0.332).

4 Conclusions

The current survey shows that social media have a broad impact on activity planning. Shared posts, photos/videos and reviews affect people's choices regarding a place visit/an activity. For this reason, users plan an activity and do their travel arrangements based on information and experiences shared online. The mobility decisions of both women and men, as well as of students and full-time job employees are affected by negative reviews or nice photos/videos and posts. These mobility decisions may be related to changes of the time and the date of an activity, the transport mode or the destination. It is worth noting, that the majority of the survey participants believe that social media help significantly their activity planning.

The findings of this survey are expected to assist digital campaigns on sustainable urban mobility. Digital technology has reshaped the way how a campaign interacts with users and this explosive growth of social media use and the amount of time being spent on them has resulted in shifting from traditional campaigns to campaigns on digital channels. Results of this survey regarding the time and frequency of social media use, the most used social media, the type of information shared as well as the type of a more appealing message are analyzed further for this purpose.

Furthermore, an extended analysis regarding the types of data that can be retrieved from social media, can be used as a guide for improving the quality of collected social media data. Finally, the impact of the social media before-during-after planning an activity, should be assessed in order to identify means for enhancing transport planning process.

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Campaigns and Awareness-Raising Strategies on Sustainable Urban Mobility

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Abstract. The increasing demand for urban mobility in modern cities leads to traffic congestion and other environmental and societal impacts, requiring a shift to more sustainable mobility behavior. However, travelers are not well informed about the possible sustainable modes and their advantages, as traffic education is often limited to learning traffic rules. To raise awareness on sustainability, various techniques may be used, such as designated educational programs, training sessions, seminars and campaigns. Acknowledging the spread and popularity of social media, the aim of the paper is to investigate how a shift in behavior towards more sustainable modes of transportation may be affected by a digital campaign. The coherent production of a successful sustainable urban mobility campaign is a complex task and requires a thorough understanding of the general needs of those affected. Firstly, the paper reviews and analyses previous campaigns and strategies related to sustainable urban mobility implemented in European countries. Analysis includes the organization, which was responsible for initiating the campaign, the time period, theme, scope, target group and type of approach. In those cases, that evaluation of the campaign was conducted, impacts on attitudes and behavior are also identified and the success attributes of the campaigns are selected. In the context of further research, an online questionnaire survey was carried out for the identification of travelers' preferences and attitudes towards innovative strategies that raise awareness in sustainable urban mobility, promoted and supported by social media (Facebook, Instagram, Twitter, etc.).

Keywords: Sustainability · Alternative transport modes
Promotional campaigns · Social media · Digital campaigns

1 Introduction

Over 70% of people live in cities and urbanization is rapidly growing worldwide. This situation demanded the creation of Sustainable Urban Mobility Plans (SUMPs) which address the design and application of urban mobility schemes, supporting sustainability. These schemes support the adoption of sustainable ways of transport, such as soft modes (cycling, walking), public transport and alternative use of private vehicles, through car-sharing and carpooling systems [1].

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Promotion is required for these alternatives to gain attention and become a transportation choice an urban resident would consider. This promotion can take the form of a marketing campaign or other awareness raising strategies that help towards a more widespread adoption of an active lifestyle or more sustainable travel behavior, such as active school travel and peer support schemes or promotional events [2]. Marketing campaigns are mainly characterized by objectives, target groups, the nature of their messages, and the evaluation methods of their results [3].

This study focuses on marketing campaigns and awareness raising strategies on sustainable urban mobility. Due to how digital technology has reshaped the way a campaign interacts with users, and taking into account the explosive growth of social media use and the amount of time being spent on them, a shift from traditional campaigns to campaigns on digital channels should be considered. As a result, an online questionnaire survey was designed and carried out, in order to recognize and evaluate the role of social media in travelers' attitudes and preferences, since they are known to be of significant help in involving community stakeholders in the decision making process of sustainable mobility policy formulation, as well as in communicating the measures to the public [4].

2 Methodology

The methodological approach of this study is organized into two parts. The first part regards the review and analysis of European campaigns and strategies addressing sustainable urban mobility. For each campaign/strategy, data were collected about the country of implementation, the responsible organization, time period, scope (local, regional or national), target groups (general or specific), main objectives, theme, media plan (i.e. internet, brochures, local events) and type of approach (i.e. informative, positive, etc.). In those cases, that the campaign or strategy was evaluated, the research design, the data collection technique and the evaluation outcomes (impacts) were also recorded.

The online questionnaire survey aimed to capture the attitudes and preferences of people towards digital campaigns and strategies raising awareness in sustainable urban mobility, supported or promoted by social media. The survey recorded the viewpoint of respondents on the use of social media (preferable media account, time and frequency) and the role of social media on travel behavior (before, during and after an activity), along with demographic characteristics.

3 Sustainable Urban Mobility Awareness Campaigns and Strategies: A Review

To gain insight and knowledge about sustainable mobility awareness campaigns and strategies, ten cases, implemented in EU countries, were studied and analyzed (Table 1). In all cases, the campaigns/strategies were part of a larger scheme or project, which aimed at promoting sustainable mobility behavior in their target groups. This indicates the need for tangible measures and strategies to be implemented in parallel with awareness campaigns, to help make the concept and importance of sustainable mobility more explicit.

The review showed that a significant number of projects have been co-funded by the European Commission (EC), which indicates the high importance of sustainable urban mobility in European Union (EU), and the significance in incentivizing member states to cooperate towards this common goal. Evidence for this, in the current study, are the eight out of ten studied campaigns/strategies that were implemented in multiple European countries [5–12]. Due to the scale and complexity of implementation, it is rare for relevant activities to be organized by a single organization. Thus, in nine out of ten cases studied, participating organizations comprised of academic and EU institutions, public bodies and private entities [5–12, 14].

The majority of the campaigns/strategies were implemented at a local level. The only exception was the Traffic Snake Game Network, which had a more easily defined target group and was implemented in primary schools across eighteen European countries. In this particular case, the schools helped with the collection and registering of the data [8]. The theme of the campaigns was generally related to the promotion of sustainable mobility and alternative sustainable transport modes. Most implementations focused on the promotion of a combination of cycling, walking and public transport modes [5, 7–10, 12], while others adopted a more focused approach, and considered only public transport [13]. There was also the case of the Today and Tomorrow project, which focused on the promotion of car-sharing and bike-sharing schemes [6].

Focusing on target groups, these ranged from the residents of the cities where the campaigns/strategies were implemented [10, 12, 13], to more specific groups like commuters to business and industrial zones [11], or potential users of a public transport mode [13]. Other target groups included primary school students and their parents [7], university students and faculty [6], company employees [8] and persons over a certain age [9]. Regarding the topics of the ten studied cases, there were slight differentiations, still revolving around the central theme of sustainable urban mobility. Some focused on the existing organizational barriers and ways to overcome them and communicate sustainable mobility to the interested parties [5, 9, 11], while others focused on the environmental impacts of urban mobility appealing to members of their target groups, to help change the situation [6]. However, the main objective of the majority of the campaigns/strategies was the promotion of the concept of sustainable urban mobility to their respective target groups, as well as its adoption by them [6, 7, 10, 12–14].

In all of the aforementioned cases, an informative and positive approach was adopted towards their target groups. The message was intended to inform the public, present the benefits of sustainable mobility and state the future consequences of the current situation. The cooperating organizations responsible for the planning and implementation of each initiative used almost every available means of communication to deliver the developed message. Internet was used in the promotion stage of each case, in conjunction with printed material, local events and the press. The use of social media however was very limited, which can be attributed to the fact that many of the campaigns/strategies were implemented before social media received their current popularity.

In most of the studied cases, their impacts were evaluated, usually by measuring a list of performance indicators, such as the reduction in the use of private car, the

Table 1. Overview of European Union campaigns and strategies.

Campaign/strategy	Country	Objective	Media plan	Evaluation	Theme	Target group	Ref.
ASTUTE	Several	Overcoming organizational barriers	Internet, brochures, local events	Longitudinal study	Cycling, walking	City inhabitants	[5]
Today and Tomorrow	Cyprus, Portugal, Italy	University mobility impacts reduction	Internet	Questionnaires, interviews	Carpooling, bike-sharing	Students and faculty	[6]
The Traffic Snake Game Network	18 EU countries	Travel behavior change	Internet, local events, posters	Before-after analysis, longitudinal study	Cycling, walking, car-sharing, public transport	Primary school children and parents	[7]
MOBI	Several	Travel behavior change	Internet	Longitudinal study, after analysis	Cycling, walking, car-sharing, gamification	23,400 employers of 117 companies	[8]
AENEAS	Several	Alternatives to car use	Internet, brochures, newsletters	Questionnaires	Walking, cycling, public transport	Senior citizens	[9]
SWITCH	Several	Soft modes promotion for short trips	Internet, local media	Before-after analysis	Walking, cycling	City inhabitants	[10]
MoMa.BIZ	Several	Business & industrial zones mobility issues	Internet, local events	Before analysis	Mobility issues	Business & industrial zones commuters	[11]
PRO.MOTION	12 EU countries	Influencing travel decisions at home	Several	SUMO evaluation method, Before-after behavioral analysis	Public transport, car-sharing, walking	City inhabitants	[12]
Casteddu Mobility Styles	Italy	Light metro service promotion	Internet	Before-after analysis	Metro service	Car users	[13]
CIVITAS	Portugal	Sustainable transport behavior	Internet, local events, posters, flyers, local press	Questionnaires, interviews	Eco-driving, school mobility, public transport	Residents, students	[14]

increase in the use of sustainable transport modes and the reduction of CO_2 emissions [5, 6, 8–10, 12, 13]. More specifically, the reduction of CO2 emissions ranged from 51 kilograms [8] to 4695,74 tons [12], while the increase in the use of alternative transport modes ranged from about 1.5% [14] to about 25% [9]. In two out of ten studied cases, the evaluation was conducted through a more qualitative approach [11, 14]. In these cases, the positive impacts were estimated by the general acceptance of the sustainable mobility concept by the target groups.

4 Survey Findings

The survey was realized during the period January-February 2018, and the sample size was determined to 237 users (56% women, 41% men). 40% of the respondents are between 18–25 years old, 52% of them between 26–35, 6% between 36–45, 1% of them younger than 18, and 1% older than 45 years old. Also, 37% of the participants are students, 47% have a full-time job, while 7% a part-time job, 7% are unemployed and the rest 2% answered other. The 80% of the respondents live in Greece and the rest 20% live currently abroad.

For the analysis of the respondents' characteristics (gender, age, occupation, etc.) descriptive statistics were applied, while Chi-square (X^2) test for homogeneity was used to test differences in responses measured by categorical variables. A confidence level of 95% and confidence interval of 5% were assumed. Results of the survey showed that 97% of the participants use social media.

The sample was grouped according to parameters such as gender (male-female) and occupation (students - full-time job) and the analysis was based on this grouping. The age of participants was not used for grouping, since the occupation-based grouping in the category students includes all the participants that are between 18–24 and the participants with full-time job are between 26–35.

The first step for a successful campaign is to choose the most appropriate social media platform. This choice should be done after the determination of the campaign's target group. Based on the survey, Facebook and Instagram are the most used social media for both women and men as well as for students and participants with full-time job. Men and participants with full-time job are also interested in job-related social media such as LinkedIn, while women are interested in inspirational image-based platforms such as Pinterest.

The time that a digital campaign goes live is also of crucial importance. Some social media tend to change the order the content is presented on the user's feed. Lately, Instagram switched up user feeds to show more interesting posts first, instead of showing posts in standard chronological order. This means that the time a post is live does not play any role on Instagram anymore. The survey participants were asked regarding the time of the day with the most frequent use of social media. The majority of men and women as well as the highest percentage of students and full-time job participants use social media between 17:00-00:00.

In social media is very important that the content the user shares to be so relevant and engaging, that the affected people should enjoy reading, seeing or hearing and feel motivated to share it with their "web friends". In this survey, participants were asked what would raise mostly their awareness on travelling possibilities and the answers are presented in Figs. 1 and 2. The majority of the participants answered that a message by a designated account related to transport would raise more their awareness. Still, the differences between the several options were not statistically significant (p-value > 0.05).

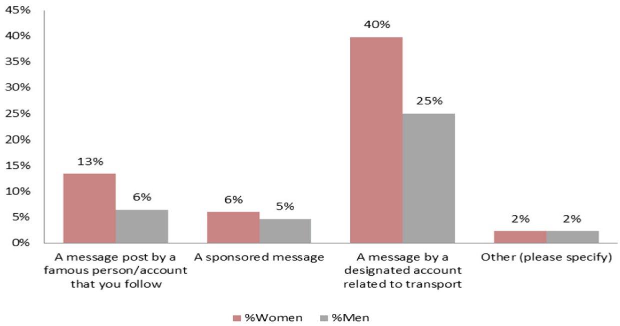

Fig. 1. Preferences on the approach of raising awareness on traveling possibilities depending on gender.

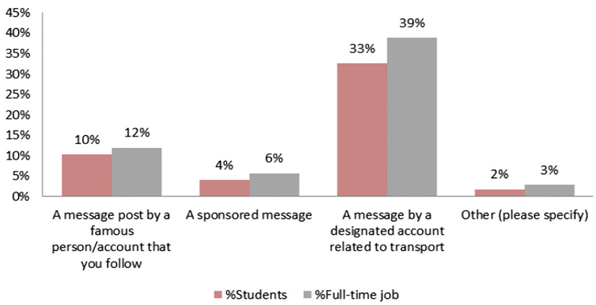

Fig. 2. Preferences on the approach of raising awareness on traveling possibilities depending on occupation.

An informative or a humorous message would be more appealing for both women-men, as well as for students and participants with full-time job (Figs. 3 and 4). Similarly, the differences between the several approaches were not statistically significant (p-value > 0.05).

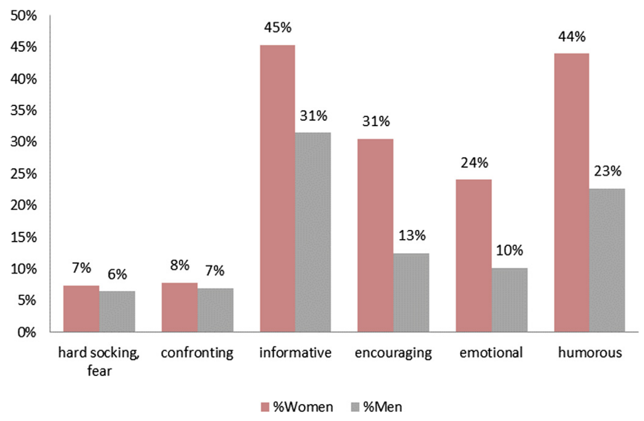

Fig. 3. Preferences on message appeal (women, men).

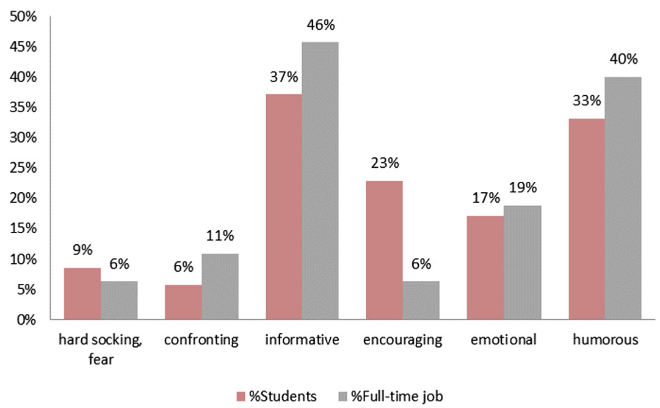

Fig. 4. Preferences on message appeal (students, full-time job).

5 Conclusions

Social media is a promising way to reach a large number of people and spread awareness and transport-related information to them. With the tremendous use of car, social media have become popular channels to promote sustainable mobility and a more active lifestyle. The survey conducted in the context of this research, showed that a message with informative content is more appealing to the users and that a message by a designated account related to transport would raise more the awareness of the majority of respondents towards implementing sustainable solutions for urban mobility. In order to influence positively this attitude towards sustainable mobility, the key is the formulation of a framework through which digital campaigns can be created to support sustainable urban mobility awareness. The current study also highlights the need for further investigation of how much people interact with the content of a digital campaign. The connection between this degree of interaction and the rate of a more sustainable behaviour adaption should be further examined.

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A Comparison of Bicyclist Attitudes in Two Urban Areas in USA and Italy

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Abstract. Over the past 40 years, the number of people using bicycles as their primary means of transportation has increased significantly. Transportation agencies around the world now promote bicycling as a way to reduce pollution and traffic congestion. However, the lack of bicycling infrastructure in many cities could significantly impede the future growth of bicycle usage. This paper used a web survey to evaluate the attitudes and preferences of bicyclists in two cities: Lexington, Kentucky, USA and Catania, Sicily, Italy. The goal of the survey was to document impediments to bicycling in both cities, determine how infrastructure could be improved. Descriptive statistics and test of hypothesis were applied to the survey data to analyze participant responses and their level of agreement. Confirming previous research, respondents in both cities overwhelmingly cited lack of infrastructure as a major obstacle to bicycling more often. Respondents indicated that improving bicycle infrastructure and pavement conditions would result in an increased number of bicycle trips. While the survey findings lend support to the idea that bicyclists around the world harbor similar attitudes about what improvements are needed to increase cycling and enhance their experiences, local conditions and practices also influence perceptions about the relevance of specific issue.

Keywords: Bicyclist mobility · Bicyclist preferences · Infrastructure

1 Introduction

Throughout the world, bicycling as a transport mode has seen a significant increase over the past decades. In the USA, the number of walking and biking trips were approximately 11.9% of the total number of trips in 2009; more than a 25% increase from 2001 [1]. Studies have also shown an increase in ridership with over 40% reporting that they have used a bicycle more often than in the past [2]. What is of interest too is that most of the trips are now utilitarian (i.e., they do not have a recreational purpose) [3]. Similar trends have been noted in the European Union (EU), where the number of bicycles per 1,000 inhabitants ranges from 52 in the Czech Republic to 1,000 in the Netherlands [4]. The most noticeable difference among EU countries is the level of bicycle usage—in some countries individuals rely on bicycles every day as a primary means of transport (such as the Netherlands and Scandinavia), while in others do so only occasionally.

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Throughout the world, transportation agencies promote bicycling as an alternative transportation option, since it provides health benefits, reduces carbon emissions, and alleviates congestion. It is imperative then that transportation agencies develop and support an appropriate infrastructure to encourage the continued growth of bicycling.

The availability of bicycle-friendly infrastructure is considered one of the factors that stimulates cycling [3]. Infrastructure qualifies as bicycle-friendly if it allows comfortable cycling in a safe and attractive traffic environment. For agencies to provide appropriate bicycle infrastructure and increase the share of bicycle as a travel mode, they must be aware of the obstacles to bicycling perceived by the active and potential bicyclists and address them accordingly. Agencies have utilized surveys to understand bicyclists' attitudes and identify required improvements.

This paper evaluates attitudes and preferences of bicyclists in Lexington, Kentucky, USA, and Catania, Sicily, Italy, using a web-based survey aimed to identify impediments to bicycling in both cities. A comparison of the two survey results could reveal whether the bicycling population expresses similar concerns and preferences across the world and illuminate how attitudes are influenced by living in a city with (Lexington) or without (Catania) bicycle infrastructure. Understanding these issues will facilitate development a plan of action for how to better address bicycling needs.

2 Background

The number of people using bicycles as a primary mode of transport has increased over the past 40 years. Much of this growth in the USA and Canada has been concentrated in large cities, where the growth rate was twice what was observed for the entire country between 1990 and 2010 [3]. Higher growth has been attributed to infrastructure improvements and the introduction of programs that advocate bicycling. These efforts have included the addition and expansion of bicycle facilities (lanes and paths), implementation of traffic calming measures, improved bicycle-transit integration, establishment of bike sharing programs, and promotional events. Another study that reviewed current installations in 14 cities found significant increases in bicycling mobility after they adopted comprehensive packages of interventions [5]. The study concluded that public policy plays a critical role in encouraging bicycling; to increase bicycle usage, a comprehensive package of several complementary interventions is required.

Bicyclists select routes based on criteria such as length of trip, frequency of left turns, intersection traffic volumes, and slopes [6]. These findings suggest that bicyclists select routes based on specific preferences, avoiding perceived high-hazard locations and opting for cycle paths, if available. However, it is not clear whether they are always aware of hazardous situations or alternative routes. Moreover, the route selection for commuter bicyclists is more sensitive to route length than other route characteristics. Bicyclists generally prefer separate facilities or at least bicycle lanes [7, 8]. Commuter bicyclists prefer on-street bike lanes over paths because lanes follow the road network and provide more direct routes [9]. Previous studies have indicated a positive correlation between cycling levels and the supply of bike paths and lanes [10, 11].

The National Documentation Project (NDP) is an annual bicycle and pedestrian count and survey effort that documents usage and demand of facilities for bicyclists and pedestrians [12]. The NDP uses a combination of traffic count and surveys to estimate non-motorized transportation needs and provides local agencies with hard-to-collect data so they can make better-informed decisions when planning infrastructure improvements. A similar survey has been administered in Europe to understand the issues people face traveling in urban areas and determine policies to achieve the goals set forth in Urban Mobility plan [13], which phase out conventionally fueled cars by 2050. The survey focused on defining transport habits, problems in cities, and ideas on improving travel. Fifty percent of the survey's respondents indicated they never use a bike as an alternative to cars; just 12% said they opt for bicycles as an alternative daily [14].

Although surveys are used routinely to understand bicycle usage in the USA and Europe, no comparative studies have been performed that systematically compare the preferences and attitudes of bicyclists. This study fills this gap and provides much-needed insights into how bicyclist attitudes vary between countries.

3 Methodology

A web-based survey was developed to solicit responses about bicyclist attitudes, opinions about bicycle infrastructure. The survey targeted audiences in two cities: Lexington, Kentucky, in the USA and Catania, Sicily, in Italy. While both cities are home to approximately 250,000 residents, their respective bicycle infrastructures differ significantly. Lexington has over 40 miles (64 km) of bicycle facilities (paths, lanes, and shared facilities), while Catania has a network of less than 5 miles (8 km). Originally developed for Catania as part of a research effort to identify infrastructure deficiencies and obstacles to mobility that discourage widespread bicycle use, the survey was also administered in Lexington to compare the responses of US and Italian bicyclists and determine the potential impact of infrastructure extent on their views.

The length of the survey was short to maximize completion rate and contained five parts: demographic questions, questions about bicycle usage and impediments to bicycling, a list of items that would help increase the use of bicycle as a transport mode. Participants had the option as well to add responses not included in the lists. Preferences were recorded using a 6-point Likert scale without ties to force a decision. The survey web-link was disseminated through email lists, social media and bicycle events. A total of 329 people took the survey; 195 in the USA and 134 in Italy.

A statistical analysis was undertaken to determine whether there was a consensus in the rankings of each group of participants and compare responses from the two cities. Kendall's coefficient of concordance (W) was used to estimate consensus on the rankings within each group of participants, and the U Mann-Whitney test was selected to detect differences in the rankings between the survey participants from each country. These tests were considered appropriate given the type of available data (i.e., ordinal data with rank orders and different sample sizes) [14].

4 Survey Results

4.1 Demographics

The questions on participant demographics showed similar levels of gender participation between counties, with males making up approximately 65% of respondents in both surveys. The age distribution was slightly different: the mean age in Catania was 33.9 with 41.8% of participants in the 25–34 age group, while in Lexington the average age was 43.5 with 31.1% in the 35–44 age group. The final demographic question asked about income to understand the relationship between it and bicycling preferences and attitudes. This question was not answered by 36.2% of the participants in Catania, while just 9% in Lexington did not respond. Overall, gender and age distributions of the participants were similar in both cities.

4.2 Frequency of Use

Frequency of bicycle use differs to some extent between Lexington and Catania. In Lexington, 45.9% of respondents use a bicycle as their primary mode of transportation each day, while just 19.6% in Catania do. The percentage of respondents who use their bike every day or more than four days per week as a primary transport mode widens this difference—64.4% in Lexington do so, while 28.3% in Catania do. These trends were similar for specific trip purposes as well, when combining the categories of daily and more than four days per week usage. In Lexington, 74.5% of respondents use bicycles to go to school or work compared to 33.3% in Catania. Furthermore, 47.2% of respondents said they bicycle to exercise, while only 8.2% in Catania do. The only area in which this trend reversed was shopping trips. A larger percentage of respondents in Catania use bikes for shopping trips (33.3%) than in Lexington (24.1%).

A question about weekly trip length also revealed differences in the behavior of the cities' bicyclists. Nearly half of the Lexington participants (48.6%) said they travel more than 15 miles (24 km) per week—an average of approximately 13.9 miles (22.4 km). Catania bicyclists noted an average distance of 5.4 miles (8.7 km) per week and the majority (54.4%) travel less than 1.25 miles (2.0 km) per week. A comparison for weekly trip distance by trip purpose did not yield additional findings, repeating the patterns observed previously. An overwhelming majority of Catania participants (85.8%) said that they travel less than 5 miles (8 km) weekly on a bicycle as a primary means of travel while almost an even percentage in Lexington noted that they use bike as a main mode for transport for short (less than 5 miles: 45.3%) and long distances (more than 10 miles: 38.8%).

4.3 Impediments to Bicycling

The next set questions attempted to identify potential impediments to bicycling. There were two questions: one focused on infrastructure issues and a second examined aspects of the roadway environment that could discourage bicycling.

For both cities, a key reason respondents gave for not cycling is the absence of bicycle infrastructure (Table 1). For Lexington, this was noted as the most important reason 36.7% of the time and for Catania 42.5%. If the presence of narrow travel lanes is counted as an infrastructure deficiency impeding bicycle use, these figures climb to 67.2% for Lexington and 47.7% for Catania. The second most cited impediment (total of both: 62.1% for Lexington and 37.3% for Catania) was lack of bicycle infrastructure. Pavement condition was the third highest ranked justification respondents gave for not bicycling, with 18.6% of participants in Lexington citing this and 29.1% in Catania. Many respondents marked this as their second choice as well. The mean rank order for the impediments shows, overall, a different ranking between the participants of the two cities. The top two choices in roadway environmental impediments are for both cities high volumes of vehicles and aggressive driver behavior. The top three choices for roadway infrastructure impediments are the same for both cities, however they are ordered differently.

Table 1. Mean scores for impediments to bicycling.

City	Roadway infrastructure impediments					
	No bike parking	No bike lane	Narrow travel lane	Poor pavement	No street light	Many intersection s
Lexington	4.52	**2.44**	**2.18**	**3.01**	4.72	4.15
Catania	4.25	**2.34**	**3.67**	**2.79**	4.04	3.90
	Roadway environmental impediments					
	High volumes	Aggressive drivers	Modal connectivit y	Weather	Pollution	Destination distances
Lexington	**2.41**	**1.94**	3.65	**3.20**	4.72	4.08
Catania	**2.45**	**2.34**	3.72	4.80	4.08	**3.61**

Note: 6-*point Likert scale 1: most relevant; 6: least relevant. Bold figures denote top choices*

The Kendall's W values were 0.345 (p = 0.000) for Lexington and 0.165 (p = 0.000) for Catania, indicating overall agreement among participants on the ranking of each impediment. This agreement was weak for Catania and moderate for Lexington. Results of the Mann-Whitney U-tests showed that Ho (i.e., there is no agreement between the participants from the two cities) cannot be rejected for the rankings related to no bike lanes (p = 0.357), many intersections (p = 0.129), poor pavement (p = 0.090) and no bike parking (p = 0.188). However, it was rejected for the narrow travel lanes and no street lights (p = 0.000). This may indicate the importance that each of these impediments have within the specific population and reflect overall perceptions.

The survey also investigated which roadway environmental factors influenced respondents' bicycling tendencies. In both cities, a primary obstacle to bicycling is aggressive drivers (Table 1). In Lexington, 47.5% of respondents identified this as the most important reason, while 40.3% of Catania participants ranked it as such. High traffic volumes were the second most frequently cited reason, with 25.4% of Lexington participants and 24.6% of Catania respondents ranking this at the top of their lists. These reasons were often noted as the second most important as well. The Kendall's W values were 0.44 ($p = 0.000$) for Lexington and 0.26 ($p = 0.000$) for Catania, which indicates that participants' rankings agreed overall. However, this agreement was weak for Catania and moderate for Lexington.

The mean rank order of environmental impediments reveals participants in Lexington and Catania had different overall rankings. The Mann-Whitney U-tests showed a significant difference in the rankings assigned by participants for weather, pollution, aggressive drivers, and modal connectivity (i.e., $p < 0.05$). Catania residents expressed greater worry about pollution and modal connectivity, while Lexington bicyclists were more apprehensive about weather conditions and aggressive drivers. Weather was not highly important for the Catania participants since the climate is more temperate and winters are not severe. Comparatively, Lexington experiences more severe weather and has a greater number of days with inclement weather (e.g., rain, snow, and ice). It was not possible to reject the hypothesis of equal rank for high traffic volumes ($p = 0.665$) and destination distances ($p = 0.592$). The results show that universally high traffic volumes could impede bicycling, while the other variables could be of greater importance based on the local experiences and conditions.

A question was also included aiming to identify potential interventions to reduce or eliminate bicycling impediments. Respondents in Lexington (81.4%) and Catania (85.1%) overwhelmingly favored the addition of new bicycle infrastructure, citing it as the most important intervention. Improving pavement conditions was ranked as the section option by respondents in both cities (39% in Lexington; 65.7% in Catania). Based on these responses, clearly respondents believe that correcting or improving infrastructure will encourage significant increases in bicycling.

The Kendall's W values for Lexington were 0.35 ($p = 0.000$) and 0.19 ($p = 0.000$) for Catania, indicating that participants exhibited overall agreement in their rankings of each impediment. This agreement was weak for Catania and moderate for Lexington. The mean rank order for the interventions shows, overall, a similar ranking by participants in both cities. The Mann-Whitney U-tests indicated that it is not possible to reject the null hypothesis of equal rank between the participants from the two cities for bike lanes ($p = 0.324$) and bike parking ($p = 0.151$). The null hypothesis (Ho) was accepted (i.e., $p < 0.05$) for the other items, with only slight differences between the ranks except for modal connectivity, which was classified as more important in Catania than in Lexington. This may be attributed to Catania lacking public transportation provisions to accommodate bicyclists; this is an issue of lesser importance in Lexington, since all public buses are equipped with bicycle transport equipment.

5 Conclusions and Discussion

This paper described the findings of a survey conducted to identify attitudes and opinions of bicyclists is two cities in Lexington, Kentucky, USA and Catania, Sicily, Italy. Survey respondents ranked impediments to bicycling as well as the potential efficacy of different interventions for removing obstacles to safe bicycling trips.

Survey results could reflect the presence or absence of bicycle infrastructure. Respondents in Lexington tend to bike more miles per week than those from Catania, possibly due to a more robust bicycle network, which accommodates longer trips and greater commute frequency. This was also reflected in statistics of the number of respondents using their bicycles either daily or more than four days per week. Another item that indicates the infrastructure effects is modal connectivity. This was not a concern for respondents in Lexington, where public transportation facilities accommodate bicycling, while the lack of modal connectivity made this a much more salient issue for bicyclists in Catania.

Survey participants in both cities overwhelmingly said that lack of quality infrastructure is a major impediment to bicycle usage; this finding mirrors the results of previous research. Factors such as presence of bicycle infrastructure, in the form of bicycle lanes, paths, or cycle tracks, and pavement conditions, have been identified as features that could encourage bicycling. Respondents' identification of interventions to improve bicycling conditions and increase the number and frequency of bicycle trips underscored this fact.

Statistical analysis indicated weak to moderate agreement among respondents. This may be the result of having small samples. Additional surveys may provide more robust statistical findings. A deeper investigation of how demographic characteristics (e.g., gender, income level, frequency of cycling, cycling distances) influence bicyclist attitudes and perceptions could be beneficial as well. The limited dataset used for the analysis described in this paper does is not sufficient to conduct a more thorough examination of demographic influences. Additional surveys should be administered to collect these data [15]. Another approach that can be used to further examine the effects of local context, is a multi-round survey (Delphi technique) where after each round the results of the previous round are given to the participants as feedback to influence their opinion [16].

Overall, the survey's findings demonstrate that bicyclists around the world hold similar opinions on what improvements are required to promote cycling and enhance their experiences. Agencies wanting to increase bicycling in their jurisdictions must improve infrastructure. However, in the current economic environment there is less money to fund infrastructure, and transportation agencies with shrinking budgets are challenged to justify all investments, especially those designed to increase bicycling as transportation mode.

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Behavior and Perceptions of University Students at Pedestrian Crossings

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Abstract. Students' behavior and perceptions at pedestrian crossings is investigated in the framework of the present paper. The research concerns five pedestrian crossings at signalized intersections which are located in the road network around the Aristotle University of Thessaloniki. A total number of 500 questionnaires addressed to students using the specific crossings were collected during spring 2013. In addition, counts concerning pedestrian flows were made as well as pedestrians' observations regarding their distraction while they were using the crossing. Moreover, traffic data, such as volume and free flow speed, used for the statistical analysis. Descriptive statistics used in order to describe pedestrians' behavior and views towards the specific pedestrian crossings, while inferential statistics aim to identify pedestrian crossings' characteristics and pedestrians' characteristics which affect their habits and perceptions. Statistical analysis concludes with the development of a binary logit model which aims to quantify the impact of specific parameters on pedestrians' opinion about the sufficiency of green light duration.

Keywords: Pedestrian crossing · Road safety · Signalized intersections University campus · Binary logistic regression model

1 Introduction

The issue of road safe crossing by the pedestrians consists an important research field at international level due to the fact that pedestrians are vulnerable road users. It was found that the variables which contribute to the possibility of violating behavior of pedestrians at signalized intersections concern the number of lanes, gender, crossing length, acceptable waiting time, traffic volumes, number of accompanying persons etc. [1]. Age plays a key role for the decision of pedestrians to cross the road with risk. More specifically, it was found that it is less possible for elderly people to cross the road with risk [2]. The increase in the number of pedestrians at crossings is associated with reduced accident risk for each pedestrian according to a research in Oslo [3].

Built environment is associated with the safety level as perceived by the pedestrians and with the actual safety level. Residents living in low density residential areas possibly consider their areas as more unsafe compared to residents of mixed land use

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despite the fact that in the second case more accidents have been recorded [4]. Weather conditions also affect pedestrians' behavior. Average walking speed increases as temperature falls in winter according to a research concerning crossing of road equipped with safety island. At the same time it is more possible that pedestrians' compliance to traffic lights will be reduced [5].

Pedestrians' crossing safety is directly associated with vehicle turning movements. The issue of left turn movements in relation to pedestrians' safety at intersections has been investigated and modelled in the framework of a wider effort aiming at the development of a simulation tool for the safety evaluation at signalized intersections [6, 7].

It has been noted that the decision concerning road crossing is based on the distance between the pedestrian and the oncoming vehicle [8]. The behavior of pedestrians when crossing the road in relation to the gap acceptance can be modelled and such a research took place in Mumbai [9]. As far as waiting time for the pedestrians at signalized crossings is concerned, it was found that pedestrians' arrival time at the intersection has a small impact on their behavior [10].

An important part to road safe crossing, especially for young pedestrians, concerns the use of mobile Internet applications which leads to distractions. It was found that attention distraction leads to increased accident risk for university students [11]. At the same time, the use of mobile phone could lead to the provision of information to pedestrians concerning the location of crossings or the presence of oncoming vehicle, thus reducing the risk for the pedestrian if he/she took advantage of the information provided [12].

Gender also plays a role to pedestrians' behavior when they cross signalized and non-signalized intersections while using their mobile phone. The different impact among women and men could be explained by the different, more demanding, attention paid to conversation over the phone by the women [13].

Type of traffic signals is associated with the safe crossing of roads. According to a research which took place in the Municipality of Kalamaria, Thessaloniki [14], where countdown signal timers for the pedestrians were installed, pedestrians have a particularly positive attitude towards such systems. The impact of that type of traffic signals on pedestrians' behavior has also been investigated [15]. In some cases, like in Lima, it was found that traffic signals for the pedestrians are not associated with their safety and the importance of traffic police presence is stressed [16].

Pedestrian trips in university campuses are of great interest and they can be considered in the framework of the design and implementation of travel plans from the university authorities. There were many respective efforts in the campus of the Aristotle University of Thessaloniki [17, 18]. The evaluation of an informational campaign for road safety referencing to pedestrians in the University of South Florida led to the conclusion that the campus became an area friendlier for the pedestrians and the bikers after the campaign [19].

Taking into account all the above mentioned findings from international research, it was considered as necessary to have an insight in the field of pedestrians' behavior and perceptions at signalized crossings. Since the youth is one of the most interesting population groups, in terms of mobility and vulnerability, the present research selects to examine students' behavior and perceptions at five signalized intersections in the perimeter road network of the campus of the Aristotle University of Thessaloniki (A.U. Th.). A questionnaire-based survey was designed and addressed to the university students. A number of 500 questionnaires were finally collected and analyzed. Moreover, pedestrian flows were recorded in the study area and observations were also made about the distractions of the pedestrians when they cross the road [20].

2 Description of the Undertaken Research

2.1 Study Area

The five pedestrian crossings which were examined include:

- One pedestrian crossing in the signalized intersection Ethnikis Amynis – Egnatia Road. This intersection is the nearest of all to the city center.
- One pedestrian crossing in the signalized intersection A.U.Th. Avenue – Egnatia Road. This intersection is located near the central library of A.U.Th.
- One pedestrian crossing in the signalized intersection of the International EXPO of Thessaloniki.
- Two pedestrian crossings in the signalized intersection Third Septemvriou – Egnatia Road. The first one is close to the University Student Club A.U.Th and the second is located near the University of Macedonia.

2.2 Questionnaire Survey

As mentioned above, 500 questionnaires were collected at the five pedestrian crossings of the signalized intersections. The survey took place during March – April 2013 in relatively good weather conditions. It was decided for the purposes of the research that 100 questionnaires would be collected in every crossing.

The questionnaire includes two sections with a total number of sixteen questions. The first section includes seven questions and it refers to the general profile of the pedestrians who participated in the survey (gender, age, occupation, education, monthly household income, possession of a private car, use of a private car). The second section includes nine questions and it refers to the pedestrian crossing behavior of the respondents as well as the factors which influence this behavior (frequency of crossing, use of the crossing, compliance with the traffic lights, safety feeling perception, countdown signal timers, decision to cross the road, duration of green light indication, priority for the pedestrians, unsafety feeling perception).

2.3 Observations and Traffic Data

Additionally, to the questionnaire survey, pedestrian flow measurements during peak hour, observations for pedestrians' distractions, timings for pedestrians' green light duration and recording of intersections' geometrical characteristics took place. Observations were made about the behavior of the pedestrians in each pedestrian crossing. More specifically, for a number of 100 pedestrians the number and type of distractions was recorded. Two types of distractions were considered for the purpose of the present research as following: (a) pedestrians talking to each other when using the crossing (b) use of mobile phone when using the crossing. Peak hour period selection at each crossing took into account the operation of specific land uses in the near area of the crossings which attract large number of students on a daily basis (e.g., A.U.Th students club). Furthermore, traffic data from Thessaloniki's Traffic Model [21], which was prepared by the Transport Engineering Laboratory, School of Civil Engineering Aristotle University of Thessaloniki, was used. More specifically, the data used were traffic volumes, capacities and free flow speeds for the links which cross the specific pedestrian crossings.

Both sets of data (questionnaires and observations/traffic) are supplementary towards the development of the binary logistic regression model. It should be mentioned that it was not feasible to curry out the interviews at the same time where the counts were made, due to human resources limitations.

3 Statistical Analysis

3.1 Descriptive Statistics

Descriptive statistics aim to provide an overview of the sample, as well as respondents' habits and perceptions.

The sample consists of 256 (51.2%) women and 244 (48.8%) men. 460 (92%) of the respondents are less or equal to 24 years old. Moreover, 480 (96%) of the respondents are undergraduate students. The vast majority (95.8%) stated that there is a private car in their household, while 170 (34%) of the respondents use private car for their daily trips. More than half of the respondents stated that they use the under study crossing up to 20 times per month while only 33 (6.6%) of them use the specific crossing more than 90 times per month.

It is notable that, despite the presence of the traffic lights, 140 (28%) of the respondents stated that they usually cross the road without using the pedestrian crossing. For those who usually cross the road using the pedestrian crossing there was a question about the most usual way of crossing with regards to the traffic light indications for the pedestrians. It is concluded that the percentage of pedestrians who stated that they cross the road only when the traffic light indication is green for them is not so high (62%).

Concerning the feeling of safety for the pedestrians when they cross the road it is concluded that around one out of four of the pedestrians feel less safe or not at all safe while only 19 (3.8%) of the respondents feel far too safe. 377 (75.4%) of the respondents stated that the installation of countdown signal timers for the pedestrians in the under study intersections could make them feel much safer.

The most influential factor in pedestrians' decision to cross is the speed of the incoming vehicle while indication of traffic light, time pressure and traffic volume have also great impact. On the other hand, distance from the crossing and number of people prepared to use the crossing were not so popular answers. It must be mentioned at this point that the respondents could gave more than one answer to the specific question. Results concerning the question of whether the green light duration for the pedestrians is considered as sufficient demonstrate that the vast majority (70.6%) of the respondents is not satisfied. The knowledge of Highway Code regulations about pedestrians' rights is examined by asking the respondents whether pedestrians are aware of the fact that drivers have to give priority to pedestrians at pedestrian crossings. Results show that pedestrians are aware to a great extent that drivers have to give priority at pedestrian crossings. However, there is still a notable percentage of 15.8% of the respondents which seems to be uninformed about this Highway Code regulation.

The results regarding the factors which create the feeling of unsafety to pedestrians when they use the pedestrian crossing demonstrate that simultaneous movement of vehicles and pedestrians is the most important factor which create unsafety for the pedestrians (50%) while red light violations from the drivers (31.8%) and insufficient green light duration for pedestrians (30.4%) also have significant impact on their perceived safety. It must be mentioned at this point that the respondents could gave more than one answer to the specific question. Red light violations from the drivers in Thessaloniki, consist a subject for which have already been attempts to investigate [22].

Finally, the descriptive statistical analysis of pedestrians' distraction shows that a high percentage of pedestrians talking to each other (36.3%) or using their mobile phone (10.8%) when using the crossing.

3.2 Inferential Statistics

Inferential statistics aim to identify pedestrian crossings' characteristics and pedestrians' characteristics which affect their habits and perceptions. For that purpose, Pearson correlation coefficient (r) used.

Functional attributes of the intersections and gender found to have strong correlation with pedestrians' habits concerning their decision to cross the road using the crossing or not. More specifically, pedestrians are more likely to use the crossing when traffic volume is increased ($r = -.137$, $p < 0.01$), speed of vehicles is increased ($r = -.122$, $p < 0.01$) or pedestrian flow is elevated ($r = -.118$, $p < 0.01$). Moreover, women are more likely than men to use the crossing ($r = -.171$, $p < 0.01$). Also, women are much more likely compared to men to cross the road when the traffic light indication is green for them ($r = -.214$, $p < 0.01$). Regarding pedestrians' perceived safety, it was found to be improved in cases of low traffic volume ($r = .125$, $p < 0.01$) and low pedestrian flow ($r = .123$, $p < 0.01$). Also, men are more likely to perceive high levels of safety ($r = .172$, $p < 0.01$). Finally, concerning the duration of green light for pedestrians only gender and frequency found to have statistically significant impact on pedestrians' feeling. Men are more likely to evaluate the duration of green light as sufficient ($r = .125$, $p < 0.01$) and the same applies for the less frequent passing through the specific intersections ($r = .111$, $p < 0.05$).

3.3 The Binary Logistic Regression Model

In the framework of the present paper, modeling of pedestrians' feeling about the duration of green light for the pedestrians is selected. The reason why this variable was chosen is that it constitutes an indication of pedestrians' perceptions and at the same time can significantly affect their behavior (cross without using the crossing or during red light indication). Taking into consideration the measurement scale of the variable (categorical dichotomous variable) a binary logistic regression model is used. The purpose of the model is to identify variables which have an impact on pedestrians' feeling about the sufficiency of green light, as well as to quantify that impact.

In the binary logistic model of this paper, the possibility of perceiving the duration of green light for the pedestrians as sufficient or insufficient is estimated. After several tests, traffic volume, gender and frequency of using the crossing selected as independent variables.

Model summary is presented in Table 1, where Nagelkerke R-Square suggests that the model can explain approximately 24.6% of the variance. It must be also mentioned that the prediction accuracy of the model is approximately 71%. Table 2 presents the beta estimates of the binary logistic regression model, the standard error, the Wald statistic, the significance level and the exponential of the beta estimates.

Table 1. Binary logistic regression model summary.

-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
590,963	.185	.246

Table 2 shows that traffic volume increase by 100 vehicles per hour results in an increase of the probability of perceiving the green light duration as insufficient by 1.105 times. Moreover, women are 1.954 times more likely than men to perceive green light duration as insufficient. Finally, pedestrians who regularly use the specific crossing are 1.333 more likely to feel that green light duration is insufficient compared to those who rarely use it.

Table 2. Parameter estimates for the binary logistic regression model.

	B	S.E.	Wald	df	Sig.	Exp(B)
Traffic volume peak hour [veh/h]	.001	.000	6.571	1	.010	1.001
Gender	.670	.181	13.699	1	.000	1.954
Frequency of using the crossing	.287	.082	12.374	1	.000	1.333

4 Conclusions

A direct conclusion derives from descriptive statistical analysis is the noncompliant behavior of the pedestrians around the University Campus. Despite the fact that there are traffic lights in the under study intersections, 28% of the respondents stated that they prefer to cross the road outside the signed crossings, something which increases the possibility of a traffic accident. What is more, only 62% of them cross the road during the green light phase for the pedestrians. In addition, pedestrians use to talk to each other and use their mobile phones when using the crossing. Pedestrians' indifference to traffic rules is partly attributed to the fact that the traffic environment is generally designed from the point of view of motorized traffic.

Inferential statistical analysis demonstrates that gender is strongly correlated with pedestrians' perceptions and behavior. Men tend to be more satisfied from crossing's safety level and green time duration. At the same time, they show unaware of the dangers as in many cases they cross the road outside the signed crossings or they cross during the red light phase. Moreover, pedestrians' habits and perceptions are also affected by intersections' functional characteristics such as traffic volume, pedestrian flow and vehicles' speed.

The interpretation of the binary logistic regression model reveals that pedestrians' feeling about the duration of green light is mainly affected by pedestrians' characteristics (gender) and traffic habits (frequency of using the crossing). However, traffic volume has also an impact. A plausible assumption for that conclusion is that an increase on traffic volume does not allow pedestrians' pass through during red light phase and as a result they expect increased green light time.

Recommendations for further research include the examination of more sites, as well the investigation of the impact of weather conditions on pedestrians' behavior.

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Influence of ICT Evolution and Innovation on Travel and Consumption Behaviour for Determining Sustainable Urban Mobility

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Abstract. The paper analyzes possible changes in people's urban mobility, understanding if and how the evolution of behaviours in connection with the ICT innovation and/or evolution, the development of digital tools (Internet, smartphone and transport applications) could facilitate travel practices. Our research field is the "Nouveau Mons" district within the European Metropolis of Lille (MEL) which has undertaken significant changes thanks to the national policies of urban regeneration. We analyze the articulation of its inhabitant's mobility within and outside the district (daily travel: work, school, shopping, etc., or more punctual movements: holidays, leisure …) and new consumption practices (Internet, Drive …). We consider their consequences in terms of development at a neighbourhood scale (offer of shared mobility, delivery points for urban freight), development of active transport modes (walking and cycling) facilitated by the short distances to be travelled in this neighbourhood that is very well innervated and served by public transport. We have conducted interviews with representatives of the city and realized focus groups with the "Nouveau Mons" inhabitants or workers.

Keywords: ICT · Travel behaviour · Focus groups

1 Introduction

Much has been written about the impacts of the late 20th century's digital revolution on mobility, first with the development of the Internet and new consumption practices (e-commerce) since the 2000s. More recently, the wide spread of individual and mobile communication tools, with their various effects on mobility behaviours, has led to a new series of academic studies. Researchers showed that ICTs modify the way people are travelling, which is part, more broadly, of households' whole daily routine. Aguilera and Rallet [1] identify three types of services which can directly affect mobility practices such as, firstly, services which help people to organize their travels, such as applications providing itineraries and real-time schedules and information. The second type of services is the possibility to use ICTs as an entertainment during the trip or while waiting for a transport connection, which changes the perception of the travel time and its utility. Thirdly, ICTs can stimulate the development of new mobility

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services such as carpooling or car-sharing, based on the coordination in real-time between supply and demand.

The paper is divided into 5 sections. After the introduction, the second section exposes the research question. The third section describes the research field. The fourth section presents the qualitative methodology choice and the focus groups organization and the content of the questionnaire. The fifth section discusses the first main results and the sixth section gives the conclusion and perspectives.

2 Research Question

The research aims to understand if and how people's behaviours have been changed in relation to the development of digital tools (Internet, smartphone, etc.). The approach is territorial, focusing on a particular neighbourhood.

Several assumptions are underlying this work. The first is that the use of digital tools and its impact on people's mobility is different according to people's age, professional activity, daily habits, spatial practices, digital literacy. These differences will be reflected particularly in the way they organize their travels and in their reflexes to address everyday situations. Moreover, digital tools could present different utilities for different persons. Indeed, mastering such tools could be more useful for working people who travel a lot and/or quite far, especially if they need to save time. Besides, different people will probably chose different uses of digital tools; some of them could prefer services to optimize their travels, while others would mainly use them as an entertainment during travel time. The last assumption linked with the socio-economic characteristics of our research field is that solidarity or sociability networks could be developed within the neighbourhood and constitute a resource for low-income population, which can make mobility less necessary in some daily life situations, as described by Fol [2]. Thus, we assume that the impact of the digital revolution on people's mobility could be less significant than what the widespread ideas on this subject can suggest, especially at local scale. We develop mainly a qualitative methodology based on focus groups with inhabitants of our research field that where crossed with quantitative data obtained by questionnaires enquiries.

3 Research Field

The research field is located in Mons en Barœul, in the European Metropolis of Lille (MEL) territory, in the Northern part of France. The neighbourhood, called the "Nouveau Mons", was built in the 60's with a very rapid urbanization characterized by a landscape of high towers of housing and large blocks of buildings. Degradation of habitat and social difficulties rapidly emerged; that conducted the municipality to undergone significant changes within the framework of the national policy of urban regeneration, led by the ANRU (French Agency for Urban Renovation). With the renovation policy, reconstructions and rehabilitations were planned linked to important work on green spaces, pedestrians' pathways and amenities. In 2014, the "Nouveau Mons" became an "eco-quartier", a national label awarded to neighbourhoods that have integrated a sustainable development dimension and taking into account ecological transition concerns. Nowadays, the “Nouveau Mons” counts 12.200 inhabitants, with a modest socioeconomic profile, a large part of low-income households, and a net income median significantly lower than the MEL median (Table 1).

Table 1. Comparison between the “Nouveau Mons” and other scales.

	«Nouveau Mons»	European Metropolis of Lille	Hauts de France Region	France (metropolitan territory)
Density (inhabitants/km^2)	14776	1854,3	188,8	104,2
Households	5067	483795	2491007	28766069
Families with children (%)	41%	38%	40%	36%
Single-parent families (%)	15%	11%	10%	9%
Owned lodgement (%)	18%	50%	58%	58%
Rented lodgement (%)	82%	49%	41%	40%
No car at all (%)	35%	25%	19%	19%
Only 1 car	51%	48%	47%	47%
2 cars or more (%)	14%	27%	34%	34%
Net income median (€)	15183,1	19308,5	18812,0	20369,0
Unemployed, 15–64 (%)	27%	17%	16,9%	14%
No-diploma population >15 (%)	41%	32%	36%	31%

The “Nouveau Mons” is an eighty hectares sized neighbourhood, less than 1 square kilometre, meaning that distances are relatively short and it is easy to be crossed by foot. Most of the shops are located outside this neighbourhood; however, it is well innervated by public transportation with three metro stations, three bus routes and a special bus route named “the Corolle” that links this town to Villeneuve d’Ascq hosting several commercial malls. It is also possible to reach the city-centre of Lille, with its various shops and amenities, in less than ten minutes by the subway. The “Nouveau Mons” benefits of a strong associative life which constitutes a resource for the population and allows creating mutual assistance networks within the neighbourhood.

4 Methodology

The research aims to identify differences in the way people's mobility habits change, depending on their profile; thus, focus groups seem to be a very appropriate methodology. They allow identifying, for each group of people, their specific behaviours and ideas; different factors that participate to change mobility practices appear.

4.1 Focus Groups Organization in the "Nouveau Mons"

With the help of the city mayor Rudy Elegeest and of the citizen council[1], seven groups have been constituted. In order to reach teenagers, two focus groups have been organized in the Secondary School "Collège Rabelais". A focus group has been led in the "Imagine" community centre with old ladies and another with a group of parents attending a cooking workshop in the "Caramel" association. Some low-income people were met through a focus group with ten beneficiaries of a solidarity grocery; six volunteers of this association participated to another focus group. Finally, a group has been constituted with ten residents of the "Europe towers", a large residence of high buildings of private housing. The discussions were recorded but there was no opposition to this procedure as the records will be erased at the end of the research. Participants' anonymity was guaranteed. They were volunteers and received no incentive.

During a focus group, three themes are discussed, firstly about their mobility practices and their use of digital tools and how they link or not these two aspects, secondly about their territorial appropriation at a local or wider level and thirdly their impression about the quality of public transportation and their life in the neighbourhood.

All the participants are asked to indicate on a map of Mons en Barœul focusing on the "Nouveau Mons" neighbourhood and on a map of Lille's region, the different places they are used to go. They put a cross on the place where they live, a triangle where they work or study, a square on the places they go to shopping, a heart where they go to see family or friends and a circle where they are used to practice sport or have leisure time (Fig. 1). Inside those different forms, they indicate a number specifying how many times per week they frequent those places. These exercises give us keys to understand to what extent inhabitants' practices are focused on the "Nouveau Mons" neighbourhood and its nearest surroundings or turned towards the outsides.

[1] In 2014, a law called MAPTAM [3] has created citizen structures called "citizen councils", mandatory for neighbourhoods having benefited from the French program of urban policy to encourage citizen participation within those neighbourhoods.

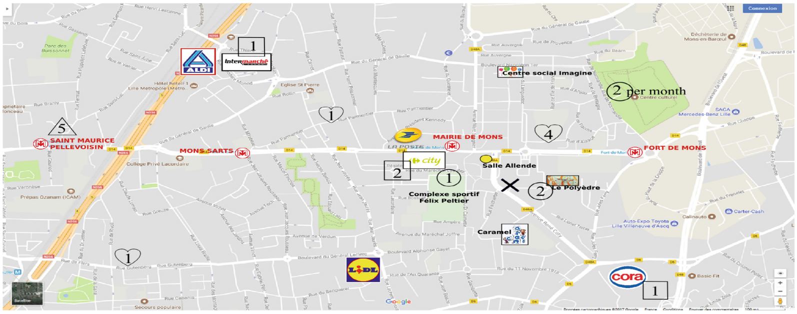

Fig. 1. Model of a map filled with frequented places.

4.2 A Questionnaire as a Complement to the Qualitative Methodology

A questionnaire was filled by the focus groups participants either before or during the meetings. The questionnaire also has been transmitted to a wider sample of "Nouveau Mons" inhabitants, in order to arouse the interest of volunteers for a focus group among them, and also to obtain information about residents even if they didn't accept to attend a focus group.

The questionnaire is composed by closed-ended questions but includes also open-ended questions, to broaden the results obtained by the focus groups. It contains mainly questions about travel practices, main modes of transportation used, digital equipment, digital literacy, use of these tools before and during travel, points of view about public transportation and subway and buses stations in the "Nouveau Mons". The questionnaire gives the possibility to rely the way people use digital tools for mobility with their sociodemographic characteristics.

5 First Findings

5.1 Focus Groups First Findings

When discussing with the 71 participants, we tried to identify their reflexes to organize their travels, by proposing scenarios and asking them how they would react in several situations. The findings show differences between youth practices, parents' practices, retired people's practices, etc. When they have to reach an unknown destination, the elderly still have the reflex to ask somebody to help them, for example a staff member of Transpole, the public transport company. They say: "I prefer human contact to machines". By contrast, the teenagers' first reflexes are to check their itinerary and schedules on a website or a smartphone application like Google Maps or Waze. Moreover, they do not dare to "bother" somebody, as they say, by asking for directions. Thus, reflexes are very different according to the age, the habits to use digital tools and the travel habits.

When discussing about the quality of public transportation in the neighbourhood and of the subways and buses stations needs such as some digital services, the results show that people seem to be more preoccupied by security in the stations than by a lack of services or amenities. Some inhabitants think that digital amenities, such as real-time schedules or a pick-up station to collect their parcels ordered on the Internet, are interesting or useful when we ask them, but they do not mention it spontaneously by themselves. Anyway, the teenagers from the Rabelais Secondary School, more used to online shopping than the others, are more enthusiastic than adults about pick-up boxes in the subways stations because they are opening late in the evening.

About their life in the “Nouveau Mons”, their local practices, the amenities, the neighbourhood’s evolution, the inhabitants regret a lack of convenient stores; a much appreciated low-prices supermarket closed and was replaced by another brand more expensive. The new one does not respond to the needs of the low-income population of the neighbourhood (Table 1). Shops are mostly located outside the neighbourhood. Leisure activities are also quite limited or too expensive according to the different groups of inhabitants we met. This explains that a significant part of leisure and shopping practices are realised outside of this neighbourhood.

Different types of practices emerge from the analysis of the maps. The following description is based on the analysis of the maps of three different focus groups’ participants, the two groups hold in the solidarity grocery and the focus group with inhabitants of the collective ownership. Those three groups comprise 3 active people, 5 unemployed people, 9 retired people with volunteer activities and 4 retired people without associative activities. 4 kinds of practices can be identified. The first one regroups persons who have limited habits, focused on the “Nouveau Mons” and not varied – purchasing practices, a few leisure activities and some visits to family and friends. It counts seven persons, all retired and not very mobile. Most of them do not use ICTs, except to communicate with their family and friends. Six persons belong to the second kind of practices; they are also focused on the “Nouveau Mons”, but more intense and more varied, with purchasing practices but also cultural, social and associative ones. Five persons are retired and one is unemployed; all of them are involved and members either in local associations, co-owners trustee or in the city council. The third type of practices regroups three persons who also have intense and diversified customs, especially in the “Nouveau Mons” but also more turned towards the Lille’s agglomeration. They have firstly many activities in their own neighbourhood, related to shopping, culture, associations and sports activities; but they also go regularly to Lille for other specific activities (exhibitions, concerts, museums, etc.). Finally, the fourth type counts five persons whose practices are diffuse and not very intense outside of work and take place in Lille as well as in the “Nouveau Mons” Two of them are active and do not have a lot of time for leisure activities. Their practices in the “Nouveau Mons” are mainly related to shopping. Two other persons of this type are unemployed and focus on finding a job; the fifth person is retired. People who regularly use ICTs for their travels are mainly those who work outside of this neighbourhood and are very mobile. People who have intense local habits do not express the need to use ICTs regularly; their use of digital tools for their travels is more punctual.

5.2 Questionnaire's First Findings

We received 120 filled questionnaires. They reveal that almost 80% of the respondents have a smartphone. According to our sample, the number of digital tools is not related with the household income level or economic difficulties. Low-income people, single-parent families or unemployed people do not possess less digital tools than the others. The questionnaire shows also a relationship between age and digital literacy. 76% of the 11–24 years old indicate they can use very easily the Internet or a smartphone; it represents 56% of the 25–64 and only 15% of the elderly (65 years old and more). The questionnaire shows a difference in the way young people and adults use digital tools for their travels. Scholars seem to use their smartphone mainly to occupy their time during the travel, by sending messages, listening music, etc. Young adults also use digital tools for these activities but also in order to optimize their travels (check schedules, itineraries, etc.). Generally, older people do not use these tools a lot to occupy their time during their travel, but rather to optimize the travels.

Among adults[2], 20% often or always check the traffic conditions before a travel. Most of them are car users who travel by car more than once a week. Checking traffic information often leads to a change of plans in case of problems: among those 20%, more than two thirds often adapt their itinerary or their departure time in case of heavy traffic or disruptions. Checking itineraries on a website or an application is also a very common reflex: if they have to go to an unknown destination, 38% always search their itinerary on the Internet, 26% often and 15% sometimes. Finally, the questionnaire indicates that only 37% of the respondents answer that they have connected activities – messages, Internet, social networks, etc. – during their travels. This result is probably related to the absence of Wi-Fi in the Lille's subway.

38% of the adult respondents are more connected than the others, using the Internet both to occupy their travel time and to plan their trips. They are younger (38 years old in average) than the whole sample (51 years old in average). More than a third of them are working people. They often use their smartphone during their travels and have a large sample of activities – videos, Internet, social networks, plays, music, chats with other people… These people who use their smartphone are more accustomed to use ICTs for programming and organising their travels and 80% of them use transport or localisation applications, against 58% of the whole sample. One third of them always or often check the traffic conditions before a travel, against 21% of the respondents. 80% of them use the Internet to look for an itinerary in case of a travel with an unknown destination (64% for the adult respondents). Finally, these smartphone users are also those whose practices have the most changed. 46% of them think that they use now the Internet to organise their travels "much more often" than few years before; for the whole sample of adult respondents, this rate is only 36%. More significantly, 54% think that they use ICTs to occupy their time during travel, against 26% for the whole adult respondents.

[2] In what follows, we didn't include teenagers (11 to 16 years old) in the analysis, because their choices in terms of mobility are limited by the facts that most of them are going to school on foot and that a lot of them still depend on their parents when they go further.

6 Conclusion and Perspectives

Many focus groups participants were recruited among association members, whose activities take place mostly during the day; most of them do not have any professional activity. Working people are less available and more difficult to recruit for a focus group. Thus, results could be biased by the weak number of workers within the sample. Consequently, participants' practices are limited and mainly focused on the "Nouveau Mons". Globally, they do not use a lot ICTs. In the focus group hold with inhabitants of the "Europe Towers", we had the opportunity to collect in-depth information from workers about their practices and points of view. Even though the results of the focus groups cannot be generalised, this information is very useful.

The questionnaire gives information about the evolution of ICTs use in travel practices with a larger sample of respondents. Retired persons and teenagers from the Rabelais Secondary School still are over represented, but one quarter of the adult sample is constituted of workers. Within the questionnaire adult respondents, one third is constituted of people who are particularly connected and use ICT to organize their travels as well as to occupy their travel time. People who are less connected have a limited use of ICT for their mobility and use the Internet mainly to find an itinerary.

A perspective to this research is to study the impact of mobility behaviours' evolution in the context of mobility hubs development, in which the services supply involving digital tools is increasing [4] – cellphones charging terminals, real-time schedules, delivery points for online shopping, etc. It would be interesting to understand how the development of these amenities in transport hubs respond to increasing demand related to new mobility practices, and how it creates new habits or practices in interchanges linked with ICTs use.

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ProMaaS - Mobility as a Service for Professionals

Integrated Sectorial Business Platform for Multimodal Cross Border Mobility

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Abstract. In recent years, multimodal mobility and Mobility as a Service (MaaS) have emerged as fundamental concepts in several professional sectors. This trend comes with a wide number of sector-specific technical and functional requirements, including for example delivery time and location in the construction sector, strict in-time delivery for sensitive materials in the healthcare sector and lower transportation times and overall costs in the logistics sector. In this context, this paper introduces a study towards developing ProMaaS: a platform concept developed to open and extend existing mobility services and technologies by addressing multimodal cross-border mobility issues through the lens of sectorial business approaches. This conceptual solution aims to facilitate the daily mobility of professional drivers in Luxembourg, which due to the country size, has an exceptionally high volume of business-related commuting needs from and to neighbouring countries (e.g. to meet partners or to visit customers).

Keywords: Multimodal transportation · Cross-border mobility Platform · Sectorial mobility · Mobility as a service

1 Introduction

Companies must frequently dispatch and route human and material resources to different business areas [1]. Therefore, many travelling options are available: public transport, private vehicles, company fleet vehicles or shared mobility solutions such as carpooling (using private or company cars). In that regard, the definition of a multimodal mobility solution considering these factor is required for all economic actors (workers, private and public organisations) to save time and money. These platforms already integrate a large set of services such as travel planning, real-time reaction, ticketing, clearing and are already adapted to cope with cross-border specific aspects. However, these solutions mostly target personal or corporate usages, e.g. EuTravel, Bonvoyage, Masai and Faye [2–5]. The objective of this paper is to present Mobility as a Service for Professionals (ProMaaS) platform. This platform aims to open and extend

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the existing technology and business models by developing an integrated solution for addressing the multimodal cross-border mobility through the lens of sectorial business approaches [6]. Indeed, each professional sector has different requirements in terms of multimodal mobility. In the construction domain, an efficient mobility service has to consider requirements such as the delivery time and location for each existing sub-project, planning and scheduling that may change depending on the evolution of the overall project [7]. In the healthcare sector, the dispatching must ensure strict in-time delivery for the materials and conform to specific security constraints [8]. In the logistic sector, the disposition of trucks and drivers – beside conventional requirements – must result in lower transportation times, lower costs for transportation to be accepted by the logistic industry [6]. Considering this diversity in requirements, which are stemmed from different business sectors, ProMaaS is designed on top of methods extracted from the design science research. It mainly consists in an iterative approach during which two mains artefacts are defined and developed [9]. The first artefact, the **Business Mobility Services**, intends to identify and highlights real and pragmatic requirements, from three main business sectors. The second artefact, the **ProMaaS Platform**, intends to provide an innovative service based on the input requirements from the first artefact. In this paper, we first review existing MaaS approaches in Sect. 2. In Sect. 3, we then present three cases of multimodal cross-border issues and requirements in different business sectors and based on these cases, we introduce innovative multimodal cross-border mobility services and the supporting platform in Sect. 4. We then discuss the opportunity arising from the deployment of this platform, conclude the paper and propose future works and perspectives in Sect. 5.

2 Related Work

Recent works address the design of MaaS platforms. Among them: Smart-X that gathers all the functionalities required to monitor and to govern a wide range of specific environments [10, 15]. Smart-X allows (1) the elaboration of cloned generic back-end architectures and (2) the design of business specific front-end interfaces, which both constitute the real specificity of the solution in regard to others approaches. A Smart-X dedicated visualisation module was additionally presented in [11]. Similarly, SeSaMe proposes a self-adaptive middleware infrastructure for highly dynamic and massive smart spaces [12]. SAPERE project proposes a general framework to support the decentralised execution of self-organising pervasive computing services, and Music supports the self-adaptation in ubiquitous and service-oriented environments [13, 14]. Unlike Smart-X, which offers the advantage to be sector-agnostic, Agila proposes a mobile agent middleware for self-adaptive wireless sensor networks and MUSA is adapted for self-adaptation in the development of a smart travel system [21, 16]. Smart and multimodal mobility has also been subject of numerous European projects like the Optimum project, which proposes an adaptive and dynamic transport system allowing managing and processing multimodal metrics in order to monitor an urban network environment [17]. In parallel to integrated centralised approaches for managing the mobility services [2, 3], other initiatives like Masai [4] propose alternative decentralised approaches by means of a “concierge” application which manage traditional services (ticketing, city guide, trip planners, etc.). MAMBA [5] is a platform for personalised multimodal trip planning composed of three main parts: a demand estimation module (simulation), a multimodal trip planner (using a web interface) and a mobility profiler (smartphone app). Few of the existing implementations offer the possibility to elaborate sound multimodal solutions and that the services allowing unique ticketing and clearing between different transports is mostly infrequent. Bonvoyage, for instance, proposes a platform for optimising multimodal door-to-door travel. It integrates basic services such as travel information, planning and ticketing, and supports automatically analysing real/non real-time data from heterogeneous databases, user profiles, and users' feedback. IT2Rail supports a complete door-to-door intermodal travel offer and integrates services like: planning, one-stop-shop ticketing, and real-time re-accommodation [18]. Among these solutions, only some of them are able to support cross-border mobility which involves additional specificities. Project supporting cross-border specificities are for instance the ETC project that offers the organisation and technology to create a seamless account-based travelling across European Union and that allows the integration of additional services such as travel planning, booking tools and e-payment [19]. Finally, it is also worth to note that addressing multimodal mobility as a service for professional purposes is still not addressed in depth. Among precursor initiatives in this area are the EuTravel and the MOBiNET projects [2, 20]. The first one has for objective to develop an "Optimodality Framework" and an "Optimodality Ecosystem Enablers" open infrastructure to offer a full range of travel support solutions (from planning to booking) in a standardized way to remove interoperability barriers. The second defines a European multi-vendor business-to-business e-market place of mobility services for business and end users, including a service directory populated by the services providers. It supports the harmonisation of services with and across borders, an instant access to transport data, a single billing and a one-stop shop for services. Although it provides a business-oriented architecture, MOBiNET does not allow defining business-specific services for the well-defined professional sectors.

3 Multimodal Cross-Border Issues and Requirements

As a base for offering ProMaaS services, we perform an analysis of multimodal cross-border issues and requirements from the three different business environments selected (construction, healthcare and logistics) in order to collect the requirements to be fulfilled by ProMaaS.

Construction: In many countries, the construction sector is one of the most important as its activity manifests continually. Because the remaining high employment rate, in some countries (like Luxembourg) most of the workers commute each day from neighbourhood countries (mostly France, Germany and Belgium). A first requirement is to collect the employees from their home and dispatch them to different construction areas (work places). The construction companies try to face this problem by providing business vans/cars to some workers and by manually organising collecting/dispatching scheduled.

Healthcare: The healthcare sector enumerates several requirements regarding mobility. The genesis for the latter comes from mobility of its employees, subsidiaries and partners (several thousands of people for cross-border urban regions like Geneva or Basel (CH)) and the goods these various actors have to transport (medical equipment, drugs, but also meals, clean sheets, etc.), with the need to ensure smooth yet efficient functioning of this daily business.

Logistics: The logistics sector requires a strict organisation due to its specificity and it presents one of the main business sectors all around the world. The backbone for the transportation of goods and the efficiency of logistic sector influences the sustainability of marketplaces. The drivers and truck organisations present an important requirement to be consider, e.g. to avoid additional parking breaks in a cross-border context by developing a flexible driver transportation service from and to dynamic "driver exchange points".

Based on those requirements, we have formulated the services (Sect. 4.1) required for the specific purpose of multimodal cross border mobility and we have designed the architecture for designing the platform prototype supporting the latter (Sect. 4.2).

4 ProMaaS

Based on the sectorial requirement detected in Sect. 3, the following subsections explain the core functionalities of ProMaaS and its two artefacts, i.e. the Sectorial Business Mobility Services and the Professional MaaS Platform.

4.1 Artefact I: Sectorial Business Mobility Services

This first concept is a set of sectorial business mobility services. A sectorial business mobility service acts as a bridge between the consumer application (clients) and the core service logic (business services provided by the platform). It allows the core service logic to remain decoupled from client applications and from business constraints. To design these services, the essential requirements collected during the requirements analysis step have been analysed and documented. This activity helped to structure and to model specific user requirements. The objective of this artefact was to build an independent "Sectorial Plug-in", which helped to integrate specific needs and requirements into the second artefact.

The IT business services, provided by the platform, are not implemented for each specific domain, but in a generic way. For this reason, a plug-in of each specific sector is provided to help external application (service consumers) to communicate with the Repository & Broker Service (RBS) of the ProMaaS platform. By default, three plugins are provided: the Health Plug in, the Logistics Plug-in and the Construction Plug-in.

4.2 Artefact II: Professional MaaS Platform

ProMaaS is a specific mobility marketplace and a technological platform enabling interactions between professionals of mobility-related content and services. It offers a centralised repository for providing, finding and consuming Business-to-Business (B2B) services as well as functionality enabling and supporting interoperability between data sources. With a single subscription, the platform provides access to services and information related to all types of public and private transport modes, including Public Transport (PT), taxis, car-pooling (private and public), car-sharing, etc. The platform manages both dissemination and updating data, information, and customers' relationships. The services are offered in the form of different packages based on user demands. It is composed of three service layers architecture composed on the following layers: **(1) Input/output layer:** is the layer on the top of the business services layer which controls all the input and output communications with external stakeholders, such as service and data providers. **(2) IT business services layer:** is composed of services that perform specific business functions and that are required for the successful completion of a business process. **(3) Logic services:** are composed of services that are action-centric components and that implement business capabilities. In ProMaaS, a default implementation is proposed for each logic service based on open-source software. Thanks to the marketplace capability of the platform and using the TIS (Three-tier Integration Service), the service providers contributes in building the ProMaaS ecosystem and in making it sustainable over time by providing new implementations of logic services (Fig. 1).

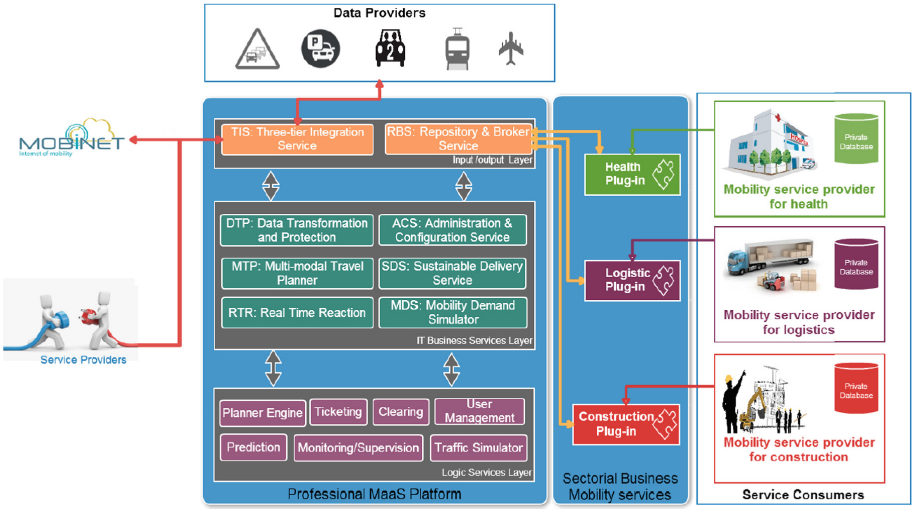

Fig. 1. ProMaaS main architecture components overview.

Any external interaction (e.g. with users) are made using a specific service from the I/O layer, the RBS (Repository & Broker Service) to communicate with service consumers and the TIS to communicate with services and data providers. A short description of IT business services as well as the input/output services is given in the following:

Multimodal Travel Planner (MTP): Combines transport (multimodal transport) used to enjoy all the benefits of different types of transport for each section of the route and optimize the itinerary of persons and goods in accordance with customer requirements: delivery times, transport costs, security, etc. In the last years, the scientific community has worked on different research areas dealing with mobility issues. One of them is the multimodal transport where related services consist in considering traveling itineraries combining public and private transport means (private car, bus, train, bike, walking, plane, boat, etc.).

Mobility Demand Simulator (MDS): The MDS is a dynamic simulation model of mobility which is a decision support tool. It assesses the functioning of an infrastructure or a road network over a given period by taking into account the interactions between the different modes of transport as well as mobility services (parking, car-sharing, route optimization, etc.).

Sustainable Delivery Service (SDS): This service will be used by companies that want to optimize their fleet, reduce costs or optimize the use of their movable workforce (typically cross-border). The core function of the sustainable delivery service is the trip optimization, which will be used to schedule tasks or missions, and allocate between resources according to their constraints (availability, location, skills required, duration of interventions, etc.).

Data Transformation and Protection (DTP): This service will be basically used by the "data providers" for both dissemination and updating data. The data providers are able to use the DTP service in order to transmit their private data to the ProMaaS platform. In the other hand, updating data consists of gathering real-time data from public and private databases (e.g. traffic information, open-data from the EU Portal…). In the project, we use standards when dealing with data. DATEX II[1] is used as the standard for road transport and traffic data. The DTP is then used in order to guarantee the integration and the compliance with DATEX II.

Administration and Configuration Service (ACS): The administration and Configuration Service (ACS) is a component which allows configuration information to be passed into the platform in order to initialize the services that is used by external stakeholders. In other words, service consumer uses this service to configure and manage business services that are planned. This service is also being used by the administrator in order to configure the platform, manage users (service consumers & providers), accesses authorizations, etc.

Real-Time Reaction (RTR): This service helps users to take advantage of the real-time data update, mainly including: (i) Public transport data: these updates contain the actual arrival and departure times, the transfer stations, and service alerts (unexpected events, delays etc.); (ii) Traffic situation: this updates data which represent the traffic density measured in real-time. The RTR service is also used by the users to update their private data and therefore benefit from the real-time update. Beside real-time data, also prediction algorithms influence decision processes. Since predictions allows a look into

[1] http://www.datex2.eu/.

the future of data like weather, availability of parking slots, fuel prices, availabilities of electric mobility charging infrastructure and so on, the real-time update of such predictions are part of the RTR.

Repository and Broker Service (RBS): This service stores crucial information regarding services and applications in a central repository to prevent duplication and promote reuse. RBS makes it easy to promote reuse by making it easy to discover and access the right services for a task. When the client (service consumer using a specific plug-in) requests a specific service, it formats its request in a specific format and sends it to its broker. The RBS selects afterwards the most suitable service (or a composition of services) to process the request.

Three-tier Integration Service (TIS): A set of distributed components provide functionality to external applications over the network using open standards. The TIS can therefore be used by applications written in different languages and executed on different platforms in different IT environments. The role of the TIS is typically to offer one or more business functions to be referred by one or more external consumers/provider (as for example data providers, MOBiNET, etc.).

5 Conclusions and Future Works

Literature related to MaaS platforms mainly focuses on personal or corporate oriented solutions, e.g. EuTravel, Bonvoyage, Masai and Faye [2–5]. Therefore, in this paper, we propose a new platform concept, which aims to provide new services tailored for professional mobility purposes. First of all, we reviewed the business requirements of three professional sectors strongly impacted by the cross-border mobility of its workers. Then, based on these requirements, we structured new professional business services and the platform concept has been built based on a portfolio of dedicated modules. Using the platform, the construction companies have been tooled to evolve towards multimodal cross-border solutions, dedicated to their specific business constraints and requirements (e.g. transportation of people, tools, and goods). At the healthcare level, while most of the health structures already have systems to manage the mobility of their employees during their working hours – including for travelling abroad –, their capability can be improved most of the time. Using ProMaaS, they would benefit from an integrated approach considering the mobility from a global and citizen point of view and encouraging shared mobility of their employees from home to work. Finally, regarding the cross-border logistic, ProMaaS has the potential to offer new integrated tools like fuel price and parking slot prediction services. Drivers may exchange dispositioning trough a dedicated ProMaaS multimodal travel planning that brings drivers to and from any exchange position, thus lowering truck parking times, and decreasing the number of trucks on the road and Cox, especially in an ecological sensitive border region. As part of industrial supply chains, truck-based logistics requires often transportation times, that exceed allowed steering times for single drivers. Therefore, ProMaaS enhances existing dispatching systems by using the MTP-services and prediction technology (e.g. weather, truck parking availabilities and fuel prices). As future work, we target the development, deployment and validation of the platform in collaboration with additional sectors. Based on these deployments, we expect additional specific modules to be defined, implemented and integrated together with new business services.

The purpose of this paper was to introduce the concept of the ProMaaS platform along with general representative use-cases. Future work or extensions of this work could lead to a greater description of the platform, or even to an implementation on a real use-case. This would include the specification of the different modules and elements of the architecture in relation to the targeted business cases.

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The Use of Social Computing in Travelers' Activities Preference Analysis

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Abstract. Each traveler moves across the physical plane to perform activities. It is known that each trip connects two distinct activities. Travelers, during their trips, make various choices in order to decide mode, route and time of departure. These choices depend on factors that are either predetermined or emotional. Other factors such as existence of various events can also affect the choices of the travelers. During the last decade, information related to the factors mentioned above, are addressed through the social networks. The amount of information provided in the social media is important and crucial in addressing the way travelers move around. On the other hand, understanding and, more importantly, predicting activities is a crucial matter in order to predict traffic conditions as well as to provide improved trip advice to travelers.

The present paper studies the possibilities and capabilities exist in order to proceed to transport modelling techniques by deriving information from the social media status updates of the users. More specifically the study reviews methodologies and techniques that can collect information from the users' status updates in order to estimate their preferences.

In the present study the development of a methodology which integrates the gathered information from the social media status updates with stated activities' preferences is being investigated. The review takes into account the social computing paradigm where humans and machines collaborate to solve a social problem. Also, multiple data sources are examined in order more integrated results to be returned.

Keywords: Social computing · Travelers activities · Social media
Data collection

1 Introduction

During the last years several new applications and services have been introduced that, according to Parameswaran and Whinston [1], *"facilitate collective action and social interaction online with rich exchange of multimedia information and evolution of aggregate knowledge"*. These websites and applications tend to dominate the Web and they are referred to under a variety of terms such as Web 2.0, online communities and social computing [1].

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Social media (also referred to as Social Networking Services or Social Networking Sites) are the product of Web 2.0 and their usage is growing due to the increased use of smart phones and tablets [2, 3]. Facebook [4], Twitter [5] and Foursquare [6] are among the most widely used applications/websites of this category.

During the last decade, a large number of research activities based on data deriving from social media have been conducted. Especially for the transport sector, the most commonly exploited information by social media platforms, until now, is based on the use of the spatial information accompanying posts (geotagged information) and the language processing of posted content [7]. The most common use and applications of social-media derived data (in general and especially in transportation research), as stated from Chaniotakis et al. [7], are presented in the table (Table 1) below.

Table 1. Most common use and applications of social-media derived data.

Most common use and applications of social-media derived data	Use and applications of social-media derived data in transportation research
Identification of spatial and temporal mobility patterns	Identification of the movement of the population
Investigation of the applicability of the social-media originated data for travel demand modelling	Definition of the cities' boundaries
Identification of users' activities	Design of the Origin-Destination (O-D) matrices
Definition of urban settings and related characteristics (e.g. points of interest, boundaries, land uses)	Investigation of the users' mobility patterns
Investigation of riders' satisfaction	Exploration of the users' social networks and their effect on transportation-related behavior
Examination of the relationship between social networks and mobility	

2 Deriving Transportation Related Data from Social Media Content – Applications and Analysis

2.1 Data Mining from Social Media Platforms

The main use of social media platforms is to post messages. The user's message shared in social networks is called Status Update Message (SUM), and apart from the text it may contain meta-information such as timestamp, geographic coordinates (latitude and longitude), user's identification (id), hashtags, mentions and links to other resources. Several SUMs referring to a certain topic or related to a limited geographic area may provide, if correctly analyzed, valuable information about an event or a topic [8, 9].

The data from these applications is usually referred as "Social Signal Data" and it is characterized by big volume, wide spatial coverage, long observational period and real-time features. Nevertheless, these characteristics may vary, depending on the source of information. This information can then be analyzed and finally travel patterns can be discovered by applying data mining techniques in these large data sets [8]. According to literature, there is a variety of categorizations of information used in transport, in terms of information, goals and findings. According to [10], the following table (Table 2) is designed.

Table 2. Main features, characteristics, types of transport-related information and types of actions.

Main features	Characteristics of social media content	Types of transport-related information	Types of actions
Either structured or unstructured information (80% of the data posted in social media is unstructured, i.e. free text SUMs)	Social media content created by an individual usually refers to an event that the individual has experienced or an intended action	Information on travelers' journey needs	Creating a new service or enhancing an existing one
Ungrammatical text (e.g. typographical errors, uses-specialized language)	The event or action commented on occurs either shortly before or shortly after the time at which the content is created	Detection of an irregular event that has an impact on mobility	Undertaking an ad-hoc solution for a problem reported through social media
	The issue raised is of some importance to the individual	Travelers' opinions on the quality of a transport service	Improving the Level-of-Service (LoS) of an existing service

In order to develop a methodology for achieving the set goals, there are two hypotheses [10, 11] concerning the potential of social media for transport policy:

- Social media contain valuable information for transport planning and management, both in terms of content and quantity.
- Such information can be harvested either automatically or semi-automatically.

The extracted information must be characterized by high volume, velocity and variety in order to require specific technologies and analytical methods for its transformation into value. This means that the information should be highly relevant to the whole concept and complete [10, 12].

Three challenges which are of importance in the context of transport and are sourced from the main features and characteristics of SUMs, as presented in the above table (Table 2) are summarized below [10, 12]:

- Analysis of text
- Representative sampling
- Integration of text and geographic information

2.2 Methodologies for Transport-Related Data Mining Models

In general, the algorithms used for data mining purposes first collect SUMs from social media and then process the fetched SUMs by applying text mining techniques, in order to assign the appropriate class label to each SUM and analyze the classified SUMs. Through this process, the system can notify the presence of a traffic event while adding geographic information is also feasible. There are four main modules, which consist the overall model architecture [9–11, 13–17]:

- Search of SUMs and Pre-processing procedures
- Elaboration of SUMs
- Classification of SUMs
- Geo-location

The data collection methodology includes two main components: data collected from the users through the Twitter's Application Programming Interface (API) [18] or other platforms' APIs (Real Time Data Collection - RTDC) component and historic data collected number of Tweets per user in order to create historical matrices (Historic Data Collection - HDC) component.

In the following figure (Fig. 1) the visualization of the above methodology, as retrieved from [14, 15, 17] is presented. The left flow is the procedure for retrieving RTDC data and the right flow the procedure for retrieving HDC data. Apart from these modules, Sinha et al. [16] include in their proposed system architecture the processes of "aggregation", "visualization" and "output".

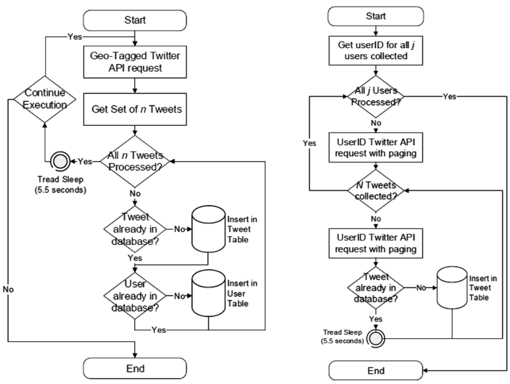

Fig. 1. Visualization of the methodology as retrieved from Chaniotakis and Antoniou [15] and Chaniotakis et al. [17].

In literature though there is another Twitter-based methodology, which proposes the use of both survey results and data mining techniques. These methodologies have been used by Efthymiou and Antoniou [19] and Cottrill et al. [20].

Efthymiou and Antoniou [19] mention that different twitter applications have been developed, which manage to create a connection between the social media platform and the statistical software R [21]. The integration of these platforms offers a powerful tool for statistical analysis. In the case of Twitter, the messages of the platform's users that are publicly available (mentioned above as SUMs) can be scrapped, parsed and analyzed in R [21], by using the appropriate packages such as TwitterXML [19, 22, 23].

The first step is the conduction of the survey and the statistical analysis of the questionnaires. Next, a script that can retrieve information about the number of the tweets containing words chosen by the user and the geographical location of Twitters' users (in case the application was enabled by the users) can be coded in R. The script reads the time format from the html page and it translates it in R and prints a graph using the ggplot2 package of R. The script also reads and stores the location of the users (in case that it is provided by them), which can then be plotted by the googleVis package [19].

According to Ruiz et al. [12] the MINERVA Project, which is a research project funded by the Minister for Economy and Competiveness of Spain, in order to enhance data collection methods for travel demand forecasting, is planned to collect passive information (without the intervention of individuals) to inferred characteristics of social network interactions and activities and travels from Social Media and mobile phones.

The methodology of the MINERVA Project consists of four main steps [12]. These steps are:

- Data extraction from Social Media.
- Data collection from mobile phones.
- Estimation and calibration of data mining algorithms.
- Data fusion techniques.

Another methodology to derive data from social media, and especially from Facebook (check-ins), and to produce a tool with spatial information has been proposed by Toumpalidis [24] and Toumpalidis and Karanikolas [25], Toumpalidis and Karanikolas [26] and partially used by Grau et al. (under review) [27] and Grau et al. (under review) [28].

The methodology is comprised of four main modules:

- Geographical Information System (GIS): Use of GIS to collect the coordinates from the study area, in order to be used for information retrieval.
- Use of Facebook API: Connection with the Facebook API [29] and use of the geographical information mentioned above (coordinates), in order to collect information for a specific area.
- Editor: Processing and formatting of the datasets.
- Visualization Tools and GIS: Visualization and analysis of the final results.

3 Proposed Methodology

The above-mentioned methodologies for transport-related data mining use a variety of algorithms in order to gather, process, validate and (in some methodologies) geo-locate and represent the outcome of each technique.

In this section a methodology based on the data mining techniques and methodologies, as these have been presented in the previous chapters is proposed. The proposed methodology uses data mining techniques in order to gather data and then validate it, but it also incorporates the activities' preferences of the users.

The purpose of the methodology is to identify activity preferences of individual users through the collection, filtering and validation of information from social media (Fig. 2).

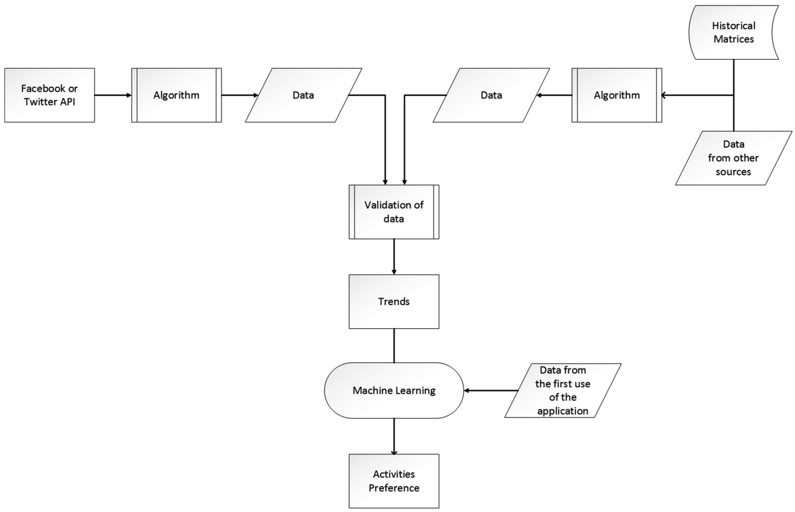

Fig. 2. Information Flow Diagram of the proposed methodology for estimating travelers' activities preference.

The main source of data is either the Twitter API [18] or the Facebook API [29] and the information derived is the number of check-ins per location. The proposed methodology is based on three datasets. The first is originated either from the Twitter API [18] or from the Facebook API [29] and provides real-time data mining. The data derived is then evaluated through the use of other two datasets; one from another social-media platform's API and one from historical matrices. The combination of those three datasets leads to information about the trends. The Cambridge Dictionary [30] defines trend as *"…one of the words, subjects, or names that is being mentioned most often on a social media website or a news website at a particular time"*.

The second step of the methodology informs each individual user about the trends, as they are extracted in the first step of the methodology, and the users provide information about their preferences. The integration of the users' preferences with the trends, through machine learning techniques, lead to the final output of the proposed methodology which is the estimation of each user's activities preference.

The methodology, as described above, will be incorporated in the application designed during the lifetime of European Union's Horizon 2020 My-TRAC Project.

4 Concluding Remarks

There are various methodologies behind the concept of providing information through the use of transport-related data from social media platforms. The main structure of the methodologies is that the transport-related data is collected through the use of data mining techniques and then there is the process and the validation of the collected datasets. Later on there is the geo-location of the fetched data and there is also the possibility for visualization of the final results in the GIS Interface.

The study of these techniques led to the development of a methodology for the identification of individual users' activities preferences through the collection, filtering and validation of the derived information from social media. The proposed methodology integrates the users' preferences with the current trends (as retrieved either from Twitter API [17] or Facebook API [29]) and, through machine learning techniques, lead to the estimation of each user's activities preference.

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Traffic Emissions and Environmental Impacts

Development of a Methodology, Using Multi-Criteria Decision Analysis (MCDA), to Choose Between Full Pedestrianization and Traffic Calming Area (Woonerf Zone Type)

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Abstract. The purpose of this paper is the development of selection criteria, as well as a respective selection methodology, between full pedestrianization and the reconstruction of an area to a woonerf type traffic calming zone. The criteria which characterize a pedestrian area as such and a woonerf type traffic calming zone as such were collected. The processing of the criteria followed as well as their comparison. The criteria based evaluation of the alternatives may lead to a decision in case they do not meet one of the alternatives. Otherwise, e.g. in case the criteria meet both the alternatives, the Analytic Hierarchy Process (AHP) method may be used for the selection of the best solution. This main idea led to the development of a methodology that is presented in this paper. Initially, a theoretical approach to the problem took place and 22 AHP questionnaires were completed by engineers of various disciplines regarding the problem, in order to draw general conclusions regarding the importance of the selected criteria. In order to test the proposed methodology in a specific case, it was applied in a case study at the Municipality of Ampelokipoi-Menemeni, Greece, where 11 AHP questionnaires were completed by residents and shopkeepers of the examined area. The results show that the proposed methodology could be a valid solution to a contemporary problem that many local authorities face.

Keywords: Analytic Hierarchy Process (AHP) · Pedestrianization Woonerf

1 Introduction

Pedestrians are the main factor in the liveliness of a city. Planning in such a way that the majority of trips are realized by walking is one of the most important goals for city sustainability [1].

According to the New Building Regulation of Greece (2012), a pedestrian area is defined as “the roads reserved exclusively for the service of pedestrians” [2]. According to the aforementioned definition, no vehicle is allowed to enter a pedestrian area. However, in combination with the Road Traffic Code of Greece [3], as amended and in

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force, it is clarified that apart from pedestrians, emergency vehicles (such as firetrucks and ambulances), city logistics vehicles, and vehicles that have available a proprietary parking space exclusively facing towards a pedestrian area are allowed to enter by exception [4].

On the other hand, woonerven zones could offer a "'via media' between the proponents and the opponents of private cars, compared to infeasible maximalist proposals and declarations of full pedestrianization" [5]. Traffic calming began in Europe as a grassroots movement in the late 1960s in the Dutch city of Delft where angry residents fought against cut-through traffic by turning their streets into what was later on called "woonerven", in Dutch, or "living yards", in English. The previous channels for the movement of cars became shared areas, with tables, sand boxes, benches, and parking bays jutting into the street. The result was to turn the street into an obstacle course for vehicles, and an extension of home for residents [6]. In 1972 the first official woonerf zone was created in Delft. In 1976, the Dutch parliament passed a legislation which legalized the construction of such zones and up until 1983 more than 2,700 woonerven zones had been constructed [7]. Moreover, "surveys indicated that the majority of the population considered the woonerven attractive. They also reduced the number of injury-related collisions by 50%. The lower speeds also contributed to a decline in the severity of the crash-related injuries" [7]. The concept of woonerf zones, "promotes a symbiotic relationship between private cars and pedestrians by giving the right of way to pedestrians, imposing a maximum speed limit of 30 km/h for the cars, which are expected to move at the [running or even less] speed of pedestrians, removing all the road signs and traffic lights, and abolishing the height differences between the sidewalks and the road. This concept is applied to residential areas, converting thus roads to open spaces, and even playgrounds, without ostracizing private cars" [5]. Woonerven zones bring more people out on the streets not only to walk, bike, and play but also to interact with each other. In other words, "a woonerf transforms the street into a livable and attractive environment for a variety of activities" [8].

In Greece, traffic calming started in the 1990s with some simple measures to control speed (e.g. road humps) in specific areas (usually residential and conservational sites). Moreover, pedestrianization schemes were applied in roads and sites of some cities, with the main objective to provide a better and safer environment for the vulnerable road users, the residents, and the visitors. The idea of traffic calming and the implementation of effective traffic calming schemes has begun to develop gradually and today is an important factor of sustainable urban mobility [9].

Whenever a local authority considers transforming an area to make it more friendly to pedestrians and vulnerable road users a questions arises: should it become a pedestrian area or a woonerf zone? This paper proposes a methodology to be used by local authorities whenever such a dilemma arises, using the selection criteria of pedestrian areas and woonerven zones and the Analytic Hierarchy Process (AHP). From the large spectrum of the existing Multi-Criteria Decision Analysis (MCDA) methods, the AHP method was selected as according to a relevant recent comprehensive literature review regarding the use of MCDA methods on transportation related projects between 1985–2012, AHP was the most used, applied in more than 1/3 of the examined case studies [10].

2 Methodology

Initially, the criteria which characterize a pedestrian area as such and a woonerf type traffic calming zone as such were collected. The processing of the criteria followed as well as their comparison. The criteria based evaluation of the alternatives may lead to a decision in case they are not met for one of the alternatives. Otherwise, e.g. in case the criteria are met for both the alternatives, the AHP method may be used for the selection of the best solution. This main idea, combined with the criteria, led to the development of the methodology presented in Fig. 1.

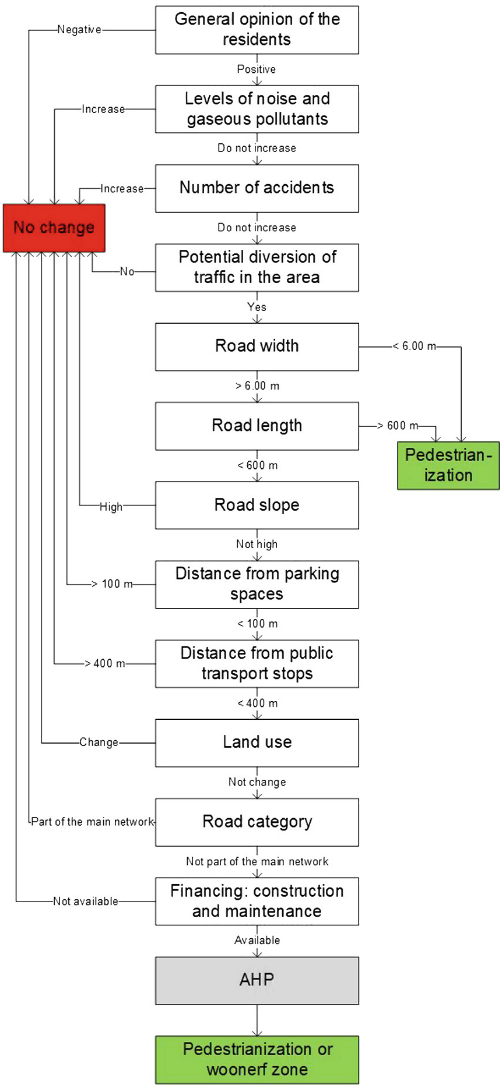

Fig. 1. Methodology for selection between pedestrian area and woonerf zone.

The proposed methodology was tested both theoretically and in a specific case study in terms of applicability and validity. The theoretical approach was restricted to the application of the AHP method for the most important AHP criteria (not to be confused with the on-off selection criteria of the phase before the AHP) which were specified as following:

1. Opinion of the residents.
2. Environmental impact.
3. Functionality.
4. Cost (finally removed from the actual proposed methodology).

According to the results that will be presented below, the criterion of cost was not considered to be as important as the other criteria. This sounds strange but probably the reason is that in Greece the cost of public works is predetermined and thus it should be considered as an on/off criterion of the phase before the application of the AHP method. Moreover, the citizens do not care so much about the cost since public works are usually funded by the central government and the European Union (EU) and not by the municipalities themselves through municipal taxes, something that the experts who answered the questionnaire are aware of. For these reasons, the criterion of cost was removed from the actual and final proposed methodology as it was applied in the specific case study.

Following, the final proposed methodology was applied in a specific case study at the Municipality of Ampelokipoi-Menemeni, Greece.

The AHP method, introduced by Thomas Saaty [11], is a quite effective tool for dealing with complex decision making processes, which may aid the decision-maker to set priorities and make the best decision in an unbiased way. By reducing complex decisions to a series of pairwise comparisons, and then synthesizing the results, the AHP method helps to capture both the subjective and the objective aspects of a decision. Moreover, the AHP method incorporates a technique for checking the consistency of the decision-maker's evaluations, thus reducing bias.

The AHP method considers a set of evaluation criteria, and also a set of alternative options among which the best decision is to be made. Since some of the criteria could be contrasting, it is not generally true that the best option is the one which optimizes each one of the criteria, rather the one that achieves the most suitable trade-off among them. The AHP method generates a weight for each criterion according to the decision-maker's pairwise comparisons of the criteria. The higher the weight is, the more important the respective criterion is. Following, for a fixed criterion, the AHP method assigns a score to each option according to the pairwise comparisons of the options based on that specific criterion. The higher the score is, the better the performance of the option with respect to the considered criterion is. Finally, the AHP method combines the criteria weights and the options' scores, determining thus a global score for each option, and a ranking. The global score for each option is the weighted sum of the scores it obtained with respect to all the criteria [11].

3 Results and Discussion

3.1 Theoretical Application

Twenty-two (22) AHP questionnaires were completed in person by experts, i.e. engineers of various disciplines, regarding the problem, in order to draw general results regarding the importance of the selected AHP criteria. Before that, a detailed discussion took place with each expert on the differences of a pedestrian area and a woonerf zone since the concept of wooneryen zones is not well known in Greece. SuperDecisions software was used with the following modelling:

- Goal: 1. Selection criteria between pedestrianization and woonerf zone type.
- Criteria: 1. Opinion of the residents; 2. Environmental impact; 3. Functionality; 4. Cost.
- Alternatives: 1. Pedestrianization; 2. Woonerf zone type (see Fig. 2).

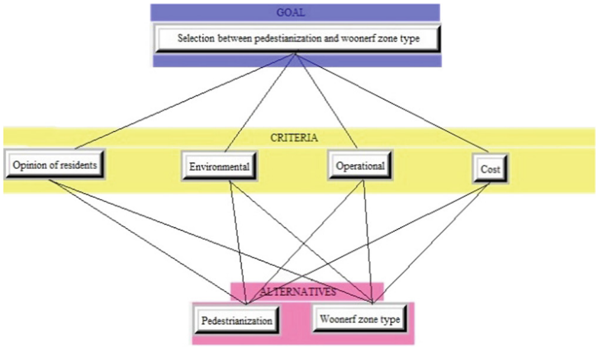

Fig. 2. Decomposition of the problem into a hierarchy.

Following the method, the items of each level of the hierarchical structure are compared with the criterion of the next highest level. This way tables are created that express the relative values of a set of properties, the number of these tables being the same as the number of tree nodes. The decision-maker should enter the problem's data by expressing his preferences through pairwise comparisons of all the elements of a level of the hierarchy defined in the hierarchical analysis of the problem (see Fig. 3).

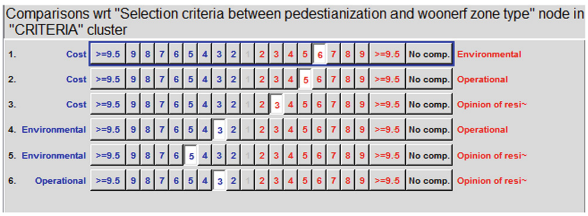

Fig. 3. Registering the items in the SuperDecisions software.

In particular, the decision-maker compares every two elements of one level with each other in the light of each element of the previous level of the hierarchy. This process ends with the comparisons of all the alternatives at the top level of the hierarchy in relation to the elements of the immediately preceding level. In order to express the preferences of the decision-maker during the comparisons, a numerical scale is used, through a discrete value system, from 1 to 9 which expresses: 1. Equal importance; 3. Moderate importance of one over another; 5. Essential or strong importance; 7. Very strong importance; 9. Extreme importance, and intermediate states [12]. This scale is known as the 9-pointed Saaty's Ratio Scale.

However, in order to accept the outcome of the whole process with the AHP, the Consistency Ratio (CR) coefficient or inconsistency, should be less than 0.10. Otherwise, the decision-maker should reconsider his answers and remove inconsistencies, at least to an acceptable level. Saaty argues that when CR = 0 then the matrix of comparisons is completely consistent and for CR > 0.1 there is an inconsistency in the decision-maker's preferences (although sometimes such a value must be accepted) [13].

The data of the 22 AHP questionnaires were entered into the SuperDecisions software and their inconsistency value was checked. The results showed that in 15 cases the inconsistency value was less than 0.10. For these 15 cases, the data were processed and the extraction of the results from the SuperDecisions software followed (see Fig. 4). According to the results, pedestrianization has a greater weight than the woonerf zone, 0.53134 and 0.46866 respectively, being thus the best solution. Probably this reflects the fact that even the experts in Greece are not very familiar with the concept of woonerf zone and also the fact that there is a maximalist tendency.

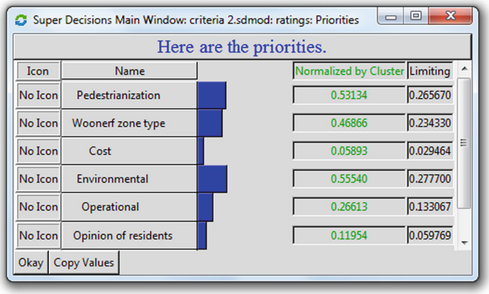

Fig. 4. Weights of the alternatives and the criteria.

Regarding the criteria, the "Environmental impact" criterion has the greater weight (0.55540), followed by the "Functionality" criterion (0.26613), the "Opinion of the residents" criterion (0.11954), and the "Cost" criterion (0.05893). Therefore, as previously mentioned, the "Cost" criterion was removed from the actual and final proposed methodology.

3.2 Application in the Municipality of Ampelokipoi-Menemeni

As a case study, the possibility of applying pedestrianization or a woonerf zone was examined, after the transformation of Georgios Halkidis Street from a two-ways road to one-way one, for the section from Eleftherios Venizelos to Kanakis street, in the Municipality of Ampelokipoi-Menemeni, Greece.

In that particular section the criteria that should apply to both pedestrianization and woonerf zone were examined (see Fig. 1). From the analysis of the criteria it was found that there was no reason to reject an alternative. Therefore, the AHP method was used to select one of the two alternatives. The AHP criteria used were the following:

1. Environmental impact.
2. Functionality.
3. Opinion of the residents.

In the context of the choice between the alternatives of pedestrianization and woonerf zone, 11 AHP questionnaires were completed in person from five (5) shopkeepers and six (6) local residents after a detailed discussion regarding the differences of a pedestrian area and a woonerf zone. Moreover, they were informed about how AHP works, as well as about the criteria. After completing each AHP questionnaire, the data was processed on the spot. In the cases where inconsistency values were greater than 0.10, there were more immediate clarifications in order for the respondent to gain a better understanding of the whole process and to complete again the AHP questionnaire. Finally, eight (8) questionnaires had CR < 0.1 and they were further processed (see Table 1).

Table 1. Results of AHP questionnaires with acceptable inconsistency (CR < 0.1).

Questionnaire	1	2	3	4	5	6	7	8	Average
Pedestrianization	0.6593	0.3626	0.1429	0.3092	0.3894	0.6719	0.3781	0.6419	0.4444
Woonerf zone	0.3407	0.6374	0.8571	0.6908	0.6106	0.3281	0.6219	0.3581	0.5556
Environmental impact	0.6955	0.2291	0.2851	0.1991	0.2790	0.7306	0.2897	0.6348	0.4179
Functionality	0.2291	0.6955	0.6527	0.7334	0.6491	0.0810	0.6554	0.2872	0.4979
Opinion of the residents	0.0754	0.0754	0.0623	0.0676	0.0719	0.1884	0.0549	0.0780	0.0842
CR	0.0735	0.0516	0.0707	0.0904	0.0624	0.0624	0.0772	0.0280	0.0645

Commenting on the results, it is noted that in total the weight of pedestrianization compared to the one of woonerf zone is smaller, 0.4444 and 0.5556 respectively, and also in five of the eight cases. Regarding the criteria, the "Functionality" criterion has the greater weight (0.4979), followed by the "Environmental impact" criterion (0.4179), and the "Opinion of the residents" criterion (0.0842).

A very interesting result is that the actual residents, and therefore users, seem to prefer a woonerf zone than a pedestrian area, in contrast with the experts and this should trouble the experts, although this is a result of just one specific case study.

4 Conclusions

The best possible choice between the two alternatives troubles those in charge. The decision depends on the correct assessment of the criteria of the two alternatives as mentioned previously. The evaluation of the criteria can lead to a decision, otherwise the choice of the best solution can be given using the AHP method. Using the AHP method rather than a simple Likert type questionnaire aims to reduce the bias of the responses. The success of the implementation of each alternative does not only depend on the criteria, but above all on the residents, who will have to respect the rules of each solution. Their active involvement in the decision-making process may have positive results. The proposed methodology can be a promising tool for the local authorities towards this direction. Finally, the experts should be troubled by the results and apart from the environment they should also consider the functionality of the proposed solution.

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Influence of Traffic Emissions on Urban Air Quality: A Case Study of a Medium Sized City

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Abstract. The road transport accounts for 73% of the CO2 emissions of transport sector in EU and constitutes one of the main sources of pollution and negative environmental implications. In the dynamic environment of urban areas, traffic flows are still a challenge since they apply substantial influence on the related generated greenhouse gas (GHG) emissions affecting air quality and health impacts on citizens. This study quantifies the environmental effect of traffic flows using the case of Amfissa, a medium sized city in Greece. The aim of this paper is to measure the environmental impacts of traffic flows on the city's central road network in terms of emissions and air quality. On-site measurements are conducted to compare the environmental effects of "normal traffic" with "zero traffic" flows in the city center. The findings reveal that GHG emissions resulting from traffic flows are significant even for medium-sized cities. As such, zero or limited traffic zones, where no or limited private vehicles are permitted, could be a possible measure for CO2-free cities deploying more sustainable and ecological ways of transport in the city center (i.e. electric vehicles, R-vehicles, etc.). The results are analyzed in the context of Amfissa's urban sustainable plans and current debates surrounding the pedestrianization actions in the city center and the challenge of reconciling environmental sustainability with urban and traffic growth.

Keywords: Traffic emissions · Urban air quality · On-site measurements

1 Introduction

The road transport accounts for 73% of the CO2 emissions of transport sector in EU and constitutes one of the main sources of pollution and negative environmental implications. In the dynamic environment of urban areas, traffic flows are still a challenge since they apply substantial influence on the related generated greenhouse

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gas (GHG) emissions affecting air quality and health impacts on citizens [1]. Considering the externalities of urban traffic flows, public authorities aim to promote reduced energy consumption and the associated GHG emissions in a short and long term horizon implementing innovative solutions that minimize the total traffic movements and enhance efficiency [2–4].

To improve efficiencies, reduce externalities and promote a better image of city transport, several initiatives are undertaken. These initiatives relate to policy and regulation that may also relate to infrastructure development, facility, time, vehicle restrictions or pricing policies. They may also relate to new and alternative energy sources, use of information and communication technologies. Following the Europe 2020 target, local and regional authorities develop proper strategies and policies to facilitate the implementation of actions that improve the energy efficiency of urban traffic flows [5, 6].

The aim of this paper is to quantify the environmental impacts of traffic flows on the city's central road network in terms of emissions and air quality after measuring at central roads in a medium sized city center. Amphissa is a prefectural and administrative center of the area consisting of the following residential units: Amfissa - Itea - Delphi area as well as a Service Center (Trade, Recreation, Urban Tourism and Public Benefit Services and Cultural Infrastructure) according to its administrative roles and population capacities. Its population is 6,919 residents (Census 2011) and according of its population is in the category of small and medium-sized cities. The city has a commercial center with high business and public service related activity and increased traffic problems [7, 8].

The findings reveal that GHG emissions resulting from traffic flows are significant even for medium-sized cities. As such, zero or limited traffic zones, where no or limited private vehicles are permitted, could be a possible measure for GHG-free cities deploying more sustainable and ecological ways of transport in the city center (i.e. electric vehicles, R-vehicles, etc.). The results are analyzed in the context of Amfissa's urban sustainable plans and current debates surrounding the pedestrianization actions in the city center and the challenge of reconciling environmental sustainability with urban and traffic growth [9, 10].

The remainder of the paper is organized as follows: Sect. 2 discusses the methodology followed for the assessment of the emissions of traffic flows and the air quality on the city's central road network. Then, the results derived of the conducted on-site measurements and the corresponding key findings are provided in Sect. 3. Finally, Sect. 4 describes the critical issues that should be considered for achieving reduced GHG emissions in the context of an action plan that supports environmental friendly traffic flows in a city.

2 Methodology

2.1 Methodological Approach

In an attempt to support the planning of Amfissa's urban sustainable plans, the methodological approach of this study involves three main stages as depicted in Fig. 1.

On-site measurements conducted to collect the necessary data for quantifying the air quality on the city's central road network and compare the environmental effects of "normal traffic" with "zero traffic" flows in the city center. The aim is to improve the knowledge of the environmental impacts in the Amfissa city derived from traffic flows on the city's central road network. This will allow an impact analysis of the pedestrianization actions that public authorities plan to implement for reducing emissions related to the aforementioned traffic flows [11].

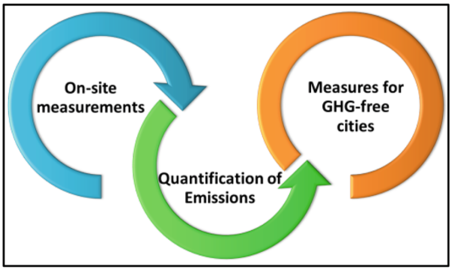

Fig. 1. Methodological approach.

The survey was targeted at main roads in the city center, so that quantitative characteristics of the traffic patterns could be assessed (Fig. 2). The roads with "zero traffic" (depicted with green color in Fig. 2) as well as the location of measurements (position of mobile lab in Fig. 2) were selected from the public authorities of the city based on the data provided by relevant stakeholders of both private and public sector. A set of key performance indicators (KPIs) was used to measure the impact of different policies in terms of air quality. The measured KPIs are O3, CO and SO2 emissions. These KPIs provide suitable data for deeper analysis to understand and to estimate the effect of potential measures for GHG-free cities giving the policy makers the possibility to evaluate long-term changes.

2.2 Equipment Description

The gas emissions – pollution measurements for this study were carried out using the Mobile Lab for Environmental, Pavement and Traffic Measurements. CERTH/HIT has created this Mobile Lab in order to promote transportation/environmental re-search in Greece and to support the relevant authorities in Greek Municipalities. The Mobile Lab is equipped with equipment for collecting and analyzing data on ambient air quality and uses three Gas Analyzers type HORIBA and two Gas Pods which provide concentrations of Ozone (O3), Carbon Monoxide (CO) and Sulfur Dioxide (SO2). The Mobile Lab is also equipped with a system for collecting, storing, processing and broadcasting the relevant collected data from the aforementioned environmental instruments, consisting of a data logger and related software (COMGRAPH) (Fig. 3).

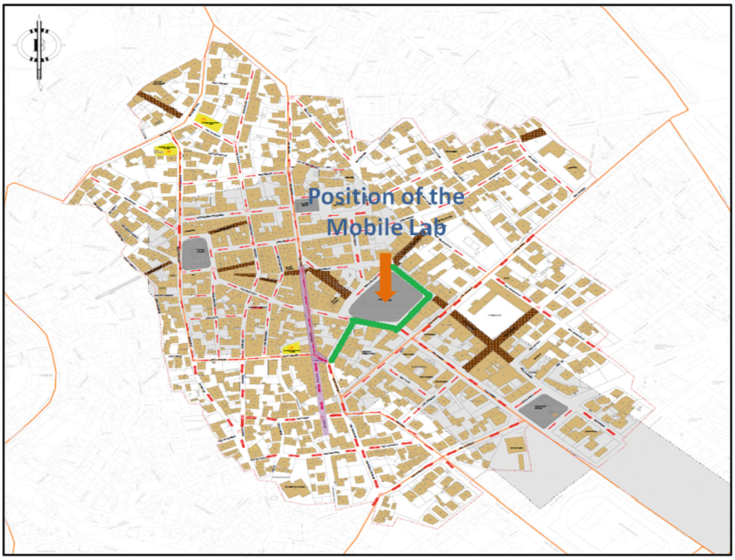

Fig. 2. Map of Amfissa city - "zero traffic" roads and location of measurements

Fig. 3. Mobile lab for environmental, pavement and traffic measurements.

3 Results

For the quantification of the emissions generated in the city center, on-site measurements are performed with both "normal traffic" and "zero traffic" flows for two separate time slots i.e. (i) 08:00–10:00 and (ii) 17:15–19:00 and 4 measurements are reported within 1 h for each case. These time slots cover both the morning and evening peak hours of the city which are 8:00–9:00 and 00:00 and 00:00.

Figure 4 summarizes the results obtained of O3, CO and SO2 emissions measurements and they show that traffic flows and GHG emissions are strongly connected even in medium sized cities. Compared to the "normal traffic" case, significant reductions are obtained with respect to O3 and SO2 emissions. Based on the results reported for CO (which appears the lowest impact), reductions up to 66.67% are reached for the “zero traffic” case within 18:15–18:30 time period. Furthermore, the cumulative values of KPIs are improved in “zero traffic” case with reductions up to 26.60% for O3, 15.20% for CO and 284.62% for SO2 emissions (Fig. 5).

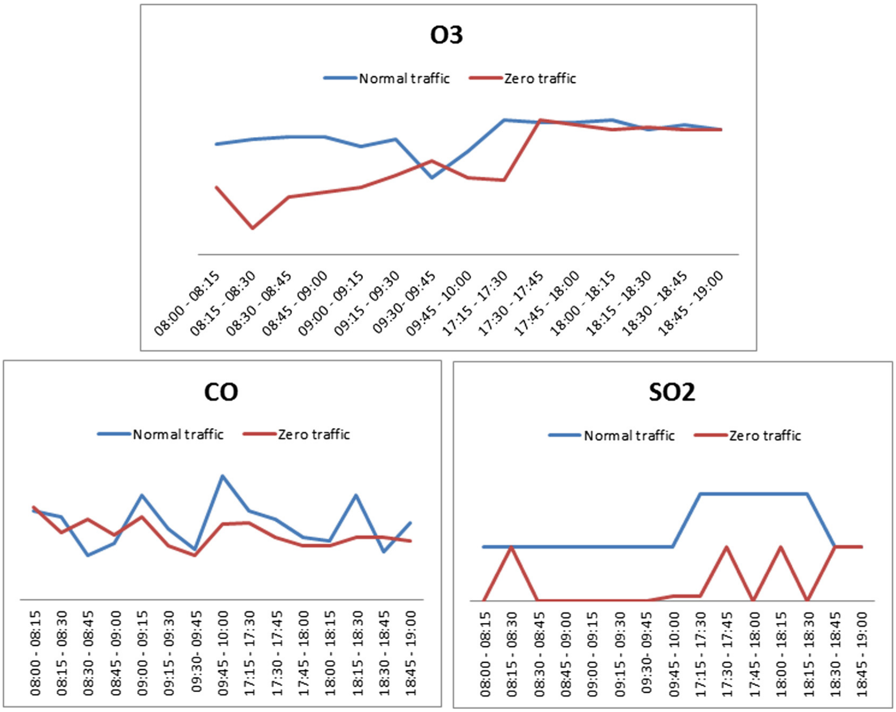

Fig. 4. O3, CO and SO2 emissions’ measurements.

However, on-site measurements revealed small increases in some KPIs for the “zero traffic” case. This deviation renders imperative a systematic planning for pedestrianization and other actions for a GHG-free urban area. A detailed survey should be conducted to collect the necessary data for analyzing urban traffic flows in the Amfissa city center in an attempt to improve the knowledge on origin/destination of traffic flows and allowing an environmental impact analysis of different measures related to traffic reductions. As such, an efficient action plan should be developed promoting an environmental friendly profile in the area.

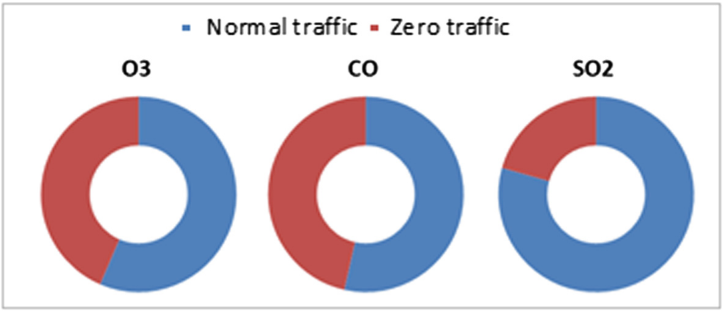

Fig. 5. Total emissions in the city centre.

4 Conclusions

This study is implemented in the case of Amfissa city in an attempt to contribute to the planning of GHG-free measures and more specifically to the decision making of public authorities. The survey described in Sect. 3 provides quantitative indicators that cover environmental aspects (i.e. O3, CO and SO2 emissions generated due to traffic flows) that could be translated into priorities for supporting societal value (such as the cost of climate change, the loss of residents etc.). Results from Amfissa case are useful for other comparable medium-sized cities in Europe experiencing increased passengers' volumes in the city centre required to be handled, imposing significant negative externalities.

Preparing a GHG-free action plan for the sensitive sector of traffic in an urban area is a challenging procedure and a series of processes should be coordinated. Determining the "best set of measures and policies" for a city depends on multiple criteria such as the GHG emission reductions, cost effectiveness, energy savings and the required time for implementation. The Municipality should analyze specific GHG-efficient measures by indicating their potential impact through surveys, simulations and studies. On the other hand, a common ground for dialogue between private and public sector should be provided as public sector aims to maximize social benefit objectives while private sector aims to profit maximization. As such, an action plan for environmental friendly traffic flows in a city should be endorsed in a strategic plan of the area, highlighting the activities that should be taken ensuring a broad environmental and economic effect on the urban environment.

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Cycling as a Key Component of the Athenian Sustainable Urban Mobility Plan

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Abstract. The Athenian Strategic Plan for Sustainable Urban Mobility (SUMP) aims to support the most efficient ways of daily commuting towards mitigating limited public spaces, pollution and delays, while increasing individual cycling use and bike sharing services. Bicycle is a major issue in terms of promoting and implementing a robust urban mobility strategy. Improvement of existing infrastructure, development of new networks and specialized lanes, adaptation of the traffic code, awareness raising and integration of technology are among the key aspects of such a strategy. The inclusion of an integrated and coherent cycling network in the Athenian SUMP is the fulfillment of a key strategy, aiming at the development of cycling policies and infrastructure within the overall priorities of a SUMP (i.e. promotion of walking, cycling and public transportation). The promotion and integration of cycling as a bold commuting mode could address a range of mobility problems, making Athens' transportation environment equivalent to other European capitals' that are healthier, functional, safe, productive and attract residents, visitors and investors. This paper presents the methodology of designing the Athenian cycling network, within a new concept of mobility management promoting coexistence rather than the conventional separation standards, while at the same time adjusting vehicle speeds in the various street types. Several elements regarding road safety enhancements are reported, as well as the specific terms of introducing cycling in the current network and bus lanes, sidewalks and pedestrian streets. Lastly proposals regard the supplementation of the existing traffic code and other institutional issues of cycling.

Keywords: Cycling · Sustainable urban mobility plan · Cycle path network
Public transport · Walking

1 Introduction

The integration of a unified and coherent cycle path network in the evolving Sustainable Urban Mobility Plan (SUMP) of the Municipality of Athens is tantamount to fulfilling the basic criteria set by the strategic directions of Sustainable Urban Mobility in Athens with the aim of promoting cycling and developing its infrastructure in the network of the city, as part of a more general change in priorities that will make the capital city a city of public transport, bicycle and walking.

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This paper presents the criteria for the integration of cycle paths in the Athenian network as they result from the analysis of: The Strategic Plan for Sustainable Mobility in the Municipality of Athens, formulated by the Sustainable Mobility Unit of the NTUA [3] and the main Strategic texts and plans that have been developed and proposed for Athens, over the last five years.

The objective is to establish the corresponding criteria for the cycling network, which will be met according to the Athenian mobility strategy, and also match the activities, proposed actions and projects developed by the SUMP Working Group in all work stages of the project. Cycling in the center of Athens when all interventions will have been completed, will address a wide range of commuting issues, helping the city to become a real European capital, healthy, functional and productive, with a high standard of living, able to attract visitors and investors.

2 Issues Related to the Integration of Bicycle into the Athenian Urban Transportation System – Theoretical Approach

According to Vlastos [10], pedestrians and cyclists are known to be the best consumers because they have advantages in terms of their increased accessibility in various activities. Their number increases where the conditions for walking and cycling are favorable. New businesses, commercial and recreational activities as well as offices are encouraged to be reallocated to the city center. According to Visitors' Satisfaction Survey & Attica Hotel Performance 2016–2017 [2], foreign visitors prefer hotels located in the historical center of the city and close to museums and shopping streets. A city like Athens, well-known all around the world, should enhance what the visitor wishes to see and enjoy managing to prolong his/her stay with attractive routes linking its key elements and monuments. This means that the whole city, besides its historic center, should be attractive, safe and easily accessible through various means.

Pedestrians and cyclists have direct contact with the space due to their low speed. It is up to them to decide how quickly or slowly they move, or when and for how long they stop according to their surroundings. This is not the case for car or motorcycle drivers who are following the rhythm and speed of the flow. Pedestrians' and cyclists' senses are vivid; hearing, vision, smell and touch allow them to immediately perceive and communicate to the physical and social environment of each trip. They have every reason to be interested and claim a city that is beautiful and rich in stimuli and incentives. These needed qualities differ to those of people who are isolated in the enclosed space of their cars.

The request for a '4 km/h architecture' argues the need for infrastructure addressed to pedestrians and cyclists, and spaces that have an identity and are in direct dialogue with people, in contrary to the common demand of those locked within their car passing through the city. The 'architecture of 50 or 80 km/h' is empty of details and silent in communication terms; it is an architecture to watch from a distance while driving through the places. It would not be an exaggeration to argue that sustainable mobility perspective paves the way while also directs the aesthetic reformation of the center of Athens. Sustainable mobility cannot exist in an urban environment which is architecturally indifferent as pedestrians and cyclists need an upgraded environment in terms of public space aesthetics and level of comfort. Cycling shall be integrated progressively in the Athenian streets, starting from where the conditions are already friendly, such as the pedestrianized historical center. It is also important for further cycling integration to be included in all future regeneration plans for the urban and environmental rehabilitation of Athens.

3 Methodology on Implementation Sustainable Mobility Strategies for Cycling

The Strategy seeks to develop a cycling promotion policy. The development of exclusive cycling infrastructure is the most conventional way of cycling enhancement and, for some, the safest way to do so. However, very few European cities have such infrastructure and most have acquired recently. However, this seems still not enough to convince residents to get on their bicycles. Many of their commuting trips rarely match with the few kilometers of separated bicycle paths that were built, due to the high cost of it or the street geometry. This is the case for the countries that do not have the necessary culture and courtesy to respect cyclists and just ‘build’ a bicycle lane with a white line on the road. It is very natural that these countries are reluctant to risk integrating cyclists in roads where flows and speeds are high.

“City bikes” appear as an alternative to the car, but also as an incentive to move in city centers, which are the most congested with various destinations in relatively close distances. They are also an incentive for residents of the suburbs to use public transport to get to the center and then use the bicycle to easily reach their specific next destinations. Shared bicycles and public transportation can function in ideal cooperation, as allies in helping citizens and cities to become less car-dependent. With regard to the traffic parameter, the presence of bicycles is a proof of prevalence of sustainable mobility conditions. Segregated infrastructure with high cost is not necessary. There is a rich experience of cities with high bicycle rates thanks to horizontal road signaling. In these cities however, there is road courtesy. That is why the Municipality of Athens should not underestimate the importance of education and awareness raising for both children and adults. In order for cycling to be enhanced, the number of on street cars (either moving or parked) shall be reduced along with their speed.

In Europe, bicycle infrastructure solutions are provided by simply drawing special lanes on the road, or by building separated bicycle paths (different surface levels), or even by extending pedestrian zones and building traffic calmed areas where no exclusive infrastructure is required. In the case of a single bike lane, a white line is easily drawn on road, quickly and without cost. However, this is not the solution to the hostile behavior of the Greek driver. This is why the Sustainable Mobility Unit of the National Technical University of Athens [11, 12], after studying road conditions in dozens of Greek cities and playing an active role to the dissemination of bicycle use, has proposed the reallocation of bike lanes from the roadway to a special lane on the sidewalk, through widening it accordingly. This was the solution that was systematically applied due to its advantages related to enhancing pedestrian convenience as many cities lacked the needed minimum sidewalk widths. However, this seemed to be the optimal solution for several cases before the Greek economic crisis and today it would be absurd to keep on with the same practice. The current optimal solution would be to develop bike lanes on road and put weight on education and training policies for drivers and motorcyclists to drive with caution.

A complete solution is to create traffic calmed zones, with a maximum speed of 30 km/h in order to protect pedestrians and cyclists. Cyclists in such zones do not demand specialized infrastructure as they can safely move along with cars in low speeds. Such zones, although very common in European cities, are quite rare in Greece. The Strategic Plan for Sustainable Mobility in the historical center of the Municipality of Athens should have traffic calmed areas at its planning core.

In addition to the above policies, the rapid growth of electric bicycle rental systems in Europe in the recent years is quite interesting [8]. They are a direct incentive that function as an alternative to the use of cars, especially in the central areas, which are the most congested with various destinations in relatively close distances. They are also an incentive for suburban residents, when they need to reach different destinations within the city center. Indeed, the electric bicycle, when public transportation is inadequate in the center, gives them a radical solution. Electric shared bicycles and public transport can function in ideal cooperation, as allies in helping citizens and cities to become less car-dependent. For visitors, e-bike rental systems are part of the city's infrastructure, a means of approaching the details and exploring the city. The installation of electric bike rental systems gives a clear boost to the first rides in an environment that is fairly considered hostile. However, it demands some key elements to be considered safe; pedestrianized streets, some bicycle lanes, pedestrianized historical centers etc. But, is this space enough? Obviously, system users will use conventional roads, and this shall progressively make drivers more cautious in every way, since the bike network is completed.

4 The Case of Municipality of Athens: Integrating Cycling in Transportation Planning

The Athenian Strategic Plan for Sustainable Mobility and Transport [5] aims to support the most efficient ways of commuting through the city, towards the issue of limited public space, and put an emphasis on strengthening the use of bicycles, both private and shared ones. Bicycle is a key pillar of the sustainable mobility strategy. It needs infrastructure improvements, several adaptations to the Road Traffic Code (RTC), raising awareness and mobilizing citizens, as well as technology upgrades. It is important to emphasize to the positive characteristics of the bicycle and its vulnerability in terms of road safety and to clearly define the conditions of its circulation on street, on bus lanes, on sidewalks and pedestrianized streets roads. Moreover, speed limits shall be redefined in various streets, on the basis of coexistence, rather than exclusion or separation.

In addition, the Plan proposes the creation of special lanes to accommodate buses and bicycles. After the trial period of bicycle circulation in the bus lanes, results were assessed, and adjustments or improvements are proposed for the institutionalization of this solution of shared bus- bicycle lanes, allowing Athens to acquire a crucial network at very low cost. The development of a Public Bike Sharing System can offer a great deal in improving mobility, and add a touch of optimism and inspiration for addressing its problems. Also, it can promote collaboration and synergy among the various institutions involved.

The Regulatory Master Plan for Athens-Attica 2021 stresses the necessity of organizing traffic at the municipal level and town planning units, based on the principles of sustainable urban mobility, with emphasis on quiet transport modes such as public transport, cycling, walking. It also emphasizes the enhancement of pedestrians' and cyclists' accessibility. As far as the bicycle is concerned, the Master Plan aims to recover public spaces by upgrading and expanding the pedestrian and bicycle network while also reallocating on-street parking to off street private spaces. In addition, it aims at building integrated networks for pedestrians and cyclists alike, between major natural, urban, transport and cultural centers. The need to extend pedestrianized zones or create pedestrian, bicycle and public transport routes on commercial roads is emphasized, following special transport studies. Pedestrian routes connecting public buildings and monuments of architectural, artistic and historical interest are also promoted. The promoted traffic related directives include the diversion of through traffic out of the central area and integrating walking and cycling areas, as well as overall cultural routes. The development of an extensive metropolitan cycling network will provide access to important areas of cultural and recreational interest, such as Elefsina, Ktima Tatoiou, Marathonas and Sounio, which if combined with local bike lanes through the surpassing municipalities can further contribute to cycling promotion in Attica basin.

The Operational Program of the Municipality of Athens (2015–2019) [7], states the various traffic issues in Athens, which seem to derive from the increase of car ownership, the lack of infrastructure and the inadequate management of the transport system. Among the most frequently encountered issues are walking and cycling inconsistensies, inadequate provision of motorbike parking (including bicycles), lack of bicycle routes, as well as the failure to make them part of the official city plan (Fig. 1).

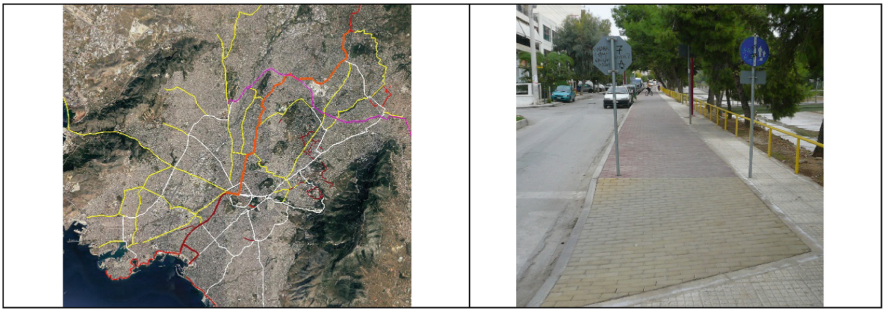

Fig. 1. (a) Athens Metropolitan Cycling Network. (b) Cycling Infrastructure in Thessalonikis Str. (Source: SMU)

The Plan for Integrated Urban Interventions [6] in the center of Athens asseses that in the city center there was no planned or constructed bicycle paths. Attempts made back in 2012 by the Municipality of Athens to implement a bicycle path connecting the archaeological sites of Kerameikos with Plato Academy were not successful, due to negative responses by the local councils of the 3rd and 4th Municipal Communities. Moreover, the plan assesses the metropolitan cycling route linking Kifissia, Athens and Faliro as divided into two sub-projects. The southern part received all necessary approvals and was eventually constructed, while the northern part connecting Gazi (Athens) to Kifissia remains unbuilt. The plan also referred to the Athens' Metropolitan Cycling Network, which was finally approved and institutionalized. The plan considers that the implementation of a pilot bicycle sharing system with 1,000 bicycles and 70 automatic pick-up and return stations, would be the lever for promoting all bike- related issues, such as cycling in bus lanes, establishing the movement of bicycles within pedestrian roads and adapting the traffic code to the new requirements for the dissemination of safe bicycle use in Greece. In line with the above, among the objectives set in this plan, the achievement of sustainable mobility conditions is also mentioned by pointing out out that "the bicycle as a means of transportation in the city is friendly to the human and the environment, while its use is costless compared to the use of other private vehicles" [6]. However, the lack of appropriate cycling infrastructure creates a sense of insecurity and discourages unfamiliar citizens who would like to use the bicycle as a means of transport on a regular or occasional basis.

In order to restore the sense of safety to cyclists, a coherent bicycle network should be created to allow for integrated cycling circulation, i.e. from any desired starting point to any desired destination, with a sense of comfort and safety. Along with the development of a bike network, solutions should also be provided for safe bike parking at destinations integrated into the public spaces. Institutional problems concern the completeness and clarity of cycling in the existing institutional framework. According to the current Traffic code bicycle is a vehicle, which makes its ability to move on sidewalks or pedestrian streets to be highly questioned, while at the same time the concept of a bicycle route is not properly defined. A similar issue is also noted for the movement of bicycles within the bus lanes. The plan also states that arrangements for the common use of bus lanes should be defined together with bus operators [6]. Lastly, the activation, co-ordination and cooperation of all parts involved (Municipality of Athens, Ministry of Transport and Networks, Ministry of Environment and Energy, Ministry of Culture, Bus Operator etc.) as well as active citizens or groups of citizens and stakeholders is a task that must be conducted through information and consultation campaigns [9].

5 Proposed Actions and Measures

Sustainable Urban Mobility Plans (SUMPs) are emerging as a new integrated and long-term urban mobility planning approach, that allow local authorities to develop and implement urban mobility strategies on the basis of in-depth analysis of the current situation. SUMPs provide a clear vision for the sustainable development of the urban areas for which they are designed, including reducing energy consumption, air and noise pollution, accidents, congestion, preservation of communal areas, etc. They rely on existing planning practices and are inspired by the principles of unified design, participation and evaluation to meet the movement and mobility needs of people today and in the future, for a better quality of life in the city and its surroundings. The bicycle is one of the 3 pillars of the SUMPs along with walking and public transport [3]. In Athens, a lot of effort shall be put on introducing decisive policies for the implementation of infrastructure, especially where the operation of the network is burdened by a large number of vehicles and motorcycles that sometimes move and park illegally, using/occupying spaces that normally belong to pedestrians and cyclists. Bicycle integration will prove to be a pleasant upgrade of the city's network. This shall not be achieved independently from the overall course of the city. Integrating the bicycle, which by default is a peaceful vehicle, in everyday transport means demands traffic calmed conditions and quality spaces. The development of cycling in Athens will largely depend on projects and policies directly related to cycling integration (such as bicycle lanes, bicycle corridors), but also on projects and policies that concern the overall transportation planning system (such as traffic regulations, BRT systems, car restrictions etc.). The key priority steps include:

- solving the institutional problems concerning the use of bicycles in the city and make legislative interventions in the Traffic Code that are compatible with the recent guidelines for integrating cycling (Decree 1053/B/14.4.2016)
- effective cooperation of the various services and authorities during the elaboration and the maturation of the needed studies, since both the SUMP and any traffic regulations required for the integration of cycling are at the responsibility of many authorities and legal bodies apart from the Municipality.
- initiating the implementation of a coherent cycling network which shall consist of primary (inter-municipal) and local cycling routes, which will provide citizens with the desired feeling of safety and comfort to use the bicycle as the main alternative means of transport.
- developing traffic calmed areas where bicycles will coexist with cars in cycle streets according to the recent guidelines for integrating cycling (Decree 1053/B/14.4.2016)
- informing, educating and raising awareness for the public and all interested stakeholders regarding the conscious use of bicycle and its benefits to the city. This shall alleviate controversies and enhance the culture of coexistence and mutual respect among citizens.
- taking action to reduce the risks of negative reactions of specific stakeholders, since the redistribution of the public space will affect those who enjoy some legitimate or illegitimate 'privileges' mostly related to parking.

6 Conclusions

Athens is currently a city that has given absolute priority to the car, while public transport sharply shrinks its ability to thrive. In these conditions, cycling commuting is struggling. However, as stated before, there are a lot to be done by the Municipality of

Athens in order to change priorities in transportation planning. Residential areas, covering the vast majority of the city's surface, should be the top priority. It could be easy to convert them into traffic calmed zones at low cost, serving both the cyclists and pedestrians. The SUMP is a critical tool for promoting cycling in the city, and it is expected that in the coming years there will be major alterations in favor of sustainable mobility compared to the current city image.

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Assessment of CO_2 Footprint of the New Athens Metro Line 4 during the Operation Phase

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Abstract. The purpose of the paper is the comparative assessment of the carbon dioxide (CO_2) emissions footprint caused by vehicular traffic on the area of affected roads of the new Athens Metro Line 4A during the first year of operation phase. Two scenarios examined comparatively for CO_2 emissions, with a time horizon of 2030: first scenario concerns the project not being implemented (Scenario 0) and the second scenario concerns the project being implemented (Scenario 1). The results of the calculations for the year 2030 were be examined comparatively with the year 2016, which is considered as the current situation. The composition of the traffic volume on the affected road network of Line 4 of the Metro is analyzed based on data collected by Attiko Metro Company.

Keywords: CO_2 emissions · Metro line · Traffic

1 Introduction

The transport sector, one of the fastest growing sectors of human activity, is a key economic and productivity factor of any society, although it progressively led to evident environmental impacts and to the appearance of harmful effects on human health. In Europe, transport is still almost totally dependent on fossil fuels (96%) and accounts for almost 60% of global oil use [1]. The problem of reducing CO_2 emissions from transport has become a growing concern for the scientific community monitoring climate change. Transport emissions have increased in recent years and now account for around one quarter of the EU's total GHG emissions. The transport sector remains the only major European economic sector in which GHG emissions have increased compared with 1990 levels. From 1990 to 2015, official GHG emissions from transport (including international aviation but excluding maritime shipping) increased by 23.1% [2].

In Greece, economic development and improved living standards of the previous decade have a significant effect on the ownership of passenger cars. The passenger cars fleet has almost tripled compared to 1990 levels. In 1990, the number of passenger cars was 1.7 million cars (1 car for every 6 inhabitants), while in 2007 this figure reached 4.8 million cars. This trend is shown to decelerate as a consequence of the economic

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crisis, although the percentage of car ownership in Greece is lower than the EU average. In 2011, final energy consumption, in Greece, was 18.6 Mtoe. The consumption of solid fuels and oil products accounts for 79.5% of total consumption. The share of transport in final energy consumption is estimated at 40.0% (in 2011) [3]. In 2014, CO_2 emissions, in Greece was 67.3 million tonnes (transport sector is 19.5 million tonnes) (Trading Economies).

This paper examines the environmental benefit, and specifically of CO_2 emissions, of the operation of the new Metro Line 4A, in the city of Athens, Greece, at the intended time of operation in 2030 (first year of operation). The road network of width of 500 m around the Metro line was considered the examined urban area as zone of traffic influence from the construction and operation of Metro. Two scenarios examined: first scenario concerns the project not being implemented (Scenario 0) and the second scenario concerns the project being implemented (Scenario 1). The results of the calculations of emissions for the year 2030, in the study area, were be examined comparatively with the year 2016, which is considered as the current situation.

2 The Global Urban Challenge

For more than half a century, cities worldwide have experienced huge change in terms of their development and mobility patterns. The current travel patterns and future projections (business as usual) are unsustainable and the transport sector must contribute much more to achieving CO_2 reductions targets [4, 5]. Transport is the one sector where a reduction in energy and emissions is proving to be extraordinarily difficult to achieve. Several studies have examined the relationship between urban form and urban transport energy use and the associated CO_2 emissions [6–8]. In Fig. 1, the correlation between urban density (person/km^2) and GHG emissions per capita in different cities worldwide is presented [9].

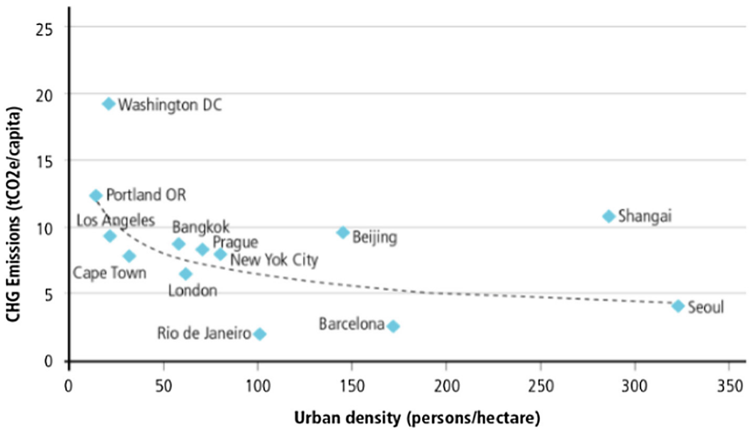

Fig. 1. Correlation between urban density and GHG emissions.

Since the early 1990s, the European Union seeks to promote the model of the "compact city" through a series of policy documents as a proposal to the transition to a sustainable mobility city, mitigating the generated traffic problems. The model of "compact city", as opposed to the model of the "diffused" city, adopts a design standard for the control of urban sprawl with compact and flexible allocation of mixed uses, reducing the intensity of individual car use and for developing higher quality public transport connectivity between city and its functional urban agglomeration. Compact cities create conditions that favor short distances on daily trips and hence reduce energy consumption for urban travel. However, energy consumption for urban travel depends on many factors, with the result that the characteristics of the urban structure are not a determining factor for energy consumption. For example, the energy required for urban travel depends on the population size of urban centers, the total size of the city, the quantitative and qualitative characteristics of public transport, the distribution of uses and activities in the area, the distances of daily population movements towards the place of work, the technologies used in the transport, etc.

3 The Case Study of Metro Line 4A in Athens

3.1 Athens in the Path of Sustainable Mobility

Athens metropolitan area consists of almost 30 municipalities and is inhabited by almost 4 million people, with the Municipality of Athens being the more dense and compact. Athens, the capital of Greece, concentrate 35% of the Greek population and 43% of the country's vehicles. According to Grammenos [10], Athens has all the elements of good urbanism - density, diversity, destinations, distance (to transit) and design. It started as a small dense settlement, as being a typical old city, which remained the focal point of a radial expansion and gradual increases in density over its subsequent evolution. Athens is a highly car-dependent city. The number of trips is estimated in average 6.500.000 daily in Athens, of which 40–45% concerns trips from and to work. Increased traffic during the peak hours leads to a series of urban mobility problems such as increased cost for the maintenance of cars, high levels of stress for the drivers and increased levels of environmental pollution. Traffic data forecast the increase of the number of transportation trips in 2030 (Table 1).

Table 1. The number of daily transportations in Athens (based on Traffic Study for Metro Line 4A Cost-Benefit Analysis, Attico Metro).

Modal split	2011		2020		2030	
Private cars	3.470.260	52,4%	3.144.328	50,4%	3.426.071	49%
Taxi	180.990	2,7%	202.077	3,2%	251.820	3,60%
Public transport	2.978.653	44,9%	2.893.780	46,4%	3.356.084	47,4%
Total	**6.629.904**		**6.240.186**		**7.069.975**	

During the last years there is a number of implemented infrastructure projects to upgrade the transportation service level such as the development of the metro network, tram network and suburban railway, the renewal of bus fleet with many green buses, the development of the peri-urban highway, Attiki Odos. However, mobility and accessibility issues had little attention and a few fragmented actions have been considered towards integrated sustainable urban mobility strategic plan [11].

3.2 Athens Metro Line 4A

The development of Metro infrastructure project has contributed at a significant level to the promotion of public transport in Athens. The current Athens Metro Development Plan includes the Metro Line 4, (Alsos Veikou – Evangelismos – Faros – Maroussi). The U-shaped Line 4 consists of two radial legs to Galatsi and Maroussi, as well as of one central part that runs through the center of Athens, its total length is 33.5 km with 30 stations and it incorporates five discrete individual sections, namely sections A (12.9 km long with 14 stations), B (9.6 km long with 8 stations), C (3.6 km long with 3 stations), D (3.0 km long with 2 stations), and E (4.4 km long with 3 stations) (Fig. 2).

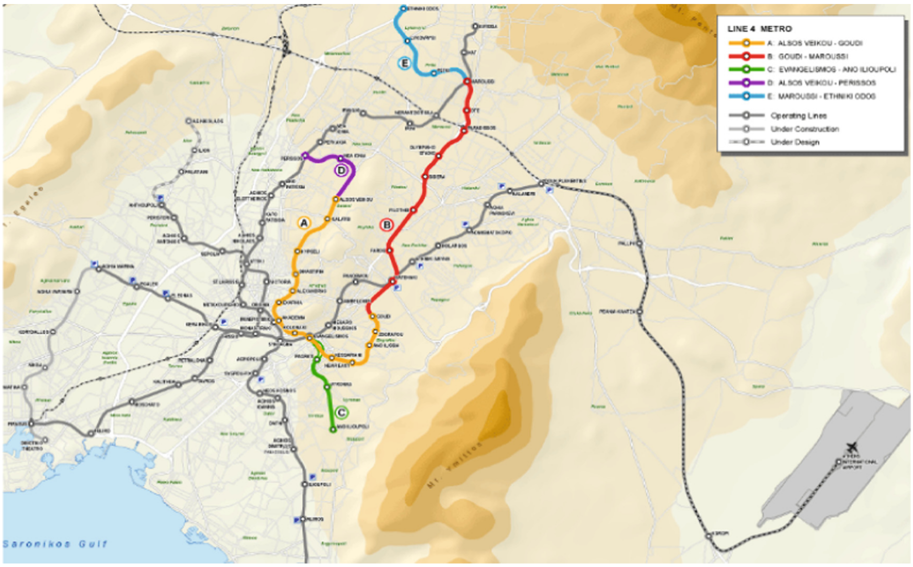

Fig. 2. Athens Metro Development Plan-Line 4 (2017).

In Table 2, the forecast of number of passengers in Metro Line 4A stations in 2030, in two directions is presented, based on relative Transport study of Attico Metro S.A. Company.

Table 2. Forecast of number of passengers in Metro Line 4A stations in 2030, in two directions (2017).

Stations	Boarding	Alighting	Stations	Boarding	Alighting
Alsos Veikou	1636	0	Evagelismos	4546	1518
Galatsi	2258	20	Kolonaki	267	1628
Kypseli	2467	121	Akademia	2179	3887
Dikastiria	719	129	Exarhia	64	2207
Alexandras	702	301	Alexandras	94	665
Exarhia	473	709	Dikastiria	35	580
Akademia	3369	3110	Kypseli	47	935
Kolonaki	171	2350	Galatsi	11	523
Evagelismos	645	3136	Alsos Veikou	0	204

3.3 Calculations of CO_2 Emissions

In order to calculate the CO_2 emissions produced by traffic in urban area around Metro Line 4A under study, the Computer program (software) to Calculate Emissions from Road Transport (COPERT4) was used. The development of COPERT is coordinated by the European Environment Agency, within the activities of the European Topic Centre on Air Pollution and Climate Change Mitigation and supported scientifically and technically by Emisia S.A. and the Aristotle University of Thessaloniki Laboratory of Applied Thermodynamics. The basic operation of COPERT is the calculation of emissions of all major air pollutants during transport; Vehicles are classified into five main groups: passenger, light, heavy, mopeds and motorcycles. Then each group is divided into subcategories, depending on the engine type of the vehicle. This provides the user with a clear picture of the traffic composition, while the program's calculations are more accurate in view of the specific emissions of each engine [12].

Table 3. Segments of Metro Line 4A (2017).

Segments	Distance area between two stations
Segment 1 (S1)	Alsos Veikou - Galatsi
Segment 2 (S2)	Galatsi - Kypseli
Segment 3 (S3)	Kypseli - Dikastiria
Segment 4 (S4)	Dikastiria - Alexandras
Segment 5 (S5)	Alexandras - Exarhia
Segment 6 (S6)	Exarhia - Akademia
Segment 7 (S7)	Akademia - Kolonaki
Segment 8 (S8)	Kolonaki - Evangelismos

The import in the software of the occurrence of each engine type, along with all the features that affect the pollutants production is an essential precondition for the correct calculation of pollutants. The line of Metro Line 4A was separated in 8 segments, between metro stations (Table 3). Data of traffic of the urban area of zone of influence of the Metro Line collected from the Traffic study of Metro project. In Table 4, the traffic volume into different categories (private vehicles, buses, heavy vehicles, motorcycles) in an area of road network at a zone 500 m. around the Metro Line4A, during the morning peak hour is presented. While, in Tables 5 and 6, the anticipation of the traffic volume in the same urban area at the intended time of operation in 2030 of Metro is presented. An anticipation for the use of new technology, in terms of engine design and alternative fuels (based on European directives), in the future was taken into account for the calculations of emissions in 2030.

Table 4. Peak hour traffic volume into different categories in the road network area, 2016.

Segments	Vehicles (veh/h)	Buses	Heavy V.	Moto	Total	Length (m)	V (km/h)
S1	25324	410	1063	11145	37942	743	31
S2	16882	184	726	7355	25147	1565	31
S3	18876	494	876	8590	28836	838	27
S4	20804	816	926	9769	32315	619	30
S5	21967	807	1040	10311	34125	618	25
S6	52081	2872	3839	26837	85629	735	25
S7	41943	1982	2505	20669	67099	724	25
S8	68956	2547	2884	32021	106408	544	27
Total	266833	10112	13859	126697	417501	6386	

Table 5. Peak hour traffic volume into different categories in the road network area, in 2030 without the Metro project (Scenario 0).

Segments	Vehicles (veh/h)	Buses	Heavy V.	Moto	Total	Length (m)	V (km/h)
S1	27756	410	1168	12175	41509	743	30
S2	18623	184	800	8091	27698	1565	30
S3	20314	494	973	9233	31014	838	26
S4	20875	816	982	9850	32523	619	30
S5	22638	797	1068	10584	35087	618	25
S6	52747	2721	4095	27181	86744	735	25
S7	43479	1878	2585	21101	69043	724	26
S8	69095	2547	3100	32281	107023	544	27
Total	275527	9847	14771	130496	430641	6386	

Table 6. Peak hour traffic volume into different categories in the road network area, in 2030 with the Metro project (Scenario 1).

Segments	Vehicles (veh/h)	Buses	Heavy V.	Moto	Total	Length (m)	V (km/h)
S1	26674	410	1193	11785	40062	743	31
S2	17766	184	820	7783	26553	1565	31
S3	19439	476	992	8806	29713	838	27
S4	20584	821	944	9707	32056	619	30
S5	21868	865	1088	10386	34207	618	25
S6	51398	2620	4141	26575	84734	735	25
S7	42505	1694	2602	20536	67337	724	25
S8	68213	2170	3144	31554	105081	544	27
Total	268447	9240	14924	127132	419743	6386	

The COPERT program was used 24 times (8 segments of Metroline, 3 Scenario). It is important to note that the volume of traffic in the future, in 2030, according to the data of Traffic study of Metro project, does not seem to be affected by the construction of a public transportation. It is already a congested road network, in the center of Athens, a car-dependence city, and only the implementation of a holistic alternative mobility paradigm would help in order to reduce the number of traffic volume.

The results of the COPERT calculations have shown that, in future, at the intended time of 2030, the first year of operation of Metro Line 4A, in the examined area of Athens, the amount of CO_2 will be reduced by 38% compared to today traffic condition. However, the contribution of the technological innovation in terms of engine design (electrical vehicle or hybrid) or the use of renewable energy sources is more important concerning the air pollution (Scenario 0) (Table 7).

Table 7. The results of COPERT calculations concerning the amount of CO_2.

	Total CO_2 emissions during peak hour (tn)	Total yearly CO_2 emissions (tn)	Percentage decrease 2030–2016 (%)
Condition in 2016	52.5	210000	
Scenario 0 (2030)	33.7	134800	36%
Scenario 1 (2030)	32.6	130400	38%

4 Conclusions

In Athens, the rapid urbanization and urban sprawl of last years had a result land uses are sparsely distributed and created the need of the development of new road infrastructure network. However, new roads create new car usage, new traffic and public transport remains inadequate to cover existing needs. Problems of mobility and accessibility have not been solved although some transportation infrastructure projects have been implemented. Today, the lines of Metro serve approximately one and half million passengers on a daily basis. Concerning the results of Traffic Study of Metro, the construction of a new public transportation project does not contribute to the reduction of car usage and the associated environmental and societal issues.

Banister [4] argues that the key for a sustainable mobility is a holistic thinking on low carbon city transport city, an approach that requires actions to reduce the need to travel (less trips), to encourage modal shift (transport policy measures), to reduce trip lengths (land use planning measures) and to encourage greater efficiency in the transport system (technological innovation).

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Considerations on Sustainable Mobility: The Contribution of Cycling to the Shift of Transportation Behaviour

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Abstract. Nowadays, mid-sized cities can achieve descent level of sustainable mobility through a balanced scheme where technological measures and revised transporting behaviour coexist harmonically. The key challenge for sustainable mobility is the modal shift to walking and cycling on a city level, leaving behind car use. Bicycle is a very flexible mean of transport which can roll on roads, sidewalks, pedestrian walkways, parks and squares. In case of tangible obstacles, like external stairs, the cyclist becomes pedestrian and carries his bike. Xanthi is a mid-sized city in Northern Greece. The traffic could be relieved from cars if a network of bicycle-paths is constructed using a ring-like scheme. More initiatives towards locomotions with bicycle must be planned by local authorities, including the sharing of public owned bicycles. In the city, the transportation infrastructure quality and moving-associated attitudes are strongly related. Neighbourhoods with no public transportation, walkways or cycling paths force households towards car use. Consequently, there is a need for coordinated decision making towards a "new thinking" based on concepts of environment protection along with the people's well-being. Planners, engineers and economists need to work in partnership with business associations to measure and monitor amendments, in an objective manner, with appropriate scale analysis. Bicycle sharing system is proposed to be implemented by the Municipality of Xanthi. The idea is based on the high numbers of university students and training young athletes needing to move during various times in the day on relatively short courses.

Keywords: Sustainable mobility · Bike · Walking · Cycling
Moving behaviour

1 Introduction: Goals in Terms of Sustainable Mobility

1.1 Walking and Cycling in Urban Areas

Walking is a free and independent way to move in the city. Almost similar is the case of cycling, as it has the potential to penetrate everywhere but also to be transported by public transport vehicles. Walking and cycling would theoretically ensure absolute accessibility. In practice, they encounter countless obstacles that force the cyclist and

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several pedestrians (people with disabilities, the elderly, young children) to limit their presence on the road [1].

Bicycle is an inexpensive way of travelling. In the era of commercialization, where unpaid activities are increasingly rare, traffic and parking of other means of transport are becoming more and more expensive, walking and cycling are becoming symbols of the city's free life. The latter is expressed by the negative attitude of pedestrians and cyclists towards traffic rules. They are systematic offenders or from another perspective, steadfast contenders of a different and less mechanized urban image.

Walking and cycling are the most environmental friendly ways of moving. However, while pedestrians and cyclists are not a threat for others, they are extremely vulnerable to cars and motorcycles [2].

1.2 Moving Behaviour in Greek Cities

Nowadays, Greek cities are full of cars and as a result they are not an attractive and safe place for cyclists. The objectives of their rehabilitation policies are aimed at many directions that can be achieved through traffic, urban planning and urban regeneration. The conditions promoting cycling include the construction of special infrastructures, the reduction of car speed, lowing noise levels, a beautiful road environment, systematically maintained urban walkways, adequate signage and information equipment [3].

The aim is citizens of all ages and incomes to choose bike as their basic transport mode, so that with simple and responsible choices to follow a different path and claim a collective city in their everyday life.

Cycling policies concern not just constructing infrastructures, but also adopting different attitudes and behaviours. Citizens' education and awareness policies are just as important as infrastructure. They naturally require planning and organizational preparation in ministries and local government. Especially with regard to the latter there is much to be done in order to successfully carry out the modern cycling policies. They need the design of another everyday life that cannot be effective without the involvement of citizens [4].

2 Previous Experiences and Changes in the City of Xanthi

2.1 Walking and Cycling Infrastructure

Xanthi is a medium-sized city in Northern Greece with a population of 56,151 inhabitants. The city area is flat without long and intermittent routes. In Xanthi, urban regenerations have been implemented in recent years to promote alternative ways of moving such as pedestrian and bicycle paths.

The pedestrian bridge on Kossynthos river connects two areas at the banks of Kossynthos river; Old Xanthi settlement with the area of Samakov. It is also accessible to people with disabilities. The construction of the bridge contributed to the abolition of a circumferential course of about 500 m.

A recreation area named Limnio Park of 11.50 acres was formatted next to the river as a theme park with walkways and bike paths (see Fig. 1).

Fig. 1. Bike Festival in Limnio Park.

A two-way bicycle path near Kossynthos river has been constructed having a length of 440 m which and is connected to the existing bicycle network leading to the Kimmeria settlement. Also, pavement construction work was carried out with provision for people with disabilities and the installation of modern urban equipment.

The ring road has been enhanced with bicycle lane. The ring road allows the diversion of vehicle traffic from the city to the hilly settlements of the area and easy access to the Hospital. The road includes two lanes separated by a traffic island. People with disabilities can move on the sidewalks while there is a bicycle path [5].

A new road has been opened near the outdoor marketplace ("pazari"). Panepistimiou is a two-way street contributing to the traffic congestion of the wider area of city centre. The sidewalks have a 180 m long bike path while they are built with the required specifications to be accessible by people with disabilities.

In Xanthi has already been made a first attempt to construct bicycle routes and the residents already start using this alternative mean of transport. The partial construction of the first phase does not favour the cultivation of particular interest.

Cycling paths are being developed on the streets Sardeon, Vas. Sofias, Kyrillou, Panepistimiou, and Katsoni (see Fig. 2). These existing sections are planned to be linked and integrated into one cycle path network.

Fig. 2. Bike lanes in Panepistimiou Street.

2.2 Designing a Bicycle Network

In the context of the promotion of alternative modes of transport, it is proposed to create an extensive bicycle path network which allows the connection of various points in the city that generate and attract journeys to offer routes that cover the needs of user groups [6].

The philosophy behind the design of bicycle paths in international experience and practice is the creation of loops - routes so that in a single way the user can be served without searching for alternative means for parts of the route [7].

The methodology is based on specific criteria such as geomorphologic conditions, disaggregation of uses and neighbourhoods, the hierarchy of the road network and the classification of the functional uses of citizens, so that the Municipality of Xanthi will be a guide for decision-making and other levels beyond the design and implementation of the bicycle path.

The city of Xanthi has a basic layout of the road network in the sense of North-South with the northern boundary of the Old Town and the southern boundary the exit towards Kavala and by extension to Komotini. This shaft is about 2.5 km long. Extending further to the east in a strong population concentration, the new facilities of the Xanthi School of Engineering of the Democritus University of Thrace (student-apartments, central amphitheatre, classrooms laboratories and workshops) and to the south - southwest to also strong population gatherings (Public Hospital area, Kallithea etc.) With the new points as mentioned above the main axis of the city acquires a length of about 6.0 km and is chosen as the basic cycling artery of the city.

On the basic bicycle artery, mainly closed routes (neighbourhoods) and focal points of special users (pupils, school rings) are structured in the concept of loops. In addition, modern road projects carried out by the Municipality of Xanthi, which include bicycle lanes, are included in the overall design of the network.

3 Critical Issues for Promoting Walking and Cycling in the City of Xanthi

People can access main areas by walking or cycling through walkways, bike paths and low traffic routes. The proposal for the creation of a bicycle path network is part of the promotion of alternative modes of transport with the aim of linking various points of the city. The proposed bicycle path network is particularly wide to cover a wide range of routes and ensure the service of its users (see Fig. 3).

At the same time, the new bicycle path network aims to connect with the existing sections described previously to enable the cyclist to make complete movements

Fig. 3. Proposed cycle path and walkways network.

throughout the city. The main feature of the network for the bicyclists to be safe must be its simplicity.

Additional network design criteria for the bike are safety, consistency and full coverage of the city, short journeys without unreasonable walkways, attractiveness of the architectural and natural environment, and driving comfort.

The course of the bicycle should not be interrupted. Every form of open space can be used to achieve the continuity of the paths: squares, parks, public gardens, sidewalks, pedestrian walkways, one-way roads where the bicycle is allowed to move in the opposite direction, private open spaces and, of course, roads in general [8].

The bicycle path is proposed to be constructed with a minimum width of 2.50 m for two-way bicycle movement and 1.00 m for a bicycle lane.

The bike path is proposed to be constructed on the sidewalk where this is feasible. At junctions, sidewalks are proposed to be downgraded so that the bike lane adapt smoothly to the level of the road.

It is emphasized that transversal extensions are provided in the above loops to serve specific uses or concentrations. Also, in each loop are recognized primary and secondary layouts so that there can be partial implementation capabilities, depending on the hierarchy of objectives and financial capabilities of each period.

4 Conclusions and Recommendations

To improve the walking and cycling conditions in urban areas and to promote a shift to those modes, several measures are recommended: the construction and improvement of sidewalks, bike lanes and paths, more convenient road crossings, matching phases of traffic lights, better signing, more and better bike parking facilities, bike sharing schemes, the introduction of lower speed limits or mobility management measures such as outreach and education campaigns and programs at schools and enterprises.

Consideration has been given to the formation or modification of some road axes where specific land uses are concentrated and serious problems are encountered in the traffic or parking of vehicles. For safer cyclists, it is proposed to change the designation of certain roads to mild traffic. The implementation of the above proposal will contribute to the smooth and safe co-existence of vehicles, bicycles and pedestrians, giving priority to pedestrians and cyclists. The measures to be taken concern changes in geometry and road formation in order to reduce vehicle speeds.

Also, organizing bike festivals and activities for young ages, can help children to develop correct driving behaviour in the city.

Municipality of Xanthi should implement a bicycle sharing system, as there are many university students and young athletes needing to move in various locations during the day. With that system you can rent a bike for some hours and then return it back on specific bicycles stations. Before renting, you will have to subscribe to the system.

Finally, there are several co-benefits of promoting walking and cycling in addition to congestion reduction, namely: less car traffic and more walking and cycling makes transport more affordable, improves personal health, reduces air and noise pollution, while is less expensive than car-dominated urban transport.

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Modelling Travelers' Behavior in the Presence of Reward Schemes Offered for Green Multimodal Choices

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Abstract. This paper aims to investigate the effectiveness of reward-based schemes on altering traveler's decision making towards sustainable multimodal transportation. For this purpose, a questionnaire survey is conducted in the context of the EC-H2020 funded project "OPTIMUM" within which suitable stated preference experiments are designed. Apart from the traditional multimodal attributes, such as travel time and travel cost, each stated preference experiment is supplemented by an attribute which represents a reward-based scheme. A mixed logit model is estimated where the individual's utility is linearly dependent on the respondent's socio-demographics and the attributes of the different multimodal alternatives. Our analysis indicates that, overall, the reward-based incentives could slightly contribute to the promotion of sustainable and emerging transport services. In specific, offering credits and monetary rewards may be effective in altering travellers' behavior, while the provision of other non-financial passenger services does not influence individuals' travel choice. In addition, it is found that individuals are more likely to use car-sharing in the presence of monetary rewards, while the alternatives "Public transport with bike-sharing" and "Public transport with Bicycle" are positively affected in the presence of credits.

Keywords: Reward schemes · Credits · Mixed logit model
Stated preference data · Multimodal choices

1 Introduction

The use of private cars remains common in many European cities. Motorization rates within cities (i.e. car ownership relative to the number of inhabitants) remain high in Europe. In 2015, the average EU rate accounted for 498 cars per 1000 inhabitants, 21.5% higher than the level of 2000 [1]. In some of the EU's largest cities, where integrated transport networks are based on rail, underground/metro and bus services, public transport is the most common form of transport for commuting to work [2]. Furthermore, active transport, which corresponds to the use of non-motorised transport means involving physical activity, such as walking and cycling, is used extensively in

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other cities. High use of bicycles to travel to work are observed in some Dutch cities, where public policies actively support public transport, pedestrian areas and cycling [3].

One measure that could raise the attractiveness of public transport and active mobility and constrain the use of individual motorized transport is the provision of rewards to transport users with the aim to change their behavior towards more sustainable travel options. Research in travel behavioral psychology indicates that individuals are motivated and act more favorably towards the desired behavior when rewarded, while policies that "punish" the individuals, such as congestion charging, may be ineffective in supporting a lasting change in travel behavior [4, 5]. In this context, some papers examine rewards which are offered to travelers to encourage them to avoid rush-hour travelling by cars [5–8] or public transport [9, 10], while a growing body of research focuses on reward schemes that encourage modal shift and the use public transport or non-motorized modes [11–15].

This paper examines different reward schemes, which aim to incentivize users towards green mobility options such as public transport, sharing schemes, active transport or a combination of the above. Three different reward schemes are examined: (i) monetary rewards, (ii) credits and (iii) the provision of "extra passenger services". In the first two cases, users receive cash back and earn credits (in the form of points) respectively, each time they use sustainable means of transport. The earned credits can be redeemed for gift cards, coupons or discounts among several stores such as restaurants, cafes, electronic stores and other retailers. In this work, the term "extra passenger services" corresponds to the provision of the following passenger services: free wi-fi access on-board, reserved seat on the bus or the metro and guaranteed parking space for the car or the bicycle. The aim of this paper is to investigate whether these rewards are effective to change travellers' choices towards sustainable means of transport. For this purpose, a mixed discrete choice model is estimated based on stated preference data.

2 Modelling Framework

To model the individual's decision making with regards to multimodal choices in the presence of rewards, a discrete choice model is developed. First, Stated Preference (SP) experiments were designed in a web-based survey, as discussed in Sect. 3, where the respondents were presented with a closed choice set of three different multimodal alternatives and they were asked to choose their preferred multimodal alternative. In this framework, the decision rule of each individual is based on the random utility theory, where the decision maker's choice lies on the assumption of utility-maximizing behavior [16, 17]. Each individual responds to more than one SP experiments resulting in repeated choices by each sampled decision maker. This, in turn, means that within each participant's responses, observations are dependent and hence correlated (even if each participant's responses are independent of the other participants), violating the assumption of identically independent distributed (iid) error components. To accommodate random taste variation, unrestricted substitution patterns, and correlation in unobserved factors unrestricted over time and to allow for repeated choices [17] a mixed discrete choice model (Mixed Logit) is developed. In the mixed logit model, the utility U_{nj} of an individual n derived from alternative j is given by Eq. (1):

$$U_{nj} = a_n + \beta_n x_{nj} + \varepsilon_{nj} \tag{1}$$

where a_n is the constant term (to be estimated), x_{nj} is a vector of observable variables with regards to alternative j and individual n, β_n denotes the vector of the parameter coefficients to be estimated and ε_{nj} is the stochastic term of the utility function. In particular, x_{nj} may include the individual's observable characteristics (i.e. socio-demographics), the attributes of the different multimodal options and the rewards offered.

The probability of an individual n to choose alternative j is defined in Eq. (2):

$$P_{nj} = \int L_{nj}(\beta) f(\beta) d\beta \tag{2}$$

where $L_{nj}(\beta)$ is the logit probability evaluated at parameters β (see Eq. (3)) and $f(\beta)$ is a density function.

$$L_{nj}(\beta) = \frac{e^{a_n + \beta_n x_{nj}}}{\sum_{j=1}^{J} e^{a_n + \beta_n x_{nj}}} \tag{3}$$

To capture the correlation over alternatives, a non-zero error component z_{nj} is included in some of the utility functions, so that the stochastic term of the utility is expressed as $\varepsilon_{nj} = \mu' z_{nj} + e_{nj}$, where μ is a vector of random terms with zero mean and e_{nj} is an iid extreme value.

3 Data

To collect the required data, a questionnaire was designed and administered through the web (daphne-new.chios.aegean.gr/~surveys/optimum) as part of the EC-H2020 funded project "OPTIMUM" in various European countries, including the pilot countries of the project namely, Austria, the United Kingdom and Slovenia. The recruitment process also included the use of relevant databases of the OPTIMUM's pilot partners in Austria and Slovenia, which included individuals who had declared their willingness to participate in studies, while in the U.K. an invitation was sent to the participants of a reward programme in U.K. Overall, a total of 706 SP responses were collected, while most of the respondents (about 42.5%) were living in U.K. The online questionnaire included several questions to cover the following topics: socio-demographics, respondents' current travel habits (typical trip purpose, preferred transport mode, personal/work constraints), while psychometric questions were asked to identify the respondents' attitudes and perceptions towards transport modes, the environment, car usage and general lifestyle. The core of the survey was the last part where the respondents were presented with discrete choice SP experiments designed to capture the effect of rewards on individuals' multimodal decision-making. The full set of the presented multimodal alternatives included: (1) Public Transport with Bicycle,

(2) Public Transport and Walking, (3) Public Transport and Bike-sharing, (4) Park and Ride, (5) Park and Ride with Car-Sharing, (6) Car-sharing, (7) Carpooling, (8) Uber and (9) Car. In each experiment, the respondents were presented with three of the above multimodal options and were requested to choose one of them based on varying information about the prevailing weather conditions, travel time (continuous variable ranging from 5 to 50 min, depending on the multimodal alternative) and travel cost (continuous variable ranging from 0 to 15 Euros). The experimental design was based on the respondent's commute habits asked in the first part of the survey (for instance, a respondent might be presented with a multimodal alternative which includes car usage, such as Park and Ride, only if he/she owns a car). After the initial multimodal choice, an additional attribute was added in the experiment representing the reward scheme. As such, the respondents were presented with hypothetical scenarios of multimodal options where, in each SP experiment, the sustainable multimodal options (which combined public transport, sharing schemes, cycling etc.) were rewarded with money, credits or additional passenger services, such as guaranteed parking space for the car/bicycle, free wi-fi access on board and reserved seat on the bus/metro. The sample gathered people with average age of 38 years. The respondents were approximately evenly distributed between the gender categories (46.7% of female and 53.3% of male), while mostly of them hold graduate or post-graduate degree (71.1% of total), are full time employed (62.2% of total) and own a car (77.8% of total). In addition, most of the respondents (about 77.8% of total respondents) chose the trip to work as their typical trip, while leisure and family care trips were indicated as typical trips by 8.9% and 6.7% of the respondents respectively.

4 Modelling Results and Application

Table 1 presents the estimation results for the mixed logit model. A brief description of the independent variables is also given and the standard error and the statistical significance of each variable are indicated. Based on the results, the model performs well in that parameters have the expected signs and are highly significant. The alternative specific constants of the utility functions represent respondents' preferences that are inherent and independent of specific attribute values presented in the SP experiments. The estimation results indicate that the respondents have some inherent propensity towards car-sharing ($a_{car\text{-}sharing}$= 4.15), carpooling ($a_{carpooling}$= 4.21) and the multimodal alternative of "Park-and-Ride/Car-Sharing" ($a_{P+R/car\text{-}sharing}$= 3.34). Concerning the travel cost estimates, the signs are as expected; the negative coefficients indicate that travel cost has a negative effect on individual's utility in all multimodal alternatives. The same also applies to travel time; the higher the travel time of a multimodal alternative, the lower the probability for an individual to choose it. With regards to the effect of socio-demographic data on individuals' utilities, the model estimates are as follows: the respondent's age negatively affects the probability to choose the alternatives of "Park-and-Ride/Car-sharing", "Car-sharing" and "Carpooling" (−0.048) and positively affects the probability to choose the "Car" alternative (0.041). This could be explained by the fact that older people may be reluctant to change their habits, give up traditional transport modes (such as car) and use emerging and innovative schemes.

Table 1. Mixed logit model estimation results.

Variable	Description	Estimate	Std. error	t-test
Alternative-specific constants (ASC) (base category: PT and Bicycle)				
a_{car}	ASC specific to Car	2.000*	1.030	1.94
$a_{car\text{-}sharing}$	ASC specific to Car-Sharing	4.150*	0.915	4.54
$a_{carpooling}$	ASC specific to Carpooling	4.210*	0.987	4.27
$a_{P+R/car\text{-}sharing}$	ASC specific to P + R and Car-Sharing	3.340*	0.878	3.81
$a_{PT/bike\text{-}sharing}$	ASC specific to PT and Bike-Sharing	0.265	0.239	1.11
$a_{PT/walking}$	ASC specific to PT and Walking	2.840*	0.595	4.78
a_{P+R}	ASC specific to P + R	1.660*	0.334	4.96
a_{uber}	ASC specific to Uber	1.590*	0.653	2.43
Travel Cost [in 10 €]				
$\beta_{TC\text{-}car}$	Travel cost specific to Car	−0.013*	0.005	−2.31
$\beta_{TC\text{-}carpooling}$	Travel cost specific to Carpooling	−0.020*	0.006	−3.29
$\beta_{TC\text{-}P+R/car\text{-}sharing}$	Travel cost specific to P + R and car-sharing	−0.021*	0.005	−4.39
$\beta_{TC\text{-}PT/bike\text{-}sharing}$	Travel cost specific to PT and bike-sharing and P + R and Bicycle	−0.008*	0.003	−3.38
$\beta_{TC\text{-}PT/walking}$	Travel cost specific to PT and walking	−0.015*	0.005	−3.04
$\beta_{TC\text{-}P+R}$	Travel cost specific to P + R	−0.012*	0.002	−5.28
Travel time [in minutes]				
$\beta_{TT\text{-}car}$	Travel time specific to Car	−0.076*	0.016	−4.81
$\beta_{TT\text{-}carpooling}$	Travel time specific to Carpooling	−0.058*	0.018	−3.28
$\beta_{TT\text{-}carsharing}$	Travel time specific to Car-sharing	−0.059*	0.016	−3.83
$\beta_{TT\text{-}P+R/car\text{-}sharing}$	Travel time specific to PT and bike-sharing and P + R and Bicycle	−0.051*	0.016	−3.28
$\beta_{TT\text{-}PT/bike\text{-}sharing}$	Travel time specific to P + R and car-sharing	−0.026*	0.008	−3.28
$\beta_{TT\text{-}PT/walking}$	Travel time specific to PT and walking	−0.090*	0.017	−5.39
$\beta_{TT\text{-}P+R}$	Travel time specific to P + R	−0.048*	0.010	−5.00
$\beta_{TT\text{-}uber}$	Travel time specific to Uber	−0.048*	0.019	−2.51
Individual's personal information (Socio-demographics)				
β_{age1}	Respondent's age (specific to car)	0.041**	0.024	1.66
β_{age2}	Respondent's age (specific to P + R/car-sharing, Car-sharing, Carpooling)	−0.048*	0.018	−2.62
β_{gender}	Respondent's gender (female) (specific to P + R/car-sharing, Car-sharing, Carpooling)	−0.529**	0.300	−1.76
$\beta_{employment}$	Full time employed-flex schedule (specific to car)	−1.850*	0.550	−3.36

(*continued*)

Table 1. (*continued*)

Variable	Description	Estimate	Std. error	t-test
Reward schemes				
β_{credit}	Credit-based reward [in €[(a)]] (specific to PT/bike-sharing and PT/Bicycle)	0.146**	0.090	1.62
$\beta_{monetary}$	Monetary reward [in 10 €] (specific to car-sharing)	0.017*	0.007	2.49
σ_{active}	Error component (specific to PT and walking, PT/Bicycle, PT/bike-sharing)	−1.210*	0.230	−5.25
LL_0	Initial log likelihood	−3418.573		
LL_β	Final log likelihood	−557.306		
ρ^2	Rho-squared	0.837		
Draws	Number of draws	300		
N	Number of observations	706		

Notes: P + R: Park-and-Ride, PT: Public Transport
*: *Statistical significance at 5% level,* **: *Statistical significance at 10% level*
[(a)]*An equivalence of 100 points = 0.5 € was assumed and presented to the survey participants*

A similar conclusion has been documented in Prieto et al. [18], where the authors concluded that older people are less likely to use car-sharing services. In addition, based on our estimates, a full-time employed individual with flexible schedule is less likely to choose car (−1.85). A reasonable explanation for the negative coefficient is that people with a flexible work schedule are more flexible to use other transport modes such as public transport, sharing schemes and active modes. Concerning the reward-based schemes, monetary- and credit-based rewards are found to be effective in altering travellers' behavior. Instead, the variable "extra passenger services" was not found to be statistically significant in any model specification, and was, thus, excluded from the utility functions. The positive coefficient of the variable "monetary rewards" (0.017) indicates that individuals are more likely to use car-sharing in the presence of monetary rewards, while individuals are more likely to choose "Public Transport with bike-sharing" and "Park-and-Ride with Bicycle" in the presence of credits. However, the corresponding coefficients (in € units) indicate that the effect of credits is stronger than the effect of monetary rewards.

The effectiveness of the reward policy is highly dependent on the level of the rewards. It is expected that the higher the reward, the more intense the behavioral change towards the promoted multimodal choices. To explore this effect, a sensitivity analysis is conducted which accounts for different levels of credits (from 0 to 500 points) and estimates the change of the probability to choose each multimodal option. Figure 1 provides an evidence of the level of credits that could be offered by policy makers so as to promote the desired multimodal alternative. Based on this, in consistency with the model estimation results, "Public Transport with Bicycle" and "Public Transport with Bike-sharing" can be promoted after the introduction of credits. In specific, Fig. 1 indicates that "Public Transport with Bike-sharing" is more sensitive on credits' effect and, thus, meets the highest benefit in its market share (+16.67% if 500 points are offered).

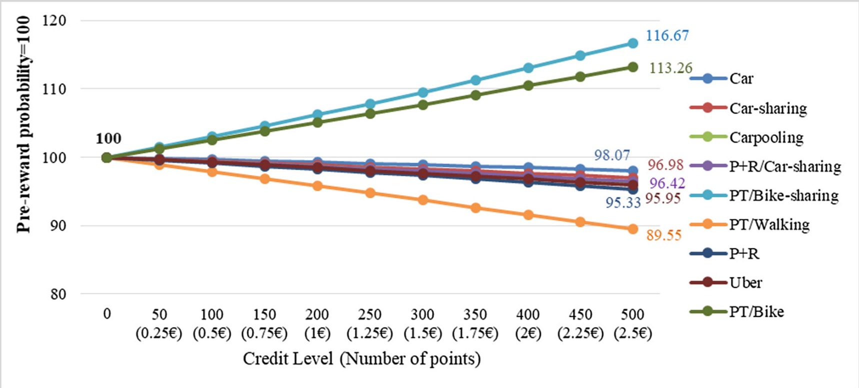

Fig. 1. Probability change in relationship with the credit level.

5 Conclusions

This paper explores the potential of a transport policy which relies on offering several types of rewards to people who use sustainable means of transport. In detail, it is examined whether monetary-, credit- or other service-based rewards could change travellers' behavior towards green mode choices, such as public transportation, sharing schemes and active transport modes.

The main conclusion drawn from our research is that, overall, reward schemes could be slightly effective on promoting some green multimodal solutions, while restraining the use of private cars. However, the level of their effectiveness seems to depend on the multimodal choice considered and the type and level of the reward offered. In particular, our estimation results indicate that monetary rewards and credits are most effective than the offer of other passenger services. In particular, monetary rewards are more likely to promote car-sharing, while credits may more likely promote "Public Transport with bike-sharing" and "Park-and-Ride with Bicycle". However, the coefficients of these variables indicate that the effect of credits is stronger than the effect of monetary rewards. Finally, the level of the reward is found to influence the individual's behavioral change. In detail, the higher the reward, the more intense the behavioral change towards the promoted multimodal choices. Our sensitivity analysis indicated that, although "Public Transport with Bicycle" and "Public Transport with Bike-sharing" can be promoted after the introduction of credits, the second alternative is more sensitive on credits and, thus, meets the highest benefit (+16.67% if 500 points are offered).

This paper could be considered as a starting research point for exploring the dynamics of reward schemes on travel behavioral change and several further research directions can be indicated. It is widely argued that individual's attitudes may strongly influence their travel-related decisions and incorporating them in a discrete choice model framework could highly improve the model estimations and resulting conclusions [19]. Towards this direction, our research could be further enhanced by exploiting the attitudinal data collected from our web-based questionnaire so as to develop latent variable models. In this way, the way individuals actually behave could be better understood and the impact of individuals' attitudes and perceptions on travel decision making additionally examined, by simultaneously considering the offer of reward schemes.

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Densification of Cities or Improved Technology to Curb Greenhouse Gas Emissions?

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Abstract. With the shift from fossil fuels to cleaner transport fuels our perception of the pollution from the sector changes. Greenhouse gas emissions become less important and land use for different transport modes, as well as health related issues, become more important.

This paper studies this shift and discusses and compares the consequences of a technology shift in the transport sector with the shift that is possible by densifying cities and thus reducing the transport volume. While densification is seen by many as a major strategy to reduce greenhouse gas emissions from the transport sector, studies show that this takes time to achieve and much longer than technology shifts in the transport fleet. This is a result of the fact that buildings have a very long life (for example 40–200 years) and the urban fabric even longer, so shifts take place very slowly, compared to in the transport sector where the average life of vehicles may be as short as 15–20 years.

By locating huge public buildings like offices and hospitals well within the city borders the transportation need is reduced, but this does surprisingly not have a considerable impact on the emissions say by 2050, compared to other alternative measures.

The method applied is international literature and project studies searches to find new research. The paper applies experience-based knowledge of urban design and evidence-based knowledge seeking new insights. The goal is to look holistically at the issue and to present a set of tools or conditions that can be used as stress testing of densification as a strategy.

Keywords: Densification · Transport-technology · CO_2-emissions

1 Introduction

Are there aspects to the general, and at times fairly cemented, echo-chamber-like densification discourse taking place, that are not highlighted? Are for example new disruptive technologies under development or new approaches that are either partly overseen or not given the attention their potential deserve? Through evaluating new literature and studies focusing on location policies, it is defined what can be achieved by locating huge public buildings like offices and hospitals well within the city borders compared to outside. The research question is; does this have a considerable impact on the emissions by 2050 and is it possible to calculate with some reasonable exactness the

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alternatives that urban planning decisions can be based on? In order to establish a base for discussion, some relative emission figures are considered as a scale.

2 Emissions as a Planning Guide

In the case of the localisation of a new hospital in Stavanger, Norway - a country generally considered run by clean energy due to its 99% electric supply from hydropower (139 TWh) and with one of the world's best electric vehicle incentives [1], locating huge public institutions creates intensive debates. It is partly an issue about employment, as public state institutions employ 10% of the Norwegian work force. In a recent study [2], it was concluded that "huge state institutions were not necessarily located according to the national planning guidelines for a coordinated housing-, land use- and transport planning and this contributes to more private vehicle traffic and greenhouse gas emissions". The new hospital with 8 000 employees is serving a region of 350 000 people within a radius of 65 km. The location choices were either in the outskirts of Stavanger, a city of 135 000 inhabitants, or within the city boundary. TØI calculated the added transport related CO_2 emissions by locating it in the outskirts compared to the within the city boundary to be 331 tons of CO_2 a year or 11 per cent. The distance between the two possible locations was less than 2 km in direct air distance and 4 km by driving on the road network.

The question is – how much is this? Is it a lot or very little and how will this figure change over time as the vehicle sector gets cleaner and possibly electrified? Although traffic congestion most probably will increase from an outskirt-of-city location and land area issues for roads etc. are important matters, this paper will limit its scope to the issue of CO_2 as a measurement. This must not diminish the importance of the other factors to be considered before making a holistic location decision.

The average lifestyle of people in the region results in CO_2 emissions of 11 tons per capita per year, but excluding each citizen's part of the huge oil exports as each Norwegian in the peak export years have been responsible for another added annual 149 tons of CO_2 from oil exported and burnt in other countries [3]. The added CO_2 emissions arising from the outskirts-of-city location versus the within-city border location are arising due to increased traffic volume. But the added 331 annual tons arising from the hospital location is not very much if seen in a more holistic way. It is equivalent to 30 individuals' annual total lifestyle emissions only and in order to save 331 tons per year other lifestyle changes, like each of the three below, could save this

- 132 Norwegians exchange their diesel car for an electric car, or
- 946 Norwegians halve their meat consumption, or
- 1 324 return flights, 45 min each way are avoided.

The new knowledge gained from the TØI report and then by calculating the above alternatives with the aim in mind to look holistically at the challenge, results in a possible conclusion that we cannot evaluate future localisation alternatives by using yesterday's or today's emission data because the field is constantly changing. Instead we must work as forecasters trying to imagine how slow changes on the one hand or dramatic disruptive changes on the other will play out in possible futures. If the transport sector becomes electrified and clean, the discussion about location decisions based on greenhouse gas emissions becomes out-dated. *Since planning of transportation systems and cities are very long-term activities we must constantly improve our ability to be forecasters so that we do not design yesterday's solutions*. Some of the envisaged changes can be exemplified as follows:

One of Norway's largest public transport companies, Ruter, serving the capital, have announced that they will order 10–30 driverless buses during 2018 and in due time they will not have many drivers at all. This will save costs and make public transport much cheaper and hence affordable to the majority of citizens [4]. The next step will be driverless car or minibus sharing. This could change the need for owning a car, as it becomes less necessary to have a car parked outside one's apartment or house 90% of the time.

This could furthermore, in a disruptive way, change our understanding of what transport is and what will it be in the future. Parking lots could be reused as building sites and parks offering new green sensible and pleasant densification possibilities. Such a development is, however, depending on a development towards zero local emission fuels, which means an electrification of transport by electric vehicles, plug in electric vehicles and hydrogen/fuel cells for larger vehicles and goods transport.

With Norway as an example, several developments are pointing in the direction of a cleaner transport sector as equipment is renewed. Some examples of this are:

- Norway is an electric vehicle pioneering country with one of the world's best incentives (no import- and registration tax, no VAT or road toll, access to bus lanes and free ferries. During December 2017, 49% of all sold personal cars, not vans and buses, in Norway were pure battery electric (BEVs) and plug in electric (PHEVs) and that trend is growing fast, from 2025 all sales of new cars in Norway is to be electric and full electrification of the entire vehicle fleet in Norway will only demand 5% of the huge hydro capacity [1].
- The many diesel ferries crossing Norwegian fjords are being electrified. In January 2018 the first battery electric car ferry in Norway was introduced and the company Fjord announced that it has ordered 27 more [5].
- The assumption of the national aviation authority, Avinor, is that by 2025 commercial electric planes will be flying the shortest routes, up to 30 min, in the country [6]. By 2040, the short-haul flights up to 1,5 h will be carried out by electric planes [8]. This raised eyebrows globally [7].

3 Technology Shifts or Densification of Cities?

Densification of cities happens slowly. The effects are not noticeable within a decade or two in the same manner as technology shifts are. This was the conclusion of the 2005 Low Emission Report [9]. It forecasted that during a 45-year time span, densification would not have much effect, while technology shift in the transport sector would. As shown in Fig. 1, densification leading to reduce need for transportation (Transport reduction) showed the potential for marginal reductions only, up to 2050.

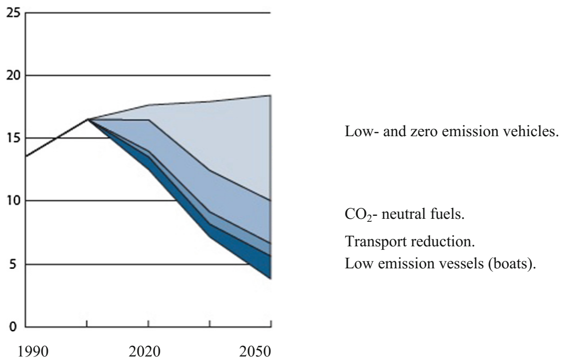

Fig. 1. The Low Emission Report concluded that reducing emissions ($MtCo_2$-eq) through technological improvements could happen faster than through densification (Transport reduction).

Densification takes time because the planning and construction of new buildings takes time, so do infill and infrastructure changes. For example, although there are strong upcoming regulations regarding energy efficiency and the use of renewable energy leading to a new energy paradigm as shown in the new EU Directive [10] stating that all *new* buildings from 2020 have to adhere to the Nearly Zero Energy Building level (NZEB), it is going to take decades to reduce the energy need in existing buildings. The reason is obvious; buildings and city infrastructure (groups of buildings), as opposed to vehicles, have a very long life.

Such buildings are durable and last from 40 to 200 years, while a vehicle fleet is normally completely shifted, scrapped, recycled in 15–20 years and the current vehicle fleet in Norway is now on average 10,5 years old, this is relatively old compared to European countries and a result of extremely high taxes on cars making them very expensive, while the EU vehicle life average is much younger, only 7,4 years [11].

Replacing the existing fleet's oldest and very polluting cars is hence a strategy that can be implemented relatively fast, compared to replacing polluting buildings with new ones. The biggest CO_2 emission reduction up to 2050 will hence happen through technological improvements of the vehicle fleet, not through buildings or cities. In a longer time perspective, on the other hand, densification could be a viable strategy, so we must continue to consider well-developed and sensitive densification projects too.

Density is normally measured as number of inhabitants per km^2. Urban areas with a higher density tend to have more frequent transportation services and shorter distances to transit stops. Densification is often promoted as a strategy to reduce the environmental impact from transport and mobility. In a new PhD Thesis [12], it was found that "it is not evident if the observed impacts of density are due to density in itself or to covariates." It continues, "On the flip side, densification of urban area can enhance phenomena such as Urban Heat Islands, which in turn increases the cooling need for buildings and public spaces. Temperatures in dense urban areas become higher than in more open windy landscapes. Differences of 12 °C or more has been measured for million sized cities [13]. In many climates such temperature rises are disastrous. The recollection of the European heat wave during 2003 where 35 000 people died, hereof 15 000 in France alone was a reminder that rising summer temperatures caused by the combined effects of global climate change and local Urban Heat Island effect cause deaths [14]. To reduce this effect, many measures are necessary. First and foremost the reduction of greenhouse gases through mode shift in the transportation sector and cleaner technology, but also through ensuring cross ventilation in apartments during heat waves. Many older and large urban apartments that originally had a considerable external envelope with windows allowing cross- ventilation have been refurbished and split into smaller apartments with windows on one side only where cross- ventilation is impossible. The inhabitants then have to rely entirely on technological solutions like air condition. In the event of the energy supply system breaking down, leading to power cuts they will not work and hence cause rapid temperature rise. This dividing up of apartments is a form of densification too and in the 2003 heat wave had negative effects along with the Urban Heat Island effect. In sum they added up to a worsened, completely technology dependent indoor environment that became very sensitive to errors.

But this is just one, although grave side effect of densification that should be considered when urban living is glorified. Urban life can be great but it can also for millions be a terrible and lonely place and many would probably have been better off living in smaller communities.

4 Stress Testing Densification as Strategy

In order to continue to argue for densification as a strategy to curb CO_2 emission caused by transport and life-style, we could develop a set of conditions to be applied as a densification design tool. Any material used in the world from plastics to metals and timbers are *stress tested* and come with a scientific declaration of its strengths and weaknesses. With densification there has not been a similar stress testing of the general densification strategies. But we are fully aware that in order to develop good densification strategies, a set of conditions has to be fulfilled. They can be listed as a set of questions to be addressed in a scheme:

- *The Heat Island Effect*: Can it be minimised through design?
- *The Wind Tunnel Effect:* Can it be avoided through design?
- *The Overshadowing Effect:* Densification by adding new buildings often lead to conflict from overshadowing. Can a more sensitive design approach reduce the negative effect of shadows thrown from new, often taller buildings? If densification is unavoidable, can reflection from neighbouring buildings be used to through daylight in directions brightening up the existing infrastructure and buildings and softening the negative impact of overshadowing?
- *The Concreting of City Land Effect:* More built, hard paved, surfaced (concrete and asphalt) near buildings where densification takes places leads to more gathering of surface water. This stresses the water escape infrastructure. Areas that earlier has been green and are now built on, loose the water absorption delaying effect. Can this be minimised and is it an argument against intense densification? The trend towards

green roofs is certainly a response to this development, but attacking the symptoms, not the cause.

- *The Discomfort to Biodiversity Effect:* A greyer more intensely built urban environment makes life hard for birds and insects. This has grave effects on natural processes but also on humans as the lack of birdsong becomes noticeable. Can design of green infrastructure and buildings avoid this?
- *The Grey Concrete Effect*: If the urban environment becomes too grey, dull and dense, will urban dwellers flee when they have a chance and escape for an extra week every now and then to a greener more exotic part of the world? If so, only one return trip a year from North Europe to South East Asia will result in greenhouse gas emissions for an individual of approximately 5 000 tons CO_2. This is half the annual CO_2 production of a typical North European, based on today's technology. Will greener urban environments avoid this?
- *The Impersonalisation Effect*: Since urban areas also can be lonely and impersonal places, can planning and design facilitate more and better meeting places, where human interaction happens both as organised activity but also in a natural way, making urban living more pleasant for more people?
- *The Citizen of Nowhere Effect*: The built environment with its steel and concrete seems adult biased accommodating the 30–40 years old. In many parts of dense cities few children live, so does elderly. The institutions needed for those groups like schools and meeting centres are not within walking distance. In these parts restlessness occurs, people move in and out and it is hard to connect with the neighbourhood because its inhabitants change so fast. Is this alienation negative to kids – our future?

5 Discussion

There are many other issues to be addressed in addition to the above examples. One particular complication from urban densification is increased congestion on roads and public transport, unless such services are developed simultaneously. Densification leading to conflict by shadows thrown by neighbouring buildings is darkening people's daily life, can have a grave impact on many and most people cannot afford to move to a place free of shadow if it implies rising living costs. The fundamental reduction in people's overall qualify of life as a result of shadows thrown after densification took place in the neighbourhood, can have a grave impact on people's minds and depressing them when loosing access to view or sunlight. Dense living can hence lead to separation and a feeling of loneliness. As early as 1949, Oxford University professor of philosophy Gilbert Ryle raised the issue of separateness of mental and physical existence in his now classic writing and teaching [15].

Through sensitive planning, *stress testing*, this can be avoided, but in many densification projects challenges pile up without being handled seriously and as a result the quality of living is degraded for many. These are downsides that must be addressed if densification is going to be intensified because all communities are fragile and sensitive to change. Sociologists have dealt with this challenge as long as the discipline has existed and the community in modern society has been studied and a lot of knowledge is gathered about human behaviour and response to change [16].

Densification of cities leads to change through gathering more people in urban areas, an apparent positive move, but not necessarily more socialising. Smart city advocates also see densification as a possible convergence of city planning theories, city rules definition and city development [17]. In the discussion of densification as a way of reducing greenhouse gas emissions through increasing critical traveller mass, the negative impact of densification on people are rarely discussed. The positive impact on reducing greenhouse gas emissions is at the core of the discussion and dominating it. The natural control question; what this does to people is rarely addressed. More and more people live alone in cities, although surrounded by people on all sides. Virtual contact networks have replaced the natural human contact networks [18]. A growing feeling of alienation is sensed and registered, to the extent that there are on-going discussions about the health issues related to loneliness. In USA 27% of all people now live alone, in New York 33%, in Sweden's capital Stockholm 58% [19].

When planning the transportation networks of the future it will be crucial to see and try to understand the whole human condition, to apply a holistic approach taking all senses and human needs into consideration [20]. *This is of course possible, but is often forgotten in a sector-by-sector planning where each discipline is engaged in its own field and that alone. Designing for the real world means designing holistically and not separately*

The case of the city of Freiburg on Germany is in this instance interesting. The transportation system and renewable energy application, the overall sustainability success of Freiburg did come about because of the cross discipline approach, the inclusion of the inhabitants and their will in the overall planning process. It was a time consuming process but it succeeded to ensure that the feeling of alienation to the place, the process and the political actors running the process was diminished, also because it had a policy on social/demographic mix, meaning different sized units and different social mix [21].

6 Conclusion

Densification offers many advantages and positive sides. Questioning it carefully is well meant and not an expression of denouncement. It is merely a call for caution and stress testing could be a way of systematizing a cautious questioning.

Through using the stress testing examples as a way of questioning a particular densification project, its viability and strength can be considered, discussed and adjusted. Through this our chances of avoiding designing unliveable cities increases. We are reminded that densification of cities is not only about reducing greenhouse gas emissions but to create the good environments people need to have a good life in a community.

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Traffic and Environmental Rehabilitation of the Agioi Anargyroi Square of the Municipality of Agioi Anargyroi – Kamatero

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Abstract. The subject of this paper is the traffic and environmental upgrading of the Agioi Anargyroi Square of the Municipality of Agioi Anargyroi – Kamatero. The aim is to improve the traffic of both the vehicles and other road users and to make the Square a reference point for the area. In this context, a three-step strategy is formulated and proposed: (a) diversion of large volumes of through traffic using driver information systems which will propose shorter trips outside the Municipality to the drivers, (b) traffic interventions and traffic management around the Agioi Anargyroi Square, and (c) urban renovation interventions at the open public spaces of the Agioi Anargyroi Square and the surrounding area, aiming to acquire a unique supra-local character. Emphasis was given mainly on the first stage and, in fact, shorter routes were found for the through traffic that bypass the Municipality. This was feasible using the Google Traffic feature of Google Maps which proved to be quite promising for further relevant applications in the future.

Keywords: Agioi Anargyroi – Kamatero · Mobility · Traffic management

1 Introduction

The Municipality of Agioi Anargyroi – Kamatero, Greece, is a typical Municipality of the Athens metropolitan area resulting from the development of modern Athens as the capital of the Greek state from the 19th century until today. In the west part of the Athens metropolitan area residential and industrial land uses have been developed during the last 50 years, together with the development of the primary and secondary sector of economic activity. The area is divided into three residential lanes, which are defined along three major traffic routes running through the area:

- the section of the European route E75 called “Kifisou Avenue”,
- the railway line Peloponnese – Athens – Thessaloniki, and
- the central avenue of the area that crosses the Municipality of Agioi Anargyroi – Kamatero called “Dimokratias Avenue”.

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The area was initially developed outside the urban planning zone, resulting in the gradual rise of permanent environmental problems that have to be faced. One of the biggest problems of the Municipality of Agioi Anargyroi – Kamatero is the preference of using private means of transport, such as private cars, instead of public transport, resulting to traffic congestion. This is a common problem of such areas around the world and probably the reason that transport is considered one of the "social determinants of health" [1]. Restrictive policies should be considered for the promotion of sustainable urban mobility, as well as for reasons such as environmental, social, human cost of accidents, and health [2].

The main problems of the Agioi Anargyroi Square and the surrounding area are the following:

- There is a need for urban renovation and reorganization of the urban space.
- Uncontrolled blending of different kinds of business activities and environmental burden with the residential areas.
- Absence of traffic planning resulting in environmental degradation.
- Lack of organized parking spaces as well as occupation of sidewalks from incompatible uses such as parking of vehicles.
- Absence of the necessary traffic and transport infrastructures resulting in the explosion of traffic load.
- The accumulation, in the wider area, of environmentally harmful uses that serve the needs of almost half of the basin of Attica, without a parallel planning and regulation of the access to them, such as the sanitary landfill of Fyli and the landfill of Ano Liosia.
- Pollution from any type of activity and air pollution from the heavy vehicle traffic.
- Lack of open public and green spaces. There is a need to move the 301 Military Base Factory and the exploitation of the area as green space and parking area and for the active protection of the nearby pine forest, as well as the upgrading and rational management of the "Antonis Tritsis" Environmental Awareness Park.

For the environmental upgrading of the Agioi Anargyroi Square and the broader area, in the frame of this paper a three-step strategy is proposed:

1. Diversion of large volumes of through traffic using driver information systems which will propose shorter trips outside the Municipality to the drivers.
2. Traffic interventions and traffic management around the Agioi Anargyroi Square.
3. Urban renovation interventions at the open public spaces of the Agioi Anargyroi Square and the surrounding area, aiming to acquire a unique supra-local character.

Apart from the proposed strategy, this paper mainly focuses on the first step for which specific proposals have been formulated using the Google Traffic feature of Google Maps in order to find alternative and better routes.

2 Methodology

2.1 General Framework

The final aim of the proposed strategy is to enhance the mobility of the pedestrians and to increase the costumers of the shops of the surrounding area of the Agioi Anargyroi Square by giving it a supra-local special character. A network of pedestrian areas and/or woonerven zones will be required that will be easily accessible to both the city's residents and the visitors. The attraction of visitors to the area is crucial for the success of the proposed strategy. The changes that will occur by the proposed strategy both at the surrounding area of the Agioi Anargyroi Square and the center of the Municipality of Agioi Anargyroi – Kamatero include the upgrading of the mobility services, the reduction of the travel delays, the increase of traffic safety, and the improvement of the quality of life of the residents and the visitors, in the general frame of sustainable urban mobility. The improvement of the environment through the reduction of air pollutants from the vehicles' emissions, is equally important.

The approach of the general framework was the following:

- Collection and study of existing relevant surveys.
- Highlighting the problems of the road network.
- Counting or finding traffic volume data from existing surveys.
- Search for the peak hour and an initial estimation of the congested road segments.
- Comparing the results from older traffic volume data with the current situation using the Google Traffic feature of Google Maps platform [3].
- Data analysis of turning movements data.
- Formulation of alternative traffic and parking scenarios, mainly through finding alternative diversion routes.
- Literature review to find relevant guidelines.
- Formulation of intervention proposals of renovation of the Agioi Anargyroi Square, introducing cycling paths, pedestrian areas and woonerven zones, and appropriate crossings.

This approach led to the formulation of the three-step strategy described above. In the present paper, the first step will be described together with elements from the other two steps.

2.2 Finding Alternative Diversion Routes (First Step)

The main aim of this step is to reduce the through traffic from the center of the Municipality of Agioi Anargyroi – Kamatero and the Agioi Anargyroi Square. This is a prerequisite for any further step since large volumes of through traffic pass through the area.

The main problem was to find alternative and better, i.e. faster, routes that could be proposed to the drivers diverting thus some of the through traffic. This was achieved by using the Google Traffic feature of Google Maps platform [3].

3 Results and Discussion

3.1 1st Step: Diversion of Large Volumes of Through Traffic

Using the Google Traffic feature of Google Maps platform [3], the times of the trips with private car passing through the Municipality of Agioi Anargyroi – Kamatero and alternative diversion routes through the Odos Thivon, the Attiki Odos, and the E75 motorway have been counted (see Figs. 1, 2, 3, 4, and 5).

Fig. 1. Alternative diversion routes: Odos Thivon (red left), E75 motorway (red right), and Attiki Odos (yellow).

The through traffic of the Municipality of Agioi Anargyroi – Kamatero may be served by the following alternative routes (see Fig. 1):

- by the E75 motorway for the east part of the Municipality, and
- by Odos Thivon for the west part of the Municipality.

Obviously, there are alternative diversion routes that the drivers do not follow mainly due lack of information (see Table 1). They think that the diversion will take more time than the straight route through the Municipality of Agioi Anargyroi – Kamatero and thus they pass through it.

The use of Variable Message Signs (VMS) informing the drivers for the alternative routes with real-time travel times could have a great impact on the diversion of large part of the through traffic volume (see Fig. 6). VMS systems are used to convey specific and real information during the passage of the motorist on traffic management and road safety issues, usually in the form of Light Emitting Diode (LED) messages. Indeed, it has been found that route time information attracts more attention than congestion information [4].

Apart from the use of VMS systems and the diversion of large traffic volumes, other measures could help reduce the traffic through the Municipality of Agioi Anargyroi – Kamatero, such as:

- Traffic calming: The main benefits for the implementation of traffic calming measures is to increase road safety, improve the level of services provided for

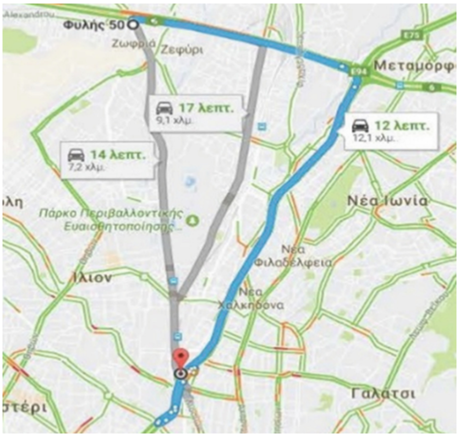

Fig. 2. Alternative routes (from Liosia to Odos Fylis 50) and times of the trips.

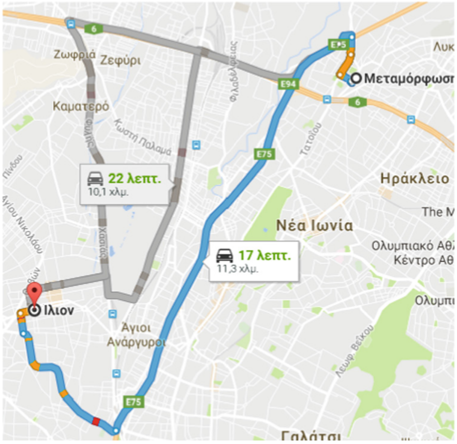

Fig. 3. Alternative routes (from Metamorfosi to Ilion) and times of the trips.

vulnerable road users, reduce the car dependency, increase neighborhood activity, increase the value of real estate, and improve the environmental conditions [5].

- The widening of the Odos Thivon will serve the northern and western suburbs. This means that the Odos Thivon will end at the intersection of Fylis with Chasia, quite north of the Municipality that will serve the northern suburbs (see Fig. 1).
- Construction of appropriate entrances and exits for the E75 motorway.
- Exclusion of heavy trucks from the center of the Municipality.
- Promotion of the Suburban Railway and public transport by creating more train and bus stops and routes.
- Utilization of Advanced Traveler Information Systems (ATIS) and Open Road Tolling (ORT) for the residents that use the Attiki Odos.

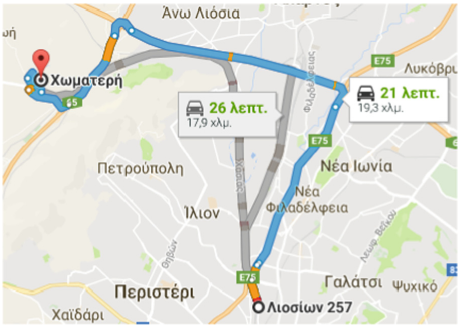

Fig. 4. Alternative routes (from Odos Liosion 257 to Chomateri) and times of the trips.

Fig. 5. Alternative routes (from Nea Chalkidona to Ano Liosia) and times of the trips.

Table 1. Travel times for different origin – destination trips through: (a) the Municipality and (b) diversion routes, and the time differences.

Starting Point	Destination	Through	Diversion	Differences
Agioi Anargyroi	Ano Liosia	19 min	15 min	4 min
Agioi Anargyroi	Acharnes	14 min	9 min	5 min
Nea Chalkidona	Kamatero	14 min	11 min	3 min
Nea Chalkidona	Ano Liosia	18 min	11 min	7 min
Ilion	Ano Liosia	23 min	20 min	3 min
Agioi Anargyroi	Zefyri	17 min	12 min	5 min
Nea Chalkidona	Petroupoli	21 min	19 min	2 min
Odos Liosion	Chomateri	26 min	21 min	5 min

Fig. 6. Roads with VMS systems [6].

- Awareness campaigns for the residents and commuters regarding the alternative diversion routes and public transport modes.

3.2 2nd Step: Traffic Interventions and Local Traffic Management

Traffic management measures aim at reducing speed, traffic volumes, ensuring user safety and improving the quality of the area. Such measures could be: parking management and control, one-way management, excluding heavy goods vehicles from the center of the Municipality, traffic restrictions, traffic calming, information provision through various means regarding congestion, woonerven zones, etc. Three relevant proposals follow:

1. **Pedestrianization of the road segment of Agioi Anargyroi Street from Iroon Polytechneiou Avenue** (which will become one-way street from Agioi Anargyroi Street to Bibiza Street) **to Dimokratias Avenue** (which will become one-way street from Bibiza Street to Dimokratias Avenue).
2. **Pedestrianization of the road segment of Dimokratias Avenue from Iroon Polytechneiou Avenue to Agioi Anargyroi Street:** Agioi Anargyroi Street will become two-way from Iroon Polytechneiou Avenue to Dimokratias Avenue; allowing left turn from Kyprou Street to Iroon Polytechneiou Avenue; prohibition of parking on the Agioi Anargyroi Street; Iroon Polytechneiou will become one-way from Agioi Anargyroi Street to Bibiza Street; Dimokratias Avenue will become one-way from Agioi Anargyroi Street to Bibiza Street.
3. **Parallel secondary interventions:**

   – The pedestrianization of Tripoleos and Kritis Street is important for reducing the number of movements on the junction and upgrading the area by solving the problem with the presence of abandoned train lines.
   – Parallel implementation of circular traffic around the Agioi Anargyroi Square, so that the traffic at the beginning of the Square is diverted to Dimokratias Avenue.
   – Prohibition of left turn of Dimokratias Avenue (from Acharnes) to Agioi Anargyroi Street.
   – The Iroon Polytechneiou Avenue will only serve the traffic from the northern suburbs to the center of Athens.
   – Kyprou Street will become one-way from Dimitriou Street to Iroon Polytechneiou Avenue.

3.3 3rd Step: Urban Renovation Interventions

The main aim of this final step of the proposed strategy is to transform the Agioi Anargyroi Square to a supra-local point of interest.

For this reason, emphasis should be given to measures creating an urban environment of enhanced aesthetics and healthy living conditions, focusing on the human, improving the daily life of the residents, enhancing the functionality of the area with appropriate infrastructure giving priority to security and cleanliness, promoting the cultural resources of the Municipality, and upgrading the economic activity using new technologies, promoting entrepreneurship, and highlighting the commerciality of the area.

4 Discussion and Conclusions

Forming an interdisciplinary group of experts is necessary to follow the proposed strategy. Transforming an area takes time and needs funding but the most important factor is the human factor and the relevant expertise. In such kind of integrated urban renovations, the participation of the residents is crucial and proper dissemination and questionnaire surveys are also needed. The same goes with the various stakeholders.

This paper is based on a postgraduate diploma thesis of the first author supervised by the third author, where many more details are provided regarding the proposed strategy which is a basis for further research [7].

The most important result presented in this paper is the fact that using new tools such as the Google Traffic feature of Google Maps, many alternative and better diversion routes can be found and exploited with the appropriate information provision.

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Investigating Mobility Gaps in University Campuses

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Abstract. The objective of the present research is to carry out a gap analysis between current mobility situations and the needs, future plans and priorities regarding a number of thematic areas on the issue of mobility in university campuses. For this purpose, an interview was conducted involving 36 experts from seven Southern European Universities. More specifically, experts from each university were asked to analyse and rate both the current and the desired situation in the campus under their responsibility with focus on the following thematic areas: parking management, soft modes infrastructure, public transport, car related issues, road infrastructure, environment and energy, mobility management, freight infrastructure and management, and Sustainable Urban Mobility Plans. Results indicate the different gaps that exist depending whether the campus is located inside or outside the urban area. More specifically, for campuses located outside urban areas, car-sharing and carpooling systems are missing and are identified as important, together with pedestrian and cycling paths for the mobility inside the campus. On the other hand, the highest gap in campuses located inside urban areas is parking management and the role of ICT tools to support every campus sustainable mobility plan.

Keywords: University campus · Sustainable urban mobility plan Gap analysis

1 Background and Objectives

University campuses in the MED Area, with a territorial average extension of 430,000 m^2 and an average population of 35,000 students and employees, are historically related to their urban area since many were built close to city center, rather than in the suburbs. A university campus is therefore similar to an urban model and in most cases, it could be used as a test area for mobility policies related to public transport, multimodality or transport restrictions [1].

Universities are a generator and attractor of highly variable demand for travel with significant mobility impact in terms of magnitude and the resulting implications on the surrounding environment. A university campus brings together groups from different

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areas, whether to work, study, live, representing different habits and attitudes. The campuses are major centers of home-work/university-home travelers, where many are marked by a strong dependence on individual transport often justified by the inefficiency of the public transport system and the lack of alternative modes that can help contribute an improvement of the situation [2]. University campuses are a microcosmos of the urban landscape and an excellent testbed for implementing and evaluating novel mobility policies regarding public transport and multi-modality. Given this, it is important to apply innovative approaches and policies, particularly in terms of transport, to counter the tendency and common practices of extensive private car use and accept the paradigm change to new forms of mobility [3].

In this context, university campuses should be seen as spaces that require the implementation of sustainable transport policies and, therefore, appropriate mobility management strategies. In an ideal scenario these should also be fully integrated and in accordance with the city's global approach on this matter. On the other hand, these locations, due to their variety of uses and most importantly their typical users, can be extremely important as an example for promoting sustainable transport habits that can be maintained throughout the entire life course. They can also act as good examples for students that in the future will have an active role on institutions responsible for urban mobility management [3].

Longo et al. [4] proposed a framework to assist the university mobility managers with the integrated development of the university campus infrastructures along with the adoption of shared electrical vehicles by the university members. In addition, based on Gori et al. [5] a classification in mobility solutions is required based on each country specific characteristics. Furthermore, several other studies analyse the effect of different sustainable solutions on university campuses and their integration with the city [6–10].

The first and one of the most important steps on the development of a Sustainable Urban Mobility Plan and more generally on every new attempt is to analyse both the current situation and the future challenges. Within this framework, a key procedure is to conduct a gap analysis, in order to establish specific target objectives by looking at the specific missions stated, strategic goals and improvement objectives [11].

In order to make any improvements in the development of any plan, the first step in the gap analysis is to understand the current situation and to set goals [12]. Initially terms have to be defined in order to conduct a gap analysis. Within this framework, several researchers have been implementing assessment tools aimed at investigating the gap that exists between needs and priorities in cities [13, 14].

The objective of the present research is the investigation of the gap between the current mobility situation and the needs, future plans and priorities regarding several thematic areas related to the mobility of university campuses. For this purpose, an interview was conducted with 36 experts from seven Southern European Universities. The paper is structured as follows. In the next section, the methodological approach is presented including details regarding the implementation of the survey and the universities that participated. The analysis results are presented in the third section whilst general conclusions are stated alongside proposals for further research.

2 Methodological Approach

2.1 Theoretical Background

Qualitative survey methods, including interviews, are increasingly being used in research and policy studies to understand traveler perceptions, attitudes and behavior, as a complement to more established quantitative surveys. Qualitative research techniques can be used either as an independent research tool or as a part of a multidisciplinary project in association with more traditional quantitative techniques. In relation to quantitative research, qualitative techniques can be used at different stages as explained below [15]:

- Prior to quantification: Qualitative research can be used to explore the range of issues present within a given population, this generally guides the design of subsequent quantification.
- In parallel with quantification: When respondents are completing questionnaires, either self-completed or interviewer-led, there is an option to consider whether to follow these interviews directly with a more open-ended qualitative interview.
- Post-quantification: It is also possible to use qualitative research to illuminate the findings, particularly if there is a concern over a particular set of findings.

A main advantage of qualitative data analysis techniques is that they result in a rich and detailed contextual description of the phenomenon under investigation. However, this strength of qualitative data is also a drawback. The output of a qualitative inquiry is fundamentally different in nature from quantitative data. As such, analysis of qualitative information can be a difficult and arduous process [16]. The sheer volume of information generated from techniques such as in-depth interviews, focus groups, and participant observation can seem intractable. Findings are often suspected of undue influence by the investigator bias and interpretation. However, proponents argue that qualitative methods can have the same rigor and credibility as quantitative methods if researchers follow a systematic process, paying attention to validity, consistency, and reliability issues during data collection and analysis [17].

2.2 Survey

Within the framework of the present research, an interview has been developed aiming to collect qualitative data (experts' views) of each campus at the local level, concerning mobility to/from and within campus areas, and to investigate the respective gap in the mobility needs. Regarding the sample, a minimum of 3-5 experts per university was set. The ideal mix of participants was described as follows:

- University mobility/planning manager, if such professional figure exists;
- At least 2 technical representatives of local, regional and national public institutions from each partner;
- At least 1 member from Associated Partners, selected by each partner;
- Project Manager of each partner.

Another key element in the interview process were the thematic areas that were identified as key terms for the project. These were parking management, soft modes infrastructure, public transport, car related issues, road infrastructure, environment and energy, mobility management, freight infrastructure and management, information and communications technology tools, Sustainable Urban Mobility Plans.

Consequently, the interviews were structured in two parts. The objective of the first part was to analyse the current situation in the campus under experts' responsibility regarding each of the thematic areas. Experts were asked to provide all the specific measures, tools and policies that exist and discuss any mobility issues related to the thematic areas both from/to and inside their campus. The second part referred to needs, future plans and priorities, and the experts were requested to describe these for the Campus under their responsibility. The responses of the interviews provide the gap that exist in each of the seven campuses and a list of effective sustainable mobility instruments and policies can be developed for the campus SUMPs. In addition, interviewers were asked to rank (from 1 to 5) the performance of each thematic area.

3 Results

Before the presentation of the results, a summary table is provided to give an overall picture of the universities and campuses that are involved in the project.

Table 1 indicates that from the eight campuses (Valencia having two separate campus areas), five were located outside the city while the rest are located inside the city. It should be noted that the overall analysis relies on two parameters. The first concerns the location of the campus as campuses are divided based on their location (inside/outside the city). The second refers to the type of mobility, whether they examined the mobility situation within or outside the campus.

Table 1. CAMP sUmp campus characteristics

	University	Location	Area (m^2)	Students	Personnel	Interviews
1	University of Catanzaro	Outside	260.000	11.000	500	9
2	National Technical University of Athens	Outside	1.000.000	13.500	3.400	8
3	University of Malta	Inside	194.452	11.500	600	2
4	University of Valencia (1 campus)	Outside	1.000.000	10.000	2.000	3
5	University of Valencia (2 campuses)	Inside	400.000	35.000	5.000	3
6	University of Split	Inside	245.000	24.000	1.500	6
7	University of Cyprus	Outside	1.200.000	7.000	1.100	5
8	University of Bologna	Outside	6.570.023	85.000	3.000	9

3.1 Campuses Located Inside Urban Areas

Figure 1 shows the results of interviews with experts based in universities located inside urban areas. These provide valuable information regarding the mobility status of the thematic areas examined in the study.

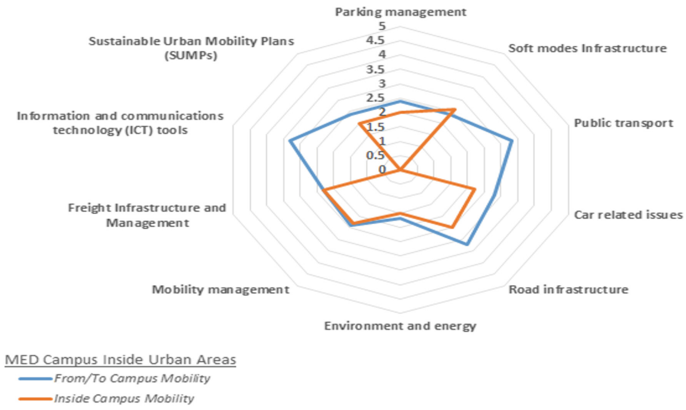

Fig. 1. Mobility gaps from/to and inside the campus for campuses inside urban areas

Results indicate several characteristics that distinguish universities whether they are located inside or outside urban areas, as well as the different gaps between the thematic areas examined. Regarding mobility from/to the campus, public transport is considered important considering the strategic place of the campus inside the city and the several ways that can be reached. The other two thematic areas that achieve high score in the analysis are road infrastructure and ICT tools. For both areas, the location of the campus inside the city is an advantage for the implementation and planning of targeted strategies on these topics.

On the other hand, a key gap detected by this analysis identifies environmental and energy issues. Since these campuses are located inside the city, they are challenged to implement strategies for the protection of the environment. Issues that need to be addressed include the use of clean vehicle technologies, on-street electric vehicle charging points (e-mobility) as well as the use of small vehicles for inside campus mobility.

Several interesting conclusions are also raised through the gap analysis regarding the mobility inside the campuses. Campuses located inside urban areas do not have public transport for the mobility inside the campus as buildings are within walking distance and easily connected. For the same reason, ICT tools do not exist on these campuses. On the other hand, road and soft modes infrastructures are the thematic areas that achieve the best scores in the analysis. Within the above areas the improvement of pedestrian networks as well as safety measures at crossings could improve walkability. Similarly, for cycling, measures could include the setting up of cycle rental services, setting up of public bicycle/bike sharing systems as well as the provision of parking areas and facilities for bicycles.

3.2 Campuses Located Outside or in Suburban Areas

In Fig. 2 the results of interviews with experts based in Universities located outside urban areas are presented.

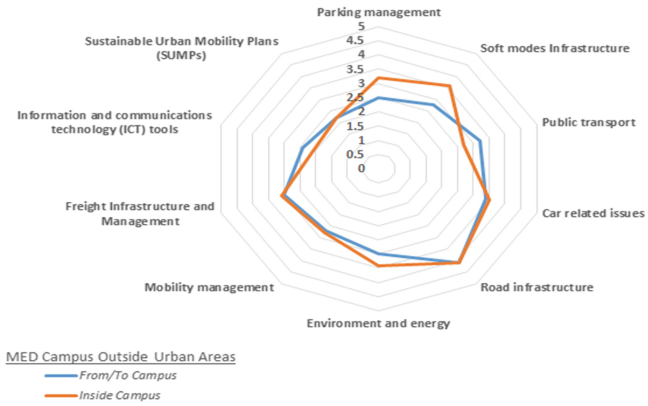

Fig. 2. Mobility gaps from/to and inside the campus for campuses outside urban areas.

The overall picture of the examined thematic areas for campuses outside urban areas are very similar for both the mobility within and outside the campus area. This consists a first very interesting difference detected by the gap analysis between the universities located inside and outside urban areas.

Any infrastructure related to road transport is the best performing area from the examined themes. This can be explained by the fact that campuses located outside urban areas are relatively new, with high quality road infrastructure leading to them. Measures that can further improve this area are mentioned for improved lighting conditions inside campus, pavement maintenance, new infrastructure for disabled access, as well as signage and road markings.

Regarding public transport, the gap analysis showed how several measures and policies should be implemented in order to decrease the gap between current and desired mobility. Indicative measures include the improvement of density and extent of public transport services, actions to improve comfort (stops, stations, and vehicles), actions to improve security (e.g. camera surveillance), ICT tools to improve information to passengers, actions to improve the ticketing systems, actions to implement Intelligent Transport Systems (ITS) as well as to increase frequencies. Mobility management is another thematic area, detected as a gap in the current situation. Measures to decrease this gap include information and advice about travel options to travelers based on ICT tools, setting up of a mobility center in the University, awareness raising activities to promote and encourage sustainable mobility as well as promotion of travel plans for the Regions.

Finally, the lowest score in both types of mobility outside and inside the campus areas are the Sustainable Urban Mobility Plans, which are seen as very important especially for universities located outside urban areas. In general, a Sustainable Urban Mobility Plan should provide a strategy to enhance the quality, security, integration and accessibility of public transport services, covering infrastructure, rolling stock, and services. A main objective of the SUMP is to raise public awareness of sustainable transport options in order to improve take-up of public transport, car sharing, cycling and walking as positive alternatives to single occupancy car use.

4 Conclusions

The innovative aspects of the present research consist both in the methodological approach as well as the key findings. More specifically, a key methodological innovation of the present research is the fact that 36 expert interviews were collected from seven Southern European Universities. The second innovative aspect concerns the key results of the present research categorized into four different groups. More specifically results were separated depending on whether the universities were located inside or outside urban areas. Furthermore, mobility gaps were defined both for mobility within and outside the campus providing useful multi-level results for the examined case studies.

Results indicate several characteristics that distinguish Universities whether they are located inside or outside urban areas, as well as the different gaps between the thematic areas examined. For campuses located inside the city, public transport is considered important given the strategic location of the campus and the several ways that they can be reached. The other two thematic areas that achieved high scores in the analysis are road infrastructure and ICT tools. For both areas, the location of the campus inside the city is an advantage for implementation and planning of targeted strategies on these topics. On the other hand, a key gap detected by the analysis, is the impact on the environment and energy issues.

Focusing on campuses located outside the city, road infrastructure, any infrastructure related to road transport, is the best performing thematic area. With regard to public transport, the gap analysis proved that several measures and policies should be implemented to decrease the gap between the current and desired mobilities. Indicative measures include the improvement of density and extent of public transport services, actions to improve comfort and security. Finally, mobility management is identified as another thematic area which is required to achieve desired mobility levels.

In the next step of the present research, a questionnaire can be developed aiming to extract quantitative data from the case studies. More specifically, by supplementing experts' views, several interesting conclusions can be extracted through a questionnaire to students, researchers and faculty members of the respective campuses.

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Big and Open Data Supporting Sustainable Mobility in Smart Cities – The Case of Thessaloniki

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Abstract. This paper presents a methodology for estimating traffic conditions and emissions using innovative data sources, illustrated with its application in the city of Thessaloniki in Greece. Two types of datasets are considered: probe data and traffic data collected through conventional methods. The probe dataset is comprised of individual objects' pulses (smart devices, navigators, etc.) tracked throughout the network at constant and pre-defined locations ("stationary" probe data collection) or during the whole trip of an "object" that continuously generates pulses ("dynamic" probe data collection). The conventionally collected traffic datasets originate from inductive loops, cameras and radars. Finally, the collected data is processed for estimating mobility and emissions indicators in the city.

Keywords: Big data · Floating car data · Probe data · Emissions

1 Introduction

Transportation is responsible for 26% of Green House Gas (GHG) emissions at European level, ranging from 12% to 63% depending on the region. The contribution of the CO2 to the GHG emissions is between 9 and 26%, being the second contributor in importance and the one most related to the transportation sector. In detail, road transport is credited with 72% of the overall sectorial emissions, presenting again a large variety of results in the different regions, from 10.8% to 95%. This variety of contributions depends on the sustainability [1, 2] of the mobility solutions provided in each region, which are significantly supported by Information and Communication Technologies applied to the transportation sector (named Intelligent Transportation Systems) as well as by Big and Open Data within the Smart Cities framework, which are strongly related to the technologies available at each city and to the social behavior and awareness as well as to the availability of data.

Technological advances have been lately attributed with an increased quality and quantity of mobility-related data. People, being nowadays in a constant state of information sharing, have transformed into active players of the data collection process.

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Luring them with the provision of real-time services in a variety of fields, ranging from routing suggestions to traffic conditions updates, technological advances have managed to engage people in a constant exchange of information. Smart phones and other portable devices that offer "internet on the go" have succeeded in overcoming the naturally-set temporal and geographical limitations, making it possible for users to be connected at any place and time, thus rendering them to online information transmitters by sending and receiving valuable information to/from the content and services providers.

Yet, the challenge of producing the best possible end-products out of these big datasets is twofold; on the one hand there is a need for developing algorithms able to fuse, filter, validate and process big amounts of data (almost) at real-time, while on the other hand, there is a constant need for developing new applications and services for providing innovative and advanced traveler information services for a more sustainable mobility, traffic management schemes and environmental indicators based on these data and processing capabilities.

The structure of this paper is as follows. The second chapter discusses big data sources for the mobility sector, while the third chapter presents an applied case for the city of Thessaloniki. Chapter four is dedicated to the different uses of big data and presents a series of applications in Thessaloniki, Greece. The paper concludes in chapter five with recommendations and suggestions for future research efforts and directions.

2 Mobility Data Sources

2.1 Conventional Traffic Data Sources

Conventional data sources mostly aim at collecting aggregated data through sensors installed at fixed locations of the network. The measurements concern vehicles' traffic flow, speed and traffic lanes' occupancy. Various sensors and technologies have been developed for counting and classifying vehicles and for measuring speed and occupancy.

The conventional, yet most commonly used traffic data methods are manual and only in some cases automatic. A basic categorization is adopted herein that categorizes traffic data to intrusive and non-intrusive. Intrusive methods include pneumatic tubes, piezoelectric sensors and magnetic loops while non-intrusive include manual counts, passive and active infra-red passive magnetic, microwave radar ultrasonic and passive acoustic and video image detections.

[3] lists the limitations of the most representative traditional traffic measurements sensors and technologies, concluding in that the common limitations are related to installation and calibration costs, low coverage and low performance under adverse weather conditions. Regarding the same sensors and technologies, [4] presents the lifetime and costs (purchase, installation, operation and management), concluding that intrusive sensors have a lifetime of 5 years and high maintenance costs, while non-intrusive sensors have a lifetime of 10 years and high purchase and installation costs.

2.2 Probe Data

Probe data is a type of crowd-sourced data collected from individuals, including vehicles, passengers, travelers or pedestrians. In this case, data is aggregated after the collection phase, which significantly increases the quality of the collected data and multiplies the capabilities for processing this data and having a better representation of the mobility patterns in a city. The sensors for probe data are mostly owned by individuals themselves. Probe data can be classified into stationary and floating. The stationary probe data is collected at fixed locations, while floating probe data is collected throughout the whole network. Stationary probe data is collected at various points located along the network by detecting communication protocol identities, such as Bluetooth, or through automatic plate number recognition (APNR) systems. The significant drawbacks of Bluetooth detectors is the need for data processing and the penetration rate of the technology, which has however significantly increased during the last years (70% of all new vehicles had a Bluetooth connectivity in 2016 [5], while the number of mobile phones and portable devices with Bluetooth exceeded 600 million in 2015 [6]). Floating car data and floating passenger data is continuously generated by moving objects (cars or users) equipped with a smart device able to calculate its own location through GPS or A-GPS. It was initially used (and still is) by fleet operators aiming at monitoring the location of the vehicles and tracking routes, events and incidents along the vehicles' routes. The major drawback of FCD is related to the accuracy of the measurements, which is actually solved by map-matching the position of the vehicle to a static map.

2.3 Data from Social Media

Social media is the most recent mobility-related data source and the one with the highest potential (up to 2 million tweets per hour [7]), but at the same time the most difficult dataset to extract and analyze information-rich content, due to its format (free text) and its lack of geo-reference (only 38% of the tweets are geo-referenced [7]). Semantic methodologies for mining and fusion are being developed for analyzing social media content, using pre-determined keywords.

3 Mobility Data in Thessaloniki

Thessaloniki is the second largest city in Greece, with a total of more than 1 million citizens in its greater area, covering a total of 1500 km^2 with an average density of 665 inhabitants per km^2. The total number of vehicles in the city exceeds 777544, including private cars, heavy vehicles and motorcycles. A complete description of the mobility indicators of the city of Thessaloniki can be found in [8]. Three mobility data sources are used in Thessaloniki for collecting mobility-related data: conventional sensors (loops, radars and cameras), probe data (stationary and floating) and social content.

3.1 Conventional Data Sources in Thessaloniki

There are three sets of conventional mobility data sensors in Thessaloniki:

- The surveillance system of the Peripheral Ring Road, monitoring a total of more than 100000 vehicles per day in both directions (green circles in Fig. 1).

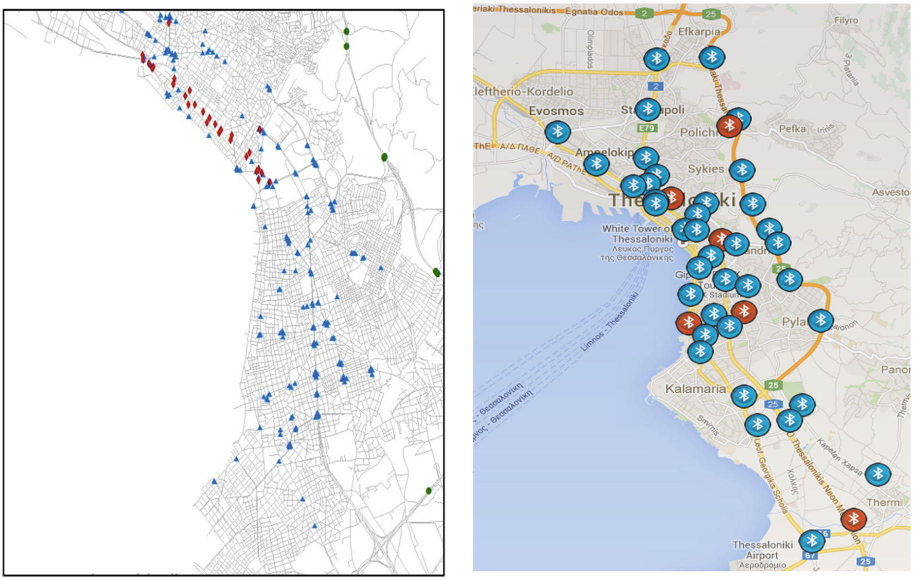

Fig. 1. Mobility sensors in the city of Thessaloniki (left); Bluetooth detectors network in the city of Thessaloniki (right).

- Thessaloniki's Urban Mobility Management System installed in the city center, monitoring more than 50000 vehicles per day (red diamond in Fig. 1).
- The traffic lights management system of the wider metropolitan area of the city (blue triangles in Fig. 1).

3.2 Stationary Probe Data

The Bluetooth detectors network of the city of Thessaloniki is comprised of 43 roadside devices, installed at selected intersections throughout the road network of the city, as shown in Fig. 1. More than 100000 Bluetooth-equipped devices are on a daily basis, generating a total of 300000 detections at the 43 locations.

3.3 Floating Car Data

The network of moving sensors (Floating Car Data) is comprised of a more than 1200 taxi vehicles, circulating in average between 16 and 24 h per day, which periodically (every 6 s) send pulses containing their location and speed. The total amount of data collected and processed reaches 2500 pulses per minute, with daily totals at approximately 1.5 million.

The quality of FCD will be significantly enriched with the provision of cooperative mobility services (connected vehicles and infrastructures) to more than 600 taxis. These vehicles will be able to provide data related to their position and speed per second as well as to detect congestion (Fig. 2).

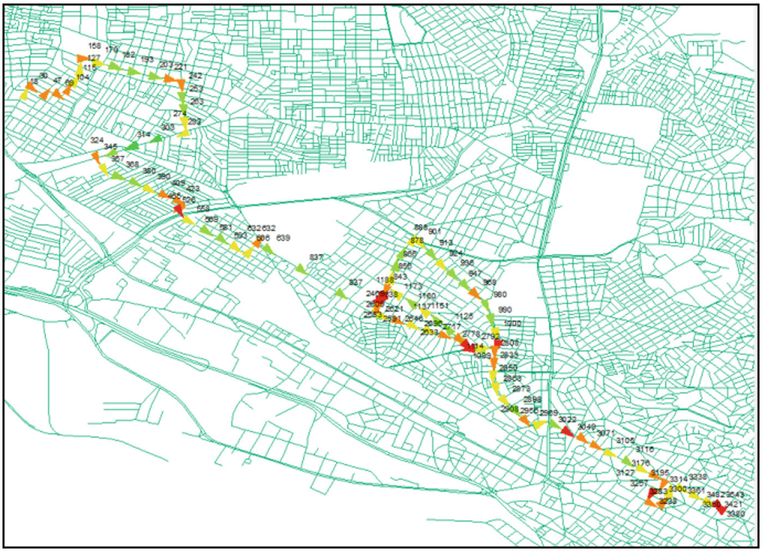

Fig. 2. Sample of floating car data in the city of Thessaloniki (one vehicle, one hour).

3.4 Social Media

The data obtained from social media content is related to individual Facebook check-ins in various locations of the city, which are obtained at real-time. A total of 1500 locations in the city center account for more than 35.000 daily check-ins of Facebook users. Figure 3 below shows the accumulated check-in events during the last hour in the historical part of the city center.

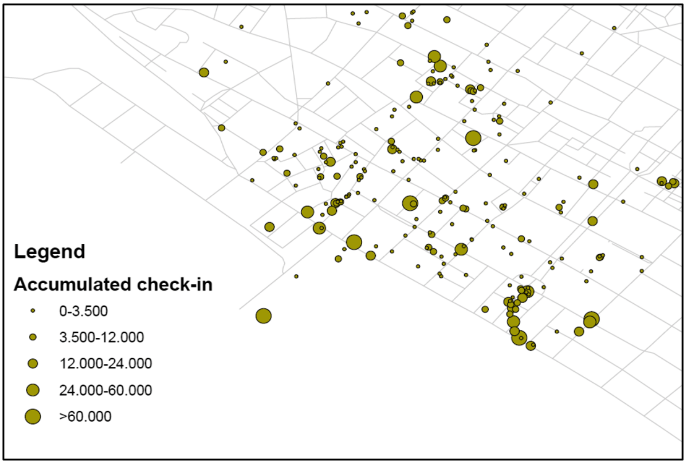

Fig. 3. Concentration of accumulated check-in in the city center.

4 Real Time Traffic Conditions and Emissions Estimation from Probe Data

The data collected by sensors and systems described above are used for estimating mobility-related indicators of the city, such as travel time along the main routes of the city, traffic flow, traffic congestion detection and other socio-economic mobility related characteristics, including environmental indicators. These new datasets can be used for providing both higher quality mobility services and for applying new and more sustainable mobility management schemes from an economic, social and environmental point of view.

New methodologies are being developed for the estimation of mobility patterns and Origin-Destination matrices, which will allow for better tackling the societal needs of the citizens, as well as road hazard detection and calibration of route choice models and macroscopic and microscopic multimodal traffic simulation models. Being able to have a better understanding of the demand and a better representation of the supply will increase the use of the capacity of the network, having direct economic impacts in the society.

By merging all the data presented above, traffic congestion in the city of Thessaloniki is estimated at real-time and forecasted in a short-term basis. Both travel time measured at selected routes by the network of Bluetooth detectors and instantaneous speeds measured from the FCD are converted into traffic flow by using volume-delay functions. All traffic flows are merged into a non-linear mathematical program by means of a modification of the Data Expansion algorithm presented by [9]. Afterwards, all measurements are forecasted by an Auto Regressive model for 15, 30, 45 and 60 min and the process is repeated, in order to obtain traffic flows for the forecasted scenarios. Finally, once the traffic flows are estimated, the emissions resultant from the road transport sector in the city of Thessaloniki is estimated and pollution maps are generated in real time. Figure 4 shows the CO emissions in Thessaloniki, which is clearly linked to the road network since other pollutant sources are missing.

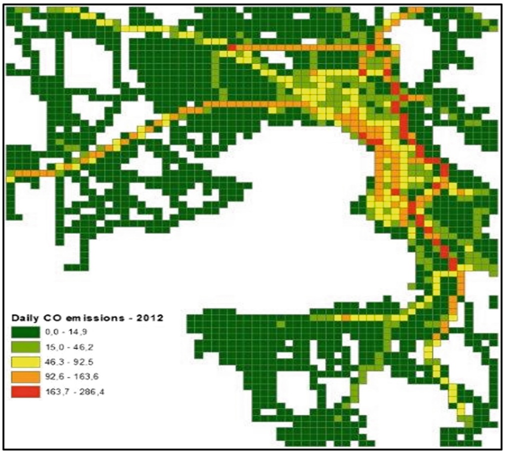

Fig. 4. Real time emissions estimation from the Thessaloniki big data framework.

5 Conclusions and Further Work

The amount of mobility-related data is huge. Technology allows for shifting from aggregated to disaggregated data collection at user level. These results to a need for aggregating methodologies and more post-processing needs, but it has enormously increased the quality of the collected data and therefore the quality of the provided mobility services, especially in urban areas.

Data curators have become an important agent in the mobility theater, passing from an era with an important lack of data to the era of data, where data privacy and quality are receiving most of the attention.

In order to foster this data ecosystem, open data schemes should be promoted by public authorities and institutions, which should make big mobility datasets available to both the research community and service providers.

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Economic Cost of Urban Freight GHG Mitigation

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Abstract. Replacing diesel freight vehicles in urban areas by electric ones would mitigate GHG emission but would also have other costs for urban freight and for public authorities as well as costs and benefits for environment. The cost of mitigating GHG by such a policy is estimated on the 2030–2050 period as the ratio between the total mitigated GHG and the over cost of 'Electric Vehicle' scenarios compared with 'Business As Usual' (BAU) scenario. Assuming that diesel freight vehicles are prohibited in urban areas, two 'Electric Vehicle' scenarios are assessed: in the first electric freight scenario (EV1), urban freight is carried in electric vans with a two tones payload while in (EV2), we assume an electric truck with a six tonnes payload. Our assumptions for these three scenarios are based on a detailed French shipper survey for freight traffic, on a study of the French Ministry of transport for traffic growth and from literature for vehicle costs. Economic costs and benefit of each scenario including BAU are assessed for the community, i.e. for urban freight transport (carriers and shippers), for public finance and external costs are assessed using tutelary values. The cost of GHG mitigation is high in scenario EV1 but in scenario EV2 the mitigation of GHG is going along with a large benefit for society.

Keywords: GHG mitigation · Urban logistics · Electric vehicles

1 The Necessity of Urban Freight GHG Mitigation

Transport accounts for nearly one quarter of global energy related GHG emissions. Within this transport GHG, freight accounts roughly for one third of emissions and grows faster than other sectors. To achieve its necessary deep cuts in GHG emissions by 2050, France must implement voluntary policies, including in the freight transport sector. French electricity is very few carbonized, because produced with a large share of nuclear. This paper sketches two scenarios of urban freight electrification and compares them with the Business as Usual (scenario (BAU) to assess their effectiveness for mitigating urban transport GHG.

The original version of this chapter was revised: For detailed information please see Correction. The correction to this chapter is available at https://doi.org/10.1007/978-3-030-02305-8_105

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2 Scenarios and Traffic

Several policies can lead to an electrification of urban freight traffic. We take here the hypothesis of a prohibition of diesel freight road vehicles in the urban zone from year 2030.

2.1 Urban Freight Electrification Scenarios

In our two electric freight scenarios, diesel trucks and vans are prohibited in urban areas from the year 2030: At the entrances of each agglomeration, the freight entering the agglomeration has to stop in a platform to be unloaded from its diesel truck and distributed on electric vans or small trucks, to continue its way. Likewise, the freight leaving the agglomeration is carried on electric vehicles, at least up to a platform. As all incoming and outgoing freight passes through these platforms, electric trucks have an excellent filling rate (80% of the payload on loaded trips) and an empty return rate of 33% of their total kilometres.

In our first electric scenario (EV1), urban freight is carried in electric vans with a payload of 2 tonnes and a range of 100 km that allows serving the entire city [11]. Shipments over 2 tonnes, are splitted into several electric vans for their urban transport. The division of a 25 tonnes shipment on these small electric trucks means to replace a single HDV (25 tonnes payload) by 13 electric vans in this scenario. To avoid congesting the road network, diesel trucks are allowed in the urban area if they stay on motorway for transit traffic (goods just passing through the agglomeration) or if they carry a shipment over 20 tonnes.

In our second electric scenario (EV2), we assume that the truck industry has been able to make electric trucks with a 6 tonnes payload and the same range of 100 km. Diesel trucks are still allowed on urban motorway for transit traffic but there is no specific authorization for diesel trucks on other roads, even for heavy shipments.

To estimate the energy consumption of these electric trucks, we started from the Zero Emissions Trucks study [2] who estimated consumption of 1 kWh/km for a truck of 10 t. and 2 kWh/km for a 40 t.; We added a fuel consumption provided by Renault Truck of 0.96 kWh/km for a 16 t. and assuming a linear relationship between energy consumption and weight, we found a consumption of 0.55 kWh/km for a 2 t. payload van (total weight 4 t.) and 0.76 kWh/km for a 6 t. payload truck (total weight 10 t.).

2.2 Traffics

To estimate traffic on the road network and compute urban GHG, we used the results of a detailed freight French shipper survey [10]. For each shipment of the shipper survey, a traffic assignment model selects the route that minimizes travel time, computes the GHG emission and splits traffic and emission between urban and non-urban. Vehicles. km and GHG emissions are first computed for all the road traffic in the BAU situation. Then, the platforms are introduced for each urban unit and the network is modified to take account of the new constraints introduced in the electric freight scenario (ban on diesel trucks in the city, except on urban highways). For the goods that have to enter or leave a town, the initial path is divided into two parts that meet on the platform closest to the point on the route. The path outside the agglomeration remains in diesel; its characteristics are not modified (type of vehicle, weight of the load). The new path of entry or exit of the agglomeration is then assumed to be in an electric truck and CO_2 is recomputed, on the urban part of the network. Finally, traffic volumes by category (electric/diesel and urban/non-urban) have been extrapolated to 2050 using a traffic growth factor (1.3% per year) estimated by Pochez et al. [7] (Table 1).

Table 1. Urban freight traffic estimates up to 2050 (billions veh.km).

	2020	2030	2050
Scenario BAU			
Diesel HDV	14,43	16,42	21,26
Diesel Van	4,60	5,23	6,77
Total urban veh.km	19,03	21,65	28,03
Scenario EV1			
Diesel vehicles (HDV + vans)	14,14	16,09	20,83
Electric vehicles	5,95	6,78	8,77
Total urban veh.km	20,09	22,87	29,60
Scenario EV2			
Diesel vehicles (HDV + vans)	13.94	15.88	20.56
Electric vehicle	2.35	2.66	3.44
Total urban veh.km	16.29	18.24	24.00

Source: computed from ECHO survey and [7]

3 GHG Mitigation

GHG emissions have been computed as the product of energy consumption by a Well to Wheel Emission Factor (WWEF) [1]. Emissions of making and maintaining the infrastructure and the vehicle are not considered here, except for the emissions of making traction batteries which is quite different between thermal and electric vehicles. The WWEF for diesel oil is assumed so stay constant - 3.17 kg of CO_2 equivalent ($kgCO_2e$) per litre of diesel oil, while the WWEF of electricity is decreasing, from 0.045 $kgCO_2e$/kWh in 2020 to 0.0225 in 2030 and stable after 2030. For each year, GHG mitigation is computed as the difference between emissions of BAU and an EV scenario.

3.1 Energy Consumption and GHG Emissions of Running Vehicles

Diesel vehicles unitary energy consumptions and their evolution have been estimated from the French statistics and their evolution from [7]. Electric vehicle unitary consumptions are assumed to be stable: 0.55 kWh per km for the 2 tonnes payload vans and 0.76 kWh per km for the 6 tonnes payload truck (Table 2).

Table 2. Evolution of unitary energy consumption of HDV and vans (diesel oil/100 km).

	2020	2030	2050
HDV	31,96	29,70	26,60
Vans	15,73	14,85	13,24

Source: Computed from bilan de la circulation 2016 and [7]

3.2 GHG of Making the Batteries

Various studies have analysed the environmental impacts of making lithium-ion traction batteries and they report widely different results [4]. Following Niels et al. (2013), we assumed that producing a 24 kWh battery in France emits 3 ton of CO_2e and that this will stay valid in the coming years, which makes 5.25 and 18.75 tonnes of CO_2e for the production of a battery of 42 kWh and 150 kWh. Then, assuming that a battery could make 170 000 km in its lifetime for the period 2030–2040 and from the year 2040, 204 000 km thanks to the evolution of the technology, we computed a CO_2e emission of making the battery in 2030: 0.03 kgCO_2e/km for a van (2t. payload) and 0.11 kgCO_2e/km for a 6 t. payload truck.

3.3 Total GHG Mitigation

GHG mitigation of electric vehicle scenarios is summarized in Table 3 here under.

Table 3. Total urban freight GHG emission and mitigation on the 2030–2050 period (MtCO_2e)

Scenario	BAU	EV1	EV2
WW running	405,5	300,4	258,9
Batteries	0	4,5	6,4
Total Urban Freight CO2e	405,5	305,0	265,3
CO_2e mitigation		100,5	140,2

Compared with the BAU scenario, our GHG mitigation estimate on the 2030–2050 period is 100 MtCO_2e in scenario EV1 (5.0 Mt/year on average, i.e. approximately 28% of French freight GHG emissions) and 140 Mt. (7.0 Mt/year) in scenario EV2 (35% of French freight GHG emissions).

4 Economic Costs of the Scenarios

To assess the costs of the different scenarios we estimate, for each year, the costs for the different stakeholders (transport operators, public authorities and environment) in each scenario, then the economic costs of the two ‘electric freight scenarios (difference of the BAU minus EV costs for all stakeholders) km of the different types of vehicles, and multiplied each year these cost per the distances run by each category of vehicle in the different scenarios. We then report all these values to the year 2030 with a discount rate of 4.5%.

4.1 Transport Operators, Carriers and Shippers

We compare the total cost of ownership of the different vehicles using assumptions on factor prices and their evolution that are summarized in Table 4 here under. They are from the Ministry of transport [7] or from the scientific literature.

Table 4. Hypothesis on the purchase prices evolutions in €.

	2030	2050
HDV	73 026	76 026
Diesel Van	36 921	38 421
EV 2 t. payload (without battery)	58 894	58 894
EV 6 t. payload (without battery)	80 080	80 080
Battery (€/kWh)	200	133
Fast electric charging station	55000	55000
Diesel fuel oil (€/litre)	1,75	2,24
Electricity (€/MWh)	128,3	128,3

In this paper, own account transport is not differentiated from hired and reward transport. We focus on operating cost and assume that lower transportation costs translate into lower prices charged to shippers if they outsource their transport.

Electric vans use two types of electricity charging station: normal or fast charging. We assume that the cost of normal (or slow) charging stations is included in the electric vehicle place and, for fast charging stations, according to the result of (Niels et al. 2013) we assume a cost of 55000 € per station (including its connection to the electricity network) and a maintenance cost of 1650 € per year (3% of the initial investment). Such a station has a lifetime of 15 years and serves 4 vehicles in EV1 and 2 vehicles in EV2 scenario (Table 5).

Table 5. Total costs of urban freight per scenario on the 2030-2050 period (billions €).

	BAU	EV1	EV2
Total transport costs	578,2	670,3	529,0
Delta cost		+92,1	−49,2

Finally, the transport over cost is important in scenario EV1 (€ 92 billions), mainly because electric vehicles are substituting for higher capacity thermal trucks. In scenario EV2, where electric vehicles have a higher capacity (6t. payload instead of 2 t.), this additional cost is replaced by a cost reduction of € 49 billions on the twenty years period.

4.2 Public Finance

We took the assumptions of the French Ministry of Environment on the future prices of energy and their taxes. From 2030 to 2050 the taxes on diesel fuel will rise from 0.68 to 1.03 €/litre, mainly because of carbon tax and the taxes on electricity will stay at 50.5 €/MWh. For public finance, the main impact of the electric freight scenarios is the taxes loss on diesel oil. Energy cost per km as well as the share of taxes in energy cost is much lower for electricity than for diesel oil. The over costs for public finance of scenarios EV1 and EV2 compared to BAU on the 2030–2050 period, are synthesised in Table 6 here under: a little less than one billion € per year in two scenarios.

Table 6. Over cost of the electric scenarios for public finance on the 2030–2050 period (billions €).

Scenario	EV1	EV2
Taxes losses on vehicle energy	17.6	17,7

4.3 Externalities: Congestion, Local Pollution and Other

The two most important externalities to consider are the costs of congestion and local pollution; we also considered noise and road safety. We used the French tutelary values of externalities, in € per vkm [8, 9]. These values of externalities evolve over time as the GDP per head (1.30%/year). On the 2030 to 2050 period, tutelary value of congestion cost grows from 0.23 to 0.28 €/vkm for HDV and from 0.12 to 0.18 €/vkm for vans; these values are the same for electric and diesel vehicles. On the same period, local pollution of diesel vehicles has a decreasing cost because of the improvements of vehicles, in line with the Euro norms: from 11,7 €c/vkm in 2030 to 13,5 in 2050 for HDV and from 2,2 to 2,6 €c/vkm for vans. The cost of local pollution is neglected for electric vehicles (Table 7).

Table 7. Costs of externalities per scenario in the 2030–2050 period (billions €).

	BAU	EV1	EV2
Road congestion	82,6	87,6	70,9
local pollution	32,6	24,4	24,3
Road accidents	20,9	17,6	15,9
Other externalities	1,1	0,8	0,8
total externalities	137,2	130,4	126,1

The total cost of externalities in scenario EV1 is nearly the same as in BAU: the higher congestion cost is compensated by lower local pollution and accident. But this total cost of externalities is clearly lower in EV2 (−11 billions €), mainly because of lower congestion and local pollution costs.

5 Conclusion: Economic Costs of the ‘Electric Urban Freight’ Scenarios

Urban GHG emissions estimated from the ECHO survey accounts for nearly half of freight transport emissions and are therefore a major challenge for a mitigation policy. The two urban electric freight scenarios that we tested differ mainly in the capacity of the electric trucks. In the first scenario, the electric vans have a capacity of 2 tonnes. Keeping in mind that these results are linked with many assumption, the economic cost for society of this scenario EV1 on the period 2030–2050 is € 110 billion for a mitigation of 100.5 $MtCO_2e$ which result in a very high mitigation cost: 1025 €/tCO_2e. This scenario increases transport operating cost per tkm, despite the hypothesis of a special authorization granted to trucks carrying heavy loads. It also increases road traffic and congestion in the cities (Table 8).

Table 8. Economic over cost of electric scenarios compared to BAU on the 2030−2050 period (billions €).

	Scenario EV1	Scenario EV2
Transport	−92,1	49,2
Public Finance	−17,6	−17,7
Externalities	6,8	11,1
Balance	−103,0	+42,7

Scenario EV2 is built upon the optimistic assumption of a high improvement on electric trucks; it is highly beneficiary for the society compared with BAU: € 43 billion for the mitigation of 140 $MtCO_2e$ on a twenty years period, which gives a ‘mitigation benefit’ of 304 €/tCO_2e. In this scenario, transport costs are reduced by € 50 billion, because of the high loading rate of electric vehicles, which mainly benefits shippers.

In the current state of technology, the cost of reducing GHG emissions by replacing all diesel vehicles with electric vehicles for the transportation of urban goods would be very high for society; a significant improvement in the characteristics of these electric vehicles would be necessary for such a scenario to become economically attractive. Furthermore, in our two electricity scenarios, public finances are losing € 18 billion, mainly because of the reduction of fuel taxes. An increase in other taxes, such as taxes on electricity would probably be necessary to offset the lost revenues.

These results are very sensible to our hypothesis on the type of use of electric vehicles, mainly the annual mileage and the vehicle fill rates that have a strong impact on transport operating costs.

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Traffic Noise Reduction and Sustainable Transportation: A Case Survey in the Cities of Athens and Thessaloniki, Greece

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Abstract. The paper examines the relationship between sustainable transportation and the reduction of perceived traffic noise levels in the cities of Athens and Thessaloniki. The research was based on a questionnaire survey conducted on a random sample of 490 participants through personal interviews in the year 2016 (271 in Athens and 219 in Thessaloniki). The questionnaire was formed of 18 questions divided into two parts. In the first part (questions 1÷6), the participants stated their demographic data and personal income comparing the years 2008 (before the economic crisis in Greece) and the year 2016 (crisis in progress). In the second part (questions 7÷18), the participants stated the change of traffic noise levels comparing the years 2008 and 2016, the influence of traffic noise in route and transport mode choice and their willingness to increase walking and bicycling due to reduction of traffic noise. Furthermore, they stated the perceived level of traffic noise in the street they resident during day and night time, their awareness of traffic noise negative impacts on public health and their willingness to change their residential area for a quieter but more expensive one. Moreover, they stated their awareness of the sustainable transport modes positive impacts in traffic noise reduction and their willingness to pay an additional tax in order to fund relative sustainable transportation and traffic noise reduction projects in their cities. The present economic crisis in Greece can be an opportunity to change the commuters travel behavior and promote sustainable transportation.

Keywords: Road traffic noise · Sustainable transportation
Transport mode choice · Route selection · Survey

1 Introduction

Traffic noise is an important environmental health concern affecting public health and wellbeing of exposed citizens. Human exposure to noise from transport can lead to annoyance, stress, sleep disturbance and related increases in the risk of hypertension

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and cardiovascular disease. Sustainable transport modes provide citizens the ability to travel in urban areas using their physical power in order to walk or bike and therefore reduce the level of traffic noise. This paper examines the relationship between sustainable transportation and the reduction of perceived traffic noise in the cities of Athens and Thessaloniki. The research was based on a questionnaire survey conducted on a random sample of 490 participants (271 in Athens and 219 in Thessaloniki) through personal interviews in the year 2016. The present economic crisis in Greece can be an opportunity to promote sustainable transportation and change commuters' travel behavior in urban areas favoring more economic, socially alternative and environmentally friendly transport modes.

2 Literature Review

World Health Organization considers noise as the third most hazardous type of pollution, following air and water pollution in big cities [1]. Serious concerns about health impacts and annoyance caused by environmental noise are growing among both the general public and policy makers in Europe. Extensive urbanization and increase of road transport define the main driving forces for the environmental noise exposure of the population. Traffic noise mitigation measures have to be introduced especially in urban motorways in order to enhance the rehabilitation of the acoustic environment. However, it is importation to notice that environmental noise protection is not only a matter of infrastructure but also a matter of "Ecological driving" [2]. The World Health Organization reported that for road traffic noise, the dataset covers the exposure distribution in approximately 20% of the total EU population as of January 2010 [3]. The European Environmental Agency estimated that environmental noise causes at least 16,600 cases of premature death in Europe each year, with almost 32 million adults annoyed by it and a further 13 million suffering from sleep disturbance. In addition, an estimated 13,000 school children suffer learning impairment due to the effects of noise near to major airports in Europe [4]. European Union adopted the Directive 2002/49/EC relative to the evaluation of ambient outdoor environmental noise [5]. Surveillance of ambient community noise is now mandatory for European cities with population over 250,000. As a result, several cities have established noise surveillance programs and set goals to reduce the size of the population exposed to high noise levels. Reducing traffic noise at the source will require new road standards and lower engine noise levels. Noise abatement programs have an environmental justice dimension and need to target the at-risk population [6].

Traffic related noise is becoming the most health-threatening environmental stressors in Europe, and more people are exposed to traffic-related noise than to any other environmental stressors. Excessive exposure to noise could be considered as a health risk in a way that noise may contribute to the development and aggravation of stress related conditions such as high blood pressure, coronary disease, ulcers and migraine headaches [7].

In recent years the importance of urban form on sustainable development has been recognized. Urban geometry and urban land-use pattern are two basic characteristics of urban form. They fundamentally determine transportation demands, which directly affect traffic noise and air pollution. Some researchers have studied the spatial relationship among urban form, traffic volume and traffic noise [8]. Other researchers have investigated the influences of existing urban forms on vehicle transport and pedestrian exposure to traffic noise [9]. Furthermore, researchers have used the Geographic Information System (GIS) as a tool in spatial analysis and modeling in order to estimate the level of noise in urban areas [10].

Motorized transportation is mainly responsible for urban traffic noise. Mopeds, scooters and motorbikes are in large use in the Southern European countries of Spain, Italy and Greece. In these countries the possibility of driving for a large part of the year under good climate conditions, together with the need to overcome the problem of city traffic congestion, makes the use of "power two vehicles" (PTW) extremely attractive. PTW produce additional traffic noise which is especially annoying to citizens directly exposed to noise as in the case of pedestrians and bicyclists. The percentage of annoyed individuals by PTW is about 16% lower than those annoyed by the PTW and cars all together, although the PTW noise is the most relevant in terms of L_{Aeq} [11].

Noise emission and their effects are differently depending on the transport mode. The noise level of road transport modes results from the overlapping of the engine noise, the rolling noise and other recurring noises [12]. Railway public transport modes such as Metro and Tramway are very important for the reduction of traffic congestion. They are considered to be sustainable means of transportation, due to the substantial reduction of air pollutant emissions by decreasing the number of cars, PTW and heavy vehicles (buses) in the urban road network. However, an important adverse effect of their operation is the increased level of ground-borne vibration and air-borne noise [13–16].

The need for studies regarding the noise pollution and its consequences for the community has motivated various researchers on this problem in several countries. A survey in the city of Kerman reported that 70% of the participants classified the noise of their street as "very high" and 86% answered that noise produce physical and psychological annoyance to them [17]. A survey in the city of Curitiba reported that the main isolated noise sources disturbing citizens were traffic (73%) and neighbors (38%) [18]. In main roads of the city of Messina the daily average sound levels due to road traffic exceeded environmental standards by about 10dBA resulting to a 25% of the resident population highly disturbed by road traffic noise. Environmental noise exhibits a certain degree of spatial variance resulting primarily from the peculiar geomorphological structure of the town and from the transport infrastructure [19].

Walking, bicycling and public transportation are sustainable transport modes due to their environmental, societal and economic benefits [20–22]. The presence of proper infrastructure for those transport modes is necessary in order to be used from commuters in their urban trips. The implementation of audit tools for pedestrians and bicyclists urban built environment results to higher level of maintenance and change of commuters travel behavior in favor of those transport modes [20, 23–25].

3 Questionnaire Survey

3.1 Methodology and Data Collection

The survey took place in the cities of Athens (capital city of Greece) and Thessaloniki in the year 2016. It was based on a questionnaire survey conducted on a random sample of 490 individuals (271 in Athens and 219 in Thessaloniki) of different age, profession and purchase power through personal interviews. The used questionnaire consisted of 18 questions and the aim of the analysis was to draw useful and factual conclusions able to demonstrate the actual effect of traffic noise on citizens' choice of transport mode, route selection and quality of life in their residential area. Furthermore, we identified of citizens are aware of the positive impacts of sustainable transport modes in traffic noise reduction are their willingness to financially support relative urban traffic noise reduction projects.

Despite the fact that the sample was random, there was an effort to select the participants as representatively as possible based on their demographic data. The answers in the survey were anonymous so the participants could answer more freely especially in questions of personal income. Due to personal interviews, participants were able to ask questions and receive clarifications regarding the survey.

The questionnaire was formed of 18 questions and split into two parts. The first part (questions 1÷6) focused on participants' demographic data and level of personal income comparing the years 2008 (before the economic crisis in Greece) and 2016 (economic crisis in progress). The second part (questions 7÷18) focused on traffic noise regarding the examined issues. Analytically, the participants stated the change of the perceived traffic noise level in their city comparing the years 2008 and 2016, the influence of the perceived traffic noise level in route and transport mode choice and their willingness to increase walking and bicycling due to reduction of traffic noise. Furthermore, they stated the perceived traffic noise level in the street they resident during day and night time, their awareness of traffic noise negative impacts on public health and their willingness to change their residential area for a quieter but more expensive one. Moreover, they stated their awareness of the sustainable transport modes positive impacts in traffic noise reduction and their willingness to pay an additional tax in order to fund relative sustainable transportation and traffic noise reduction projects in their cities. Finally, they revealed the level of trust to the municipality officials to successfully manage those projects.

After the data collection there was the analysis and export of results and conclusions. The data were analyzed with the use of Microsoft Office Excel software and IBM SPSS Statistics analysis software.

3.2 Results

In Table 1, are presented the results of the questions 1÷4 about the demographic data of the participants. In Table 2, are presented the results of the questions 5÷6 about the financial situation and personal income of the participants comparing the years 2008 (before the economic crisis) and 2016 (economic crisis in progress). In Tables 3 and 4 are presented the results of the questions 7÷18, focused on traffic noise regarding the examined issues.

Table 1. Questions 1÷4.

Question 1: Age (%)		Question 3: Profession (%)		Question 4: Education (%)	
<18	3.7%	Public servant	11.4%	Primary school	2.9%
18–25	7.6%	Private employee	39.2%	Secondary school	5.5%
26–35	29.8%	Self-occupant	15.3%	High school	19.8%
36–45	26.3%	Scholar	6.1%	University	71.8%
46–55	19.6%	Student	10.2%	Question 2: Sex	
>55	13.1%	Unemployed	12.4%	Male	48.4%
Sample	490	Retired	5.3%	Female	51.6%

Table 2. Questions 5÷6.

Question 5: Personal income in the year 2008 (before taxes) (%)				
<5,000€	5,001€÷10,000€	10,001€÷15,000€	10,001€÷15,000€	>20,000€
21.4%	25.1%	16.3%	13.5%	23.7%
Question 6: Personal income in the year 2016 (before taxes) (%)				
<5,000€	5,001€÷10,000€	10,001€÷15,000€	10,001€÷15,000€	>20,000€
40.4%	20.0%	14.1%	11.6%	13.9%

Table 3. Questions 7÷12.

Question 7: Change of traffic noise level in the city after the year 2008 (%)				
Increased	Decreased	Unchanged	Unknown	
4.1%	18.6%	30.2%	47.1%	
Question 8: Influence of traffic noise level in route selection (%)				
None	Low	Moderate	High	Very high
25.3%	25.9%	26.1%	16.3%	6.3%
Question 9: Influence of traffic noise level in selection of transport mode (%)				
None	Low	Moderate	High	Very high
25.1%	20.4%	35.1%	13.9%	5.5%
Question 10: Choice to walk in case of reduced traffic noise level (%)				
Never	Rarely	Occasionally	Often	Very often
5.5%	14.7%	43.3%	30.4%	6.1%
Question 11: Choice to bike in case of reduced traffic noise level (%)				
Never	Rarely	Occasionally	Often	Very often
24.5%	20.8%	27.6%	11.8%	15.3%
Question 12: Most favorable actions to decrease traffic noise (%)				
Pedestrian zones	Sidewalk construction	Sidewalk maintenance	Road traffic volume reduction	Road traffic speed reduction
22.0%	15.1%	15.5%	33.1%	14.3%

Table 4. Questions 13÷18.

Question 13: Traffic noise level in residence street (%)					
Day time			Night time		
Low	Moderate	High	Low	Moderate	High
29.8%	52.9%	17.3%	68.6%	14.1%	17.3%
Question 14: Choice to resident in an area with higher cost of living but lower traffic noise (%)					
Yes	Possibly	No	Unknown		
12.2%	30.6%	39.8%	17.3%		
Question 15: Awareness of traffic noise negative impacts on public health (%)			Question 16: Awareness of positive impacts of sustainable transport modes in reduction of traffic noise (%)		
Yes	Moderate	No	Yes	Moderate	No
43.3%	30.8%	25.9%	76.1%	16.1%	7.8%
Question 17: Annual tax per capita for sustainable transportation and traffic noise reduction projects (€) (%)					
0€	1€÷10€	11€÷20€	21€÷30€	31€÷50€	>50€
38.2%	24.9%	24.5%	6.5%	4.3%	1.6%
Question 18: Level of trust to the municipality officials to successfully manage and execute relative sustainable transportation and traffic noise reduction projects (%)					
None	Low	Moderate	High	Very high	
56.1%	19.4%	20.8%	2.4%	1.2%	

4 Conclusions

The main conclusions of the survey are the following:

- The perceived levels of traffic noise in the cities have been decreased (18.6%) or remained unchanged (30.2%) since the year 2008. It is important to mention that 47.1% of the participants could not evaluate the change of the perceived level of traffic noise in their city.
- Traffic noise affects moderately the commuters' choice of route (moderately: 26.1%, low: 25.9%) and transport mode (moderately: 35.1%, low: 20.4%). There is also an important part of the participants who are influenced from traffic noise in route selection (high: 16.3%, very high: 6.3%) and transport mode selection (high: 13.9%, very high: 5.5%).
- Participants would select to walk in case of reduced traffic noise levels (often: 30.4%, very often: 6.1%) and bike (often: 11.8%, very often: 15.3%).
- The reduction of road traffic volume (33.1%) and implementation of pedestrian zones (22.0%) were the most favorable actions to decrease traffic noise.

- The perceived level of traffic noise was high in residence street during day time (17.3%) and night time (17.4%) and some participants were willing to move to a quitter but more expensive area (yes: 12.2%, possibly: 30.6%).
- Participants were aware of the negative impacts of traffic noise on public health (43.3%) and the positive impacts of sustainable transportation in reduction of traffic noise (76.1%).
- Participants were willing to pay an annual tax for relative sustainable transportation and traffic noise reduction projects (61.8%) but did not trust municipality officials to successfully manage and execute these projects (level of trust none: 56.1%, low: 19.4%, moderate: 20.8%).

The promotion of sustainable transportation can reduce the levels of traffic noise in urban areas with numerous environmental, societal and economic benefits for the citizens. The commuters in Greek cities are aware of the traffic noise issue and are willing to change their travel behavior and support traffic noise reduction actions.

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Sustainable Urban Mobility Plans in Mediterranean Port-Cities: The SUMPORT Project

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Abstract. SUMPORT is an on-going project, co-financed by the Interreg MED Programme, which aims to increase the capacity of authorities of Mediterranean Port-cities in sustainable urban mobility planning, through exchange of experiences, trainings and implementation of pilot actions. The paper presents the SUMPORT context, details out its contents and anticipated results, presents the methodology for the preparation, implementation, monitoring and evaluation of the pilot activities foreseen, as well as the progress of the project implementation.

Keywords: Sustainable mobility · Urban mobility · Port-Cities SUMPORT project · Sustainable urban mobility plans

1 Introduction

Sustainable Urban Mobility Plans (**SUMPs**) are acknowledged as an indispensable tool for ensuring the integration of the sustainability approach in a long-term urban mobility planning. Like all European cities have similar types of problems related to mobility, namely congestion, pollution, emissions and noise, the cities of the northern coasts of the Mediterranean have similar issues to confront, such as the geographical limitations of the coastal boundary defining the urban planning. Especially for those where ports are located, the issue of port originated/attracted traffic must be tackled, i.e. to consider their ports as a major and integral part of the city functional area and not in a fragmented and a distinct way.

It is also valid that Mediterranean area consists of people with similar mentality and culture, which affects their mobility habits and lifestyle, but on the other hand of people living in countries of different economic and social status. In terms of mobility planning, some cities are well advanced, having the economic potential and proactiveness to promote sustainable mobility, but on the contrary some others are substantially lagging behind.

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2 Insights of the SUMPORT Project

2.1 Cooperation Context

The idea for the Sustainable Urban Mobility Plans in Mediterranean port-cities (**SUMPORT**) project emerged from the recognition of slow adoption of SUMPs in the region, especially in some countries, and the opportunity to assist them in promoting sustainable mobility through experience and knowledge transfer from their counterparts in more advanced countries, in order to alleviate their hesitance due to inexperience in SUMPs [1] and due to lack of available funds. Basic facts about the project are presented below:

Financing. The project is co-financed by the European Union Interreg Mediterranean Programme, and specifically by the European Regional Development Fund (ERDF) and the Instrument for Pre-Accession (IPA) II.

Duration. The project's duration is 30 months (February 2017 – July 2019).

Partnership. The project is led by the Central European Initiative (CEI), an international organization based in Trieste, assisted for scientific aspects by the Aristotle University of Thessaloniki, for the transferability of results by the Foundation of the Valentian Community to promote strategic urban development and innovation (Las Naves) and for communication-dissemination aspects by the Institute for Transport and Logistics Foundation (ITL). The rest of the partnership comprises six cities/areas, where ports are located: Durres (Albania), Koper (Slovenia), Kotor (Montenegro), Limassol (Cyprus), Thesprotia (Regional Unit - Greece) and Valencia Port (Spain). Additionally, there are five additional Associated Partners: Port Authority of Valencia, Cyprus Port Authority (as responsible for all ports in Cyprus), Port of Koper, Port of Kotor and Port of Igoumenitsa.

2.2 Activities and Anticipated Results

Apart from the two Work Packages (**WPs**) dedicated to Management and Communication, respectively, the technical activities of the project have been grouped in two WPs [2]: one for the testing activities preparation, implementation and evaluation and another for transferability of the gained experience and results. More specifically, the first of these WPs is a group of activities for SUMP elaboration and small-scale investments that include bike lanes implementation, improvement of public transport through ICT, bike-sharing and car-pooling systems implementation. These activities, main subject of this paper, are presented in more detail in the next chapter.

But besides these activities, four training seminars with respective number of modules are foreseen, which are addressed to planning practitioners and policy/decision makers from the participating cities. Practitioners from mobility planning authorities of neighboring towns and areas in each country represented in the project is envisaged to uptake the lessons learnt from SUMPORT partners through local dissemination events foreseen within the second technical WP. Moreover, an e-learning platform will be developed, which would host educational material of the project, as well as from all projects currently implemented under the Interreg MED Programme.

3 "Pilot" Actions – Methodology for Implementation, Monitoring and Evaluation

3.1 The "Pilot" Actions

As aforementioned, a series of pilot activities are foreseen within a specific technical WP of the project. These "pilots" are practically plans/studies (**P/S**) and small-scale investments (**SSI**), as summarized in Table 1.

Table 1. Type of pilot actions of SUMPORT partners.

City/Region/Port	Pilot action	Pilot type
Durres	SUMP elaboration	P/S
Durres	Extension of existing bicycle lanes	SSI
Koper	Equipping parking slots near bus stops with sensors, indicating the occupancy-availability of slots for promotion of Park and Ride – Development of new specific App providing real-time information and establishment of a regional mobility center	SSI
Koper	Equipping buses with GPS sensors, communicating with a new App, providing real-time information and journey planning – Installation of monitors at bus stops for provision of real-time information	SSI
Kotor	Bicycle lanes implementation along a 5 km coastal route	SSI
Limassol	Connection of the existing coastal bicycle lanes located on the east and west sides of the city for the creation of a complete network, including the construction of a "bus and bike" terminal at the Port	SSI
Limassol	Simulation of new maritime transport service along the coastline	P/S
Thesprotia	Extension of the Sustainable Mobility principles to the entire Regional Unit	P/S
Thesprotia	Extension of existing bike-sharing system in the city of Igoumenitsa	SSI
Valencia Port	Update of Sustainable Mobility Plan of the Port	P/S
Valencia Port	E-bike-sharing system development	SSI
Valencia Port	Upgrade of the car-pooling system for the staff of the Port	SSI

It is evident that the above-mentioned variety of actions serve the general objective of SUMPs, which is towards accomplishing and maintaining a sustainable balance of the need of the users/citizens for mobility and accessibility with the protection of the public health and the environment. To this contribute the specific updates of existing

SUMPs or elaboration of new ones. And to the objectives of sustainable mobility and environmental and health protection contribute the promotion of less polluting and less energy consuming transport modes and the coordinated exploitation (i.e. complementarity and synergy) of all available transport modes.

3.2 Preparation and Planning

From the budget allocated to the WP of the pilot actions, which is almost half of the project's budget, the largest share (around €0.7 million) concerns the preparation and implementation of the pilots [3]. Therefore, taking also into consideration the limited capacities of some of the partners for in-house elaboration of the necessary studies and thus the need for externalization of consultancy services as for equipment procurement and works, well prepared activities has been crucial during the first period of the project. This would eventually ensure smooth implementation, financial management and reporting, according to the project's plan and the Programme's rules.

In this aspect, a set of preparatory (preliminary) studies per partner and activity (P/S or SSI) has been anticipated during the early stages of the project, based on a joint methodology elaborated to serve as guidelines to the partners concerned. This methodology included inter alia a harmonized time plan of main activities and milestones, which was further specialized by defining sub-activities per type of pilot.

Especially regarding SUMPs, it should be clarified that SUMPORT is targeted to all process up to the official adoption of the SUMP. Therefore, the SUMPs elaboration process as described in the ELTISplus Guidelines [4] with the four main quadrants of the planning cycle is valid up to the third quadrant (i. preparation/analysis of problems and opportunities; ii. goal setting/measures identified; iii. plan elaboration/SUMP adopted), i.e. excludes the implementation phase, for obvious reasons (project duration, funding requirements). Therefore, an indicative adjustment in two main stages was proposed as follows:

- 1st stage – 1st phase of SUMP elaboration (4–5 months) – activities of the "preparation" quadrant
- 1st stage – 2nd phase of SUMP elaboration (7–8 months) – activities of the "goal setting" quadrant
- 2nd stage – 1st phase of SUMP elaboration (4 months) – activities of the "goal setting" quadrant
- 2nd stage – 2nd phase of SUMP elaboration (5 months) – activities of the "plan elaboration" quadrant

Hence, including the 3 months of preparatory stage, where activities are considered as part of the "preparation" quadrant, the total duration for SUMP elaboration is 20 months. The same duration applies also for the small-scale investments implementation and the simulation activity elaboration.

3.3 Implementation and Monitoring

The partners, among their other responsibilities set out for the preparation of their activities, should establish an effective monitoring and supervision mechanism, to ensure their SUMPs and pilots appropriate elaboration/implementation and the contribution to the evaluation of their applied procedures and results [5]. Direct communication links have been established between the partnership, specifically for the update of the partnership about the progress of the activities. This communication is informal and on two-month basis, presenting briefly the state of play of the activity, any problems encountered and proposed solutions to these problems. Also, ad-hoc communications are very common for problem solving and it is anticipated that they will be intensified during periods of completion of tasks and reporting. Finally, performance of missions (including site visits) at all partner-cities for discussing SUMP and pilot specifics and for monitoring the progress of activities is foreseen.

3.4 Evaluation

For the evaluation of the pilots thirty-six simple, measurable and transparent key performance indicators (**KPIs**) has been identified, grouped in six clusters, according to the nature of the pilots. Moreover, a set of criteria have been set [6], according to the sustainable mobility objectives and orientations that match with the SUMPORT pilots: Active mobility improvement (3 KPIs); Environmental and societal benefits (7 KPIs); Equipment and infrastructure improvement (6 KPIs); IT and technology exploitation (3 KPIs); Promotion of shared mobility (2 KPIs); Service development (2 KPIs); End user utilization (6 KPIs); and SUMP policy and maturity/adoption & pilot action maturity and acceptance (7 KPIs).

Partners are guided in data collection for the KPIs measurements and calculations before and after their pilots' implementation and at specific intervals. It is anticipated that the completion of the relevant monitoring forms would be an effective tool for the partners to prepare Evaluation Reports per pilot action, anticipated two months after the pilots' implementation completion and two months before the preparation of a consolidated evaluation report for all pilots, by the end of the project.

4 State of Play of Pilots' Preparation and Implementation

4.1 Pilots' Specifics and Achieved Progress

In the following paragraphs are presented more details about the pilots per SUMPORT partner [7]:

Durres. The city of Durres is one of the major economic centers and transportation hubs of Albania. The SUMP elaboration in the framework of the will contribute to a better transport system, which is burdened by traffic growth and tourist flows, especially during the last decade. Main identified weaknesses and threats for the SUMP elaboration and implementation are the lack of previous relevant experiences, the strong placement of private car in ordinary life, budget limitations and the risk of low involvement of local stakeholders. However, it seems that there is political will for improvement of mobility through appropriate planning and low-cost measures, exploiting the opportunities provided due to the city's favorable social and environmental conditions. This is aligned with the pilot action to be implemented, i.e. the extension of the existing coastal bicycle lane, where the only challenge identified is the rearrangement of the public space to incorporate the new lane for cyclists against space for motorized traffic and parking. Consultants for the elaboration of the SUMP and design of the bicycle lane have been selected.

Koper. Since the early beginning of SUMPORT (April 2017) the city has an adopted SUMP. The Municipality has broad experience in implementing measures for sustainable mobility, and within SUMPORT envisages to promote info-mobility through the development of a regional mobility center, the creation of smart parking system, the installation of necessary equipment for facilitating public transport use and Park & Ride operations and the development of smartphone applications for journey planning and provision of real-time information. An advanced preparatory study is being drafted and the Municipality organizes the necessary procurement process.

Kotor. The Municipality has already a Local Sustainable Mobility Plan in place and within the project it is envisaged to implement bicycle lanes on a coastal road stretch of 5 km between the old town to St. Stasije (intersection with E-80), in order to address the citizens' needs for more sustainable mobility options. Though the route under study seems to be very attractive for tourists, and there is also potential for local population (commuters to work and students) to use, the main challenge is to deal with the space constraints and ensure safe coexistence of motorized traffic and bicycle. At time being, the necessary study should have started, and implementation/works are foreseen to start after summer, due to restrictions by law during that period.

Limassol. A SUMP is currently being elaborated for the Limassol greater area, under the responsibility of the Ministry of Transport, Communication and Works of Cyprus. Within SUMPORT, the Municipality is planning the implementation of a bicycle lane which will contribute to the connection of existing bicycle lanes network and to bridge the existing gap between the marina and the new Port of the city, where also the construction of a bike-bus terminal is foreseen through the same project. As for the cases of other similar pilots, a risk of success for this pilot is the dependence on private car and lack of sustainable mobility culture. However, the provision of an integrated bicycle infrastructure is an attractive alternative for citizens and tourists as well. The second action for Limassol within SUMPORT is the simulation of the introduction of a new maritime public transport system along a 25 km route, between the new Port and the old marina (i.e. from west to east side of the city), with several intermediate stops. The simulation, actually a feasibility study, will comprise three main scenarios (sea-buses, taxis, and bicycles) and a number of sub-scenarios having as main variables the number of stations, the frequency of service, etc.

Regional Unit of Thesprotia. A SUMP is being already developed for the main Municipality of the Regional Unit, Igoumenitsa. The extension of the principles of sustainable mobility to the other two municipalities is the subject of the plan that is currently under elaboration in the framework of SUMPORT. Moreover, within the same project is foreseen to extend the existing bike-sharing system in Igoumenitsa, with a new rental station and by tripling the number of available bikes for rental. Currently, for both activities the data collection and stakeholders' identification are in progress.

Valencia Port. An update of the existing Port Sustainable Mobility Plan of the period (2012–2017) and its integration with the SUMP of Valencia is envisaged. Additionally, two pilots are envisaged: (a) improvement/upgrade of the – already implemented through the existing SUMP – car-pooling application for the workers of the Port and (b) development of an e-bike-sharing system offered to the continuously increasing number of cruise passengers. At time being, activities are in phase of preparation of more detailed analysis: for the SUMP update a "wayfinding" study has been completed and surveys data collection are underway; the car-pooling application will be tested by selected users for analysis of its shortfalls and upgrading requirements. For the e-bikes system, legal aspects, parking area and services have been defined and a tender procedure is under preparation for selection of a service provider. Among the identified risks for the update of SUMP and the car-pooling system implementation are potentially the lack of commitment of key-players and the poor involvement of stakeholders. For the e-bike sharing an identified weakness is the complexity of process for authorizations and among the possible risks are the lack of interest from e-bike service providers and eventually the competition with bus transfer and other services provided by cruise companies.

4.2 Encountered Problems and Next Steps

The main problems have been experienced during the first stages of the project have been mainly of administrative nature. Some of them concerned procedures of mobilization of funds in non-EU member states and others bureaucratic and administrative barriers for the procurement of services for the preparation of the studies necessary to prepare and implement the pilot actions. Only in few cases the preliminary studies have been elaborated in-house by the relevant partners, which is an evidence of lack of expertise in some cases, as well as understaffing (limitation of human resources) in most of these cases.

Subsequently, a larger period than expected has been dedicated to the preparation of the necessary studies, but this did not necessarily cause delays to the procedures for the preparation of the required procurement processes, which concerned mainly the externalization of services for SUMPs elaboration, detailed studies for the implementation of the pilots, and the simulation study preparation. Therefore, it is planned that the partners will proceed with the activities foreseen, while an interim report per pilot action is foreseen during the second semester of the year. During the same period a series of on-site visits to be performed by the WP leader is planned, to be combined with technical meetings with the relevant city-partners.

5 Discussion

The presented paper concerns a trans-national cooperation project in progress, which aims to enhancing sustainable mobility planning and implementation of measures promoting alternative, active and shared, mobility. As the project is in its initial phase of the distinct measures preparation for implementation, tangible results – in terms of physical implementation (where applicable) and of estimations of their impacts – are yet not available. What is still evident is the commitment of the project partners to the scope and activities of the project, despite difficulties emerging from administrative obstacles that emerged in some cases, and which it seems that have been overcome. The project partners, including the authors of this paper, who are in charge for monitoring and coordinating the pilot actions, continue more intensively with the activities implementation.

The implementation of the pilot actions is anticipated with great interest, but especially the results of the evaluation of their success and their estimated or measured impacts. Besides, challenge remains the transferability methodology and action plan that are currently under elaboration for the transfer of the experience to cities with similar characteristics and problems through an e-platform and dissemination events, which would maximize the outreach of the experienced gained from the project in the Mediterranean area and contribute to the goals of the "Urban Transport Community" (https://urban-transports.interreg-med.eu) established from all relevant projects of the Interreg Med Programme for the communication, dissemination and capitalization of the knowledge and results towards low-carbon transport and mobility measures.

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Cooperative Intelligent Transport Systems as a Policy Tool for Mitigating the Impacts of Climate Change on Road Transport

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Abstract. This paper aims to address the contribution of Cooperative Intelligent Transport Systems (C-ITS) services to the mitigation of climate change impacts in road transport. Climate change is a fact perturbing human activities in various ways. The exacerbation of weather conditions has considerable impacts on transportation, hence indicating transport vulnerability to climate change. Europe is already confronting several changes in the climatic conditions, including increased temperatures, extreme precipitation events, cold waves and sea level rise. Interaction between climate change and road transport is evident in terms of increasing risks for network managers and users, and negatively affecting transport performance major parameters, such as safety, reliability and cost efficiency. The need to limit adverse weather conditions effects to road transport urges to adapt new mitigation policies, which will ensure transport resilience and sustainability. C-ITS services constitute an innovative array of technologies, enabled by digital connectivity among vehicles and between vehicles and transport infrastructure, expected to significantly improve road safety, traffic efficiency and comfort of driving. In this way C-ITS services have the potential to increase the levels of safety for drivers within extreme weather situations, by helping them to take the right decisions and adapt to the traffic situation. The C-MobILE project, funded under the Horizon 2020 programme, envisions a fully safe and efficient road transport without casualties and serious injuries on European roads, by deploying C-ITS services for specific mobility challenges. The project will execute large scale C-ITS deployment activities in eight cities in Europe. The C-ITS services will be provided in bundles, aiming to improve safety and traffic efficiency. The paper includes an extended review of the relevant literature. Then an assessment of the C-MobILE C-ITS services' potential contribution to the mitigation of these effects is presented and assessed.

Keywords: Climate change · Extreme weather events · Road transport
Cooperative intelligent transport systems

1 Introduction

Europe is already facing severe impacts of climate change, affecting the full EU territory with regional differences [1]. Changes in the climate system are already having an impact on road transport infrastructure and services in Europe. Adverse weather and

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road conditions are a considerable cause of an elevated risk of traffic accidents and compromised traffic flow in Europe [1, 2]. Cooperative Intelligent Transport Systems (C-ITS) is an array of technologies, enabling the various elements of the modern surface transportation system to communicate via Vehicle-to-Infrastructure (V2I) or Vehicle-to-Vehicle (V2V) communications, with each other [3]. C-ITS services are expected to contribute to the further reduction of the number of casualties and severity of accidents, through the utilization of warning systems and by influencing drivers' behavior [4].

This paper aims to prove the potential contribution of the C-ITS services, deployed under the framework of the C-MobILE project, to the mitigation of the impacts of climate change in road transport. Firstly, an overview of the various weather phenomena, responsible for road accidents' rise and traffic flow disruption, derived from an extensive literature review, is presented. Then an assessment of the impacts of specific C-ITS services, to be deployed in the C-MobILE framework as well, on road safety and traffic efficiency increase is presented. The impact rates were derived from data collected from the literature review [5].

2 Methodology

First, an extensive literature review was conducted, in order to exhibit the implications of climate change induced adverse weather conditions in road transport. Impact areas highly affected are road safety and traffic efficiency. Then, the perspective of C-ITS services as a policy tool for mitigating such impacts is presented. Literature review data prove that specific C-ITS services, to be deployed as well in large scale in the framework of the C-MobILE project, have the potential to contribute in road safety and traffic efficiency increase.

3 Implications of Adverse Weather Conditions in Road Transport

Empirical findings and research outputs have shown that road transport services perform worse under adverse and extreme weather conditions. Road transport is almost continuously subjected to meteorological hazards, impacting upon driving conditions, causing accidents and traffic congestion problems. From the viewpoint of the available research, factors contributing to accidents can be grouped into three categories: (a) 90% human factors, (b) 30% environment, and (c) 10% vehicle [6]. Road traffic accidents in the Member States of the European Union claimed about 26.000 lives and left more than 1,3 million people injured in 2014. Data indicate that approximately 12% of the fatalities were caused due to inclement weather conditions [7].

An extended review of the literature shows that inclement weather due to rain is associated with more hazardous driving conditions than wet weather. Reduced friction on the road surface, leading to longer braking distances, and low visibility due to the reflection on wet surfaces, are among the main causes of accidents during rainfall. A significant number of papers display valid results on the correlation between precipitations and increase of traffic crashes. Accident risk during driving on slippery roads is proven to be higher than on dry pavement conditions [8–19]. Intense precipitation produces also more flooding, affecting the performance of urban transportation networks in terms of delays, detours and trip cancellation. Due to flooding incidents trips are typically cancelled, while the ones occurring take much longer, since drivers are forced to take circuitous routes from origin to destination or stuck in traffic on passable links [19, 20].

Travel during snow events is considered as rather not a safe driving experience, since driving on roads with snow and ice not only extends travel time but also places drivers in a dangerous position. Low friction pavement increases the difficulty of operating and maneuvering a vehicle. Impaired atmospheric visibility limits driver sight distance and restricts driver's ability to judge the unexpected conditions ahead. Several studies indicate that snowfall contributes to high accident rates and decrease of traffic volumes, with snowstorm duration and intensity being the major deteriorating factors [10, 19–31].

Research findings show that the presence of high winds increases accident risk significantly [31, 32]. Cross winds affecting the exposed sides of a vehicle, are commonly as strong as the vehicle velocity induced air-speed, hence the air pressure acting sideways can be high as the drag force in the driving direction [31]. Wind accidents statistics reveal the frequent appearance of heavy goods vehicles, while private cars hauling any kind of trailers are considered also as of high risk vehicle categories [31].

Fog constitutes an inclement weather event, causing accidents, which tend to result in more severe injuries and involve multiple vehicles [33–35]. Vision obstruction, occurring mostly during the morning hours in the months of December to February, is the prevalent reason for crashes. Other contributing factors, having direct or indirect effect on the occurrence of fog induced crashes, are speed, lighting conditions, age, area (urban, rural), number of lanes, and presence or absence of sidewalk [35].

4 The C-MobILE Project

Coping with climate change requires mitigation and adaptation policies. These two strategies constitute complementary actions [36]. The overall aim of the EU Strategy is to contribute to a more climate-resilient Europe. The C-MobILE (Accelerating C-ITS Mobility Innovation and depLoyment in Europe) project, funded under Horizon 2020, envisions a fully safe and efficient road transport without casualties and serious injuries on European roads, in particular in complex urban areas and for Vulnerable Road Users (VRUs) [37]. Eight C-ITS equipped cities/ regions are involved in C-MobILE, Barcelona, Bilbao, Bordeaux, Copenhagen, Newcastle, North Brabant Region, Thessaloniki and Vigo, which will be elevated to large-scale deployment locations of sustainable services. This will be achieved by opening up the existing ITS-enabled cities and providing C-ITS services in a seamless, uninterrupted cross-modal and cross-border way [37]. Specific C-ITS services are expected to have certain impacts in road accidents reduction and traffic efficiency increase.

4.1 The C-MobILE C-ITS Services' Contribution to the Mitigation of Climate Change Induced Road Hazards

Road safety and traffic efficiency constitute impact areas affected mostly by extreme weather events. C-ITS services providing warnings for various road conditions could contribute in avoiding road accidents, as well as in increasing traffic efficiency [38, 39]. Traffic data collection and mobility information provision, addressing in real-time weather impacts on arterial traffic flow (e.g. congestion), could result in travel time savings and reduction of vehicle-hours [39].

Road Works Warning (RWW). Road works warning aims to inform drivers in a timely manner about road works, changes to the road layout and applicable driving regulations. Situations, such as unplanned (ad-hoc) road works and especially emergency repairs due to infrastructure damages caused by extreme weather events, require more attentive driving while approaching and passing the work zone. While approaching the road work zone, drivers having access to the service, receive road works related information, warnings and/ or guidance on an in-vehicle display or smartphone. Instructions typically include reduction of driving velocity, change lanes, or prepare for a steering maneuver. The main aim of the service is to improve road safety by reducing the number of collisions [40].

Road Hazard Warning (RHW). Road hazard warning aims to inform drivers in a timely manner of upcoming, and possibly dangerous events and locations. Unawareness of hazardous locations may lead to driving situations with high risk or in the worst case accidents, especially when drivers do not anticipate appropriately to them. The in-vehicle driving assistance information improves the awareness of drivers, increases their attentiveness and allows them to better anticipate to various situations. Situations associated to weather induced hazards comprise of limited visibility, asphalt adhesion, potholes, objects on the road or spilled load, and traffic congestion. Through the provision of timely in-vehicle driving assistance information, i.e. notifications and warnings, on hazardous locations downstream of the current position and in the driving direction of the vehicle, RHW enables drivers to be better prepared for the upcoming hazards and make necessary adjustments and maneuvers in advance [40].

Emergency Vehicle Warning (EVW). The main objective of Emergency Vehicle Warning is to provide other vehicle drivers with an early warning indication of an emergency vehicle approaching, in order to timely give way to it. Severe weather phenomena, mainly floods and blizzards, constitute the cause of many disaster events, which require an emergency response. At the same time, they affect the way assistance, i.e. the emergency vehicle, will reach the emergency point. EVW enables emergency vehicles to identify themselves and inform other vehicles in the vicinity about their position, direction and speed, even when their siren and light bar may not be audible or visible due to weather conditions. The primary impact of the service is the prevention of possible accidents due to drivers' clumsy behavior, while trying in a hasty manner to give way in an emergency vehicle approaching [40].

In-vehicle Signage (IVS). In-Vehicle Signage is meant to inform drivers via in-vehicle information systems on static and dynamic road signs as indicated on physical road signs and on additional digital displays along the road. Dynamic traffic signs provide travelers with information about special events, such as traffic congestion, accidents, incidents, speed limits, roadwork zones, or road closures, frequently triggered by adverse weather conditions. Both advisory and mandatory road signs are in scope of IVS, while information is retrieved by means of I2V communication. While driving, drivers receive actual IVS related information, warnings and/ or guidance on the in-vehicle display, advising them to adapt driving velocity in line with the road conditions, to change lanes or to prepare for a steering maneuver if necessary [40].

Probe Vehicle Data. **Probe Vehicle Data** is data generated by vehicles, then collected and used as input for operational traffic management, long term tactical/ strategic purposes and for traveler information services. Data broadcasted by vehicles may refer to various implications of inclement weather on the road network, e.g. slippery spots and traffic jams. Such data provide road operators with insight in the traffic situation and surroundings, enabling them to allocate warnings to vehicle drivers, in order to avoid dangerous situations and change the driving behavior (e.g. brake, accelerate, and change routes) [40].

Emergency Brake Light. **Emergency Brake Light** aims to avoid (fatal) rear-end collisions, which can occur if a vehicle ahead suddenly brakes, especially in dense driving situations or in other hazardous situations, such as decreased visibility or slippery roads. Drivers are not valid estimators of accident risk while driving in adverse weather conditions, and they do not always adjust their driving behavior sufficiently. The underestimation of the slipperiness of a road, for instance, may trigger hard breaking, causing skid related accidents. EBL aims to enable a vehicle to warn all following vehicles of its sudden slowdown, limiting this way the risk of longitudinal collision and improving traffic safety [40].

Slow/ Stationary Vehicle Warning (SSVW). Slow or stationary vehicle warning aims to inform/ alert approaching vehicles of (dangerously) immobilized, stationary or slow vehicles, which impose significant risk. Inclement weather could force a vehicle's immobilization, e.g. accidents, vehicle problems, emergency vehicles. The service focuses on providing timely in-car driving assistance information on a stationary vehicle, offering drivers an extra time to react appropriately, and hence contributing to accidents' decrease [40].

Warning System for Pedestrians (WSP). Warning system for pedestrian aims to detect risky situations (e.g. road crossing) involving pedestrians, allowing the possibility to warn vehicle drivers. Visibility obstruction due to fog, mist, haze, snowfall or freezing drizzle impedes drivers' detection skills, limiting the chances to spot the behavior of a VRU, i.e. pedestrian or cyclist, in the vicinity of the vehicle. The service seeks to track whether dangerous scenarios may occur, in order to notify the driver timely. The expected impact is the provision of comfortable driving, as well as the enhancement of traffic safety, as a result of avoided accidents [40].

Motorcycle Approaching Indication (MAI). Motorcycle approaching indication warns the driver of an approaching/ passing motorcycle (the scope can be extended to cover as well VRUs). Adverse weather conditions are among the most common causes of motorcycle accidents, especially collisions with passenger vehicles, as most vehicle drivers don not notice motorcycles on the roadways due to limited visibility. The objective of the service is to provide timely in-vehicle driving assistance information on an approaching motorized or powered two-wheeler in the driving direction of the vehicle, in order to reduce the risk of an accident [40].

The following table presents average values of data collected from the literature review [5], depicting road safety and traffic efficiency related impacts of C-ITS services on individual vehicles when installed across different vehicles and road types at EU level (Table 1).

Table 1. Average values of C-ITS services' impacts on road safety and traffic efficiency increase.

Impact area					
C-ITS services	Road safety				Traffic efficiency
	Fatalities	Severe injuries	Slight injuries	Material damages	Average speed
RWW	−3,4%	−3,4%	−3,4%	−3,4%	+2%
RHW	−4,1%	−4,2%	−4,2%	−4,2%	
EVW	−0,8%	−0,8%	−0,8%	−0,8%	
IVS	−6,9%	−3,9%	−3,9%	−3,9%	
PVD	−2,6%	−3,7%	−3,7%	−3,7%	
EBL	−2,7%	−2,5%	−2,5%	−2,5%	
SSWV	−1,9%	−0,7%	−0,7%	−0,7%	
WSP	−1,8%	−1,9%	−1,9%	−1,9%	
MAI	−3,8%	−3,8%	−3,8%	−3,8%	

5 Conclusions

In this paper the contribution of the C-MobILE C-ITS services to the mitigation of climate change impacts in road transport is presented. Firstly, climate change induced extreme weather events, impacting upon road transport, are thoroughly presented. Precipitation, snow, wind and fog constitute the main weather-related hazards, affecting harshly road safety and traffic efficiency. Subsequently, the C-ITS services to be deployed within the framework of the C-MobILE project, and which could potentially act as factors reducing accidents and increasing traffic flow, are described. The most prominent C-ITS services, having the greatest impact in road safety and traffic efficiency, are Road Hazard Warning and In-vehicle Signage. Overall, it is demonstrated that the C-ITS services deployment constitutes a mitigation measure, which could establish a resilient transport system, able to anticipate climate changes and cope with them.

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Analysis of Mobility Patterns in Selected University Campus Areas

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Abstract. The objective of the present research is to better understand mobility in university campus areas, using local and transnational data, policies and planning instruments. This analysis looks at integrating student's mobility flows to/from and inside Campus areas with urban mobility. Within this framework, a survey was developed for seven Southern European universities including a mobility questionnaire on current mobility, desired mobility, mobility problems, proposed measures/policies/tools as well as demographic characteristics of the participants which were mainly undergraduate students, post graduate students, academic/faculty members and administrative staff. For the purpose of the survey, 1,090 questionnaires were collected and further analyse. Regarding the mobility to/from the city, campuses are further distinguished into those that are inside and outside the city. Results highlight differences in the policies that are most critical based on the location of each University. More specifically, for campuses located inside urban area, the most important transport measures include public transport and environmental issues. On the other hand, for mobility in campuses located outside urban areas, results indicate that measures should address public transport and road infrastructure, to help accessibility to and from the campus areas.

Keywords: University campus · Sustainable urban mobility plan · Policies Mobility measures · Tools

1 Background and Objectives

Sustainable Urban Mobility Plans (SUMPs) define a set of interrelated measures designed to satisfy the mobility needs of people. They consist of an integrated planning approach and address all modes and forms of transport in cities and their surrounding areas [1]. Focusing on university campuses, a special characteristic concerns the fact that universities are unique places functioning in specific contexts [2, 3, 11]. Universities are characterized by the fact that they represent a cross section of the population from different socio-economic backgrounds and ages, generate irregular schedules and the constant movement of people throughout the day. This is even more noticeable in university campuses located in suburban settings: Daily commuting of the university

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population, longer distances travelled, and the predominance of private car use over non-motorised means of transport [4].

A key parameter which affects the entire mobility system of a campus is whether it is located in the city center, in the suburbs or outside the urban area. Most campuses located to the city centers face mobility problems, due to the city's congestion, the lack of space for parking, active modes of transport, but also have advantages on the accessibility as they are easily accessed by public transport and soft modes [5]. In the last decades, there has been a tendency to move universities outside cities, based on the worldwide trend to establish new or relocate campuses to city outskirts or rural areas, in an effort to move away from congested city centers [6]. Such decentralized locations offer advantages, such as additional space for facilities and infrastructure, and an environment of improved quality to members, suitable for research and academic endeavors. Throughout the years, these institutions have been transformed into independent communities with the size, infrastructures, and activity levels of small cities [6].

Several plans and practices in universities have been conducted aiming at enhancing the general quality of urban areas in terms of mobility using several strategies and initiatives adapted and inspired by local characteristics and mobility needs. A prevailing example is the sustainable urban mobility plan of the University of Barcelona, which is supported by the recurring University Community Mobility Habits survey [4]. In Milan, the "Mobility Management in the university system of Milan" project intended to identify, to define and to test intervention policies to reduce environmental impacts joined to the mobility of working and students in the University of Milan. The output of the plan was to elaborate and to implement mobility action plans in the various university sites in order to control and to optimize the flows and to develop a methodology to the approach to the mobility management problems [7]. Through the MOST project, in 2002, a mobility management plan in University of Catalonia was implemented and achieved to improve the access of the Catalonia University through specific measures that encourage people to use sustainable transport modes [8]. Furthermore, Roma Tre University managed to reduce the use of private car in favor of collective transport modes, to offer solutions and sustainable ways to move such as collective public transport, to implement of low environmental impact means such as bicycles or electric motorcycles and to develop an application of car-pooling and car-sharing within the university [7].

Based on the above, the objective of the present research is to retrieve quantitative data for mobility across a number of university campus areas. For this purpose, a questionnaire has been developed in which 1,090 participants from seven Southern European Universities participated. The paper is structured as follows. In the next chapter, the methodological approach of the research is presented including details regarding the implementation of the survey and the universities that participated. Then analysis results are presented, general conclusions are stated as well as proposals for further research.

2 Methodological Approach

The questionnaire was developed within the framework of the CAMP-sUmp (CAMPus sustainable University mobility plans in MED areas) project, a European research project co-financed by the European Regional Development Fund aiming to improve sustainable urban mobility planning instruments through innovative mobility strategies for students' flows inside the MED Area University Campus and their integration with the urban areas. The survey took place in the following universities: University of Catanzaro, National Technical University of Athens, University of Malta, University of Valencia, University of Split, University of Cyprus, University of Bologna.

2.1 Questionnaire Design

Self-reports and especially questionnaires present several advantages. They are less expensive than studies using an instrumented vehicle or a driving simulator, they provide quite more detailed information than observations, and they can reach quite a large number of people in a short time. Representativeness of the sample is easy to establish and can be measured with direct statistical comparisons to driver population. Moreover, due to large samples, detailed and complicated statistical analyses can be conducted [9]. It is clearly vital that a survey should be carried out using the correct sampling procedures, but also that the questionnaire used should be clear and unambiguous for both the interviewers and the respondents [10].

For the purposes of the present research a mobility questionnaire was developed including questions on the following topics:

- Current mobility - to present current mobility of the participants both regarding mobility from/to and inside the Campus
- Desired Mobility - to present the desired mobility of the participants both regarding mobility from/to and inside the Campus
- Mobility problems - to identify the mobility problems both regarding mobility from/to and inside the Campus.
- Proposed measures/policies/tools - to evaluate specific measures, policies and tools that are already implemented regarding the mobility from/to and inside the campus
- Participant information including age, gender, affiliation etc.

Universities were asked to collect questionnaires based on the following sample criteria.

- Faculty members: 10%
- Administration personnel: 20%
- Students – postgraduate: 20%
- Students – graduate: 50%

The above percentages were decided in order to achieve a representative sample in all universities with focus on the affiliation of the participants. The questionnaire's data collection took place approximately 1 month and the overall results per University are summarized in the following table (Table 1):

Table 1. Campuses characteristics.

	University	Location	Area (m^2)	Students	Questionnaires
1	University of Catanzaro	Outside	260.000	11.000	104
2	National Technical University of Athens	Outside	1.000.000	13.500	124
3	University of Malta	Inside	194.452	11.500	250
4	University of Valencia (1 campus)	Outside	1.000.000	10.000	227
5	University of Valencia (2 campuses)	Inside	400.000	35.000	100
6	University of Split	Inside	245.000	24.000	100
7	University of Cyprus	Outside	1.200.000	7.000	85
8	University of Bologna	Outside	6.570.023	85.000	100

3 Results

In the present section, an overall synthesis of the findings is presented divided in three sub-sections. In the first section, the selection of mode of transport is presented in order to provide a clear picture of the mobility status of campuses located inside and outside urban areas. In the second section an evaluation of the mobility problems is presented while in the third section the most valuable mobility policies/measures/tools desired to be implemented are presented and analysed.

3.1 Mobility Status

In Fig. 1, the selection of mode of transport (1: car, 2: public transport, 3: motorcycle, 4: bicycle, 5: walking) for the mobility from/to the campus per trip duration, campus location and frequency of the traveling is presented.

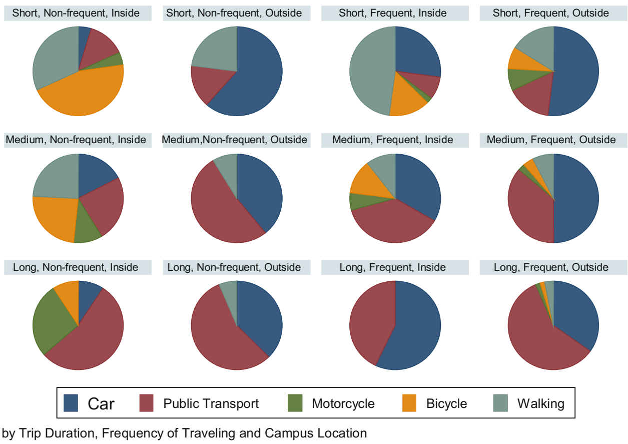

Fig. 1. Mode of transport for the mobility from/to the campus per trip duration campus location and frequency of traveler.

Results indicate that **passenger car** is the preferable mode of transport in campuses located outside urban areas regardless of trip duration. On the other hand, in campuses located inside the city the percentage of walking and cycling is significantly higher. Finally, public transport is more often reported on long trip durations in campuses located outside urban areas.

3.2 Mobility Problems

In Table 2 the evaluation of mobility problems is presented under eight mobility areas. Participants were asked to rank these problems in their campus for which level 5 indicated the highest level of the problem and level 1 the lowest.

Table 2. Assessment of mobility problems.

Mobility problems	Campuses inside area		Campuses outside area	
	From/To	Inside	From/To	Inside
Parking management	4.1	3.7	3.0	3.3
Walking	3.4	3.7	3.4	3.3
Cycling	3.3	3.4	3.6	3.6
Public transport	3.8	2.9	3.9	3.7
Road Infrastructure	3.8	3.6	3.3	3.5
Environmental/Energy	3.8	3.5	3.4	3.6
Mobility management	3.7	3.5	3.5	3.6
Freight management	3.2	3.1	2.8	3.1

Table 2 indicates that in campuses located inside urban areas parking management is the most problematic concern. On the other hand, with focus on campuses located outside urban areas public transport is ranked as most problematic, with stakeholders pointing out this as an important measure for future intervention.

3.3 Mobility Policies/Measures/Tools

As mentioned earlier, a section of the questionnaire concerned an evaluation of proposed measures/policies/tools. Within this scope, participants were asked to reply the following question "How important do you consider the following measures/policies/tools regarding mobility from/to your Campus in a scale from 1 (not important) to 5 (very important)". Figs. 2 and 3 present the results.

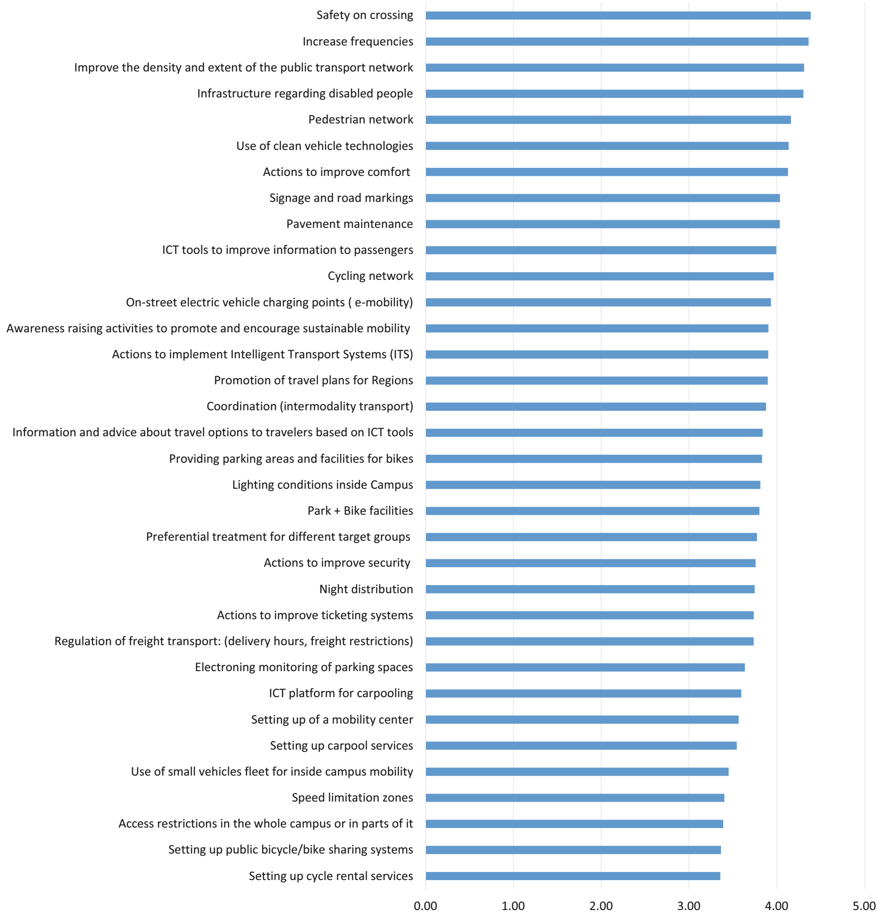

Fig. 2. Evaluation of measures for the mobility in campuses located inside urban areas.

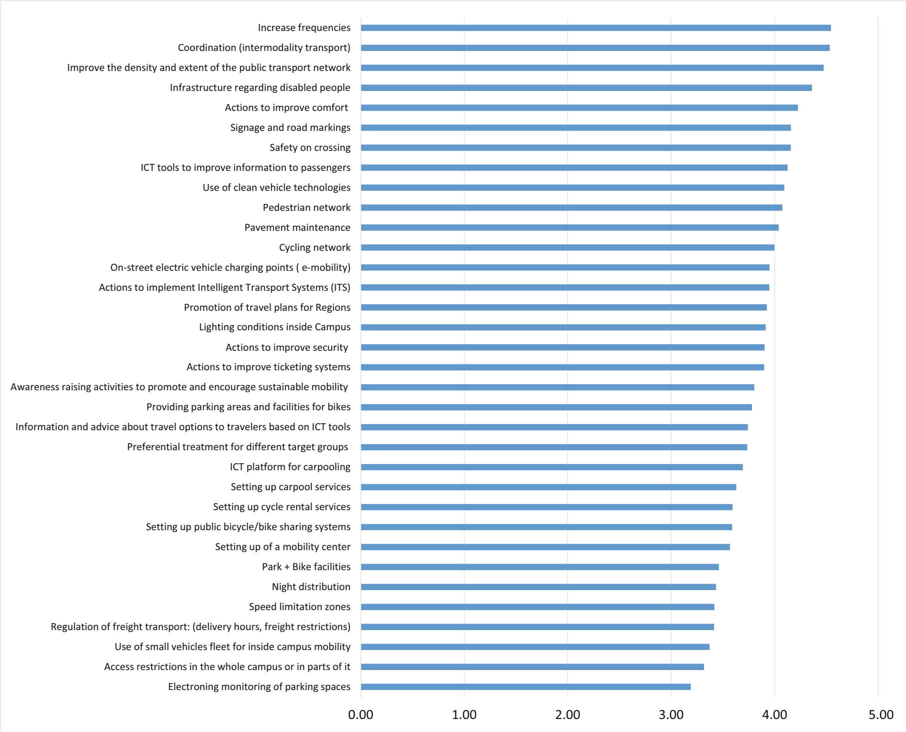

Fig. 3. Evaluation of measures for the mobility in campuses located outside urban areas

4 Conclusions

The development and implementation of the questionnaire lead to several interesting conclusions that are presented in this study. More specifically, with focus on the measures that are evaluated by the participants, results highlight differences in the measures that are most critical based on the location of each University. More specifically, regarding campuses located inside urban areas, the most important measures concern walking, public transport, road infrastructure and environment. Safety at crossings is the most critical action to be taken, followed by measures on public transport such as an increase in frequencies and the improvement of the density and extent of the public transport network.

On the other hand, regarding mobility in campuses located outside urban areas, results indicate that measures should be taken with a focus on public transport and road infrastructure, to help the accessibility to the campus. The most critical measures concern public transport (increase of frequencies, coordination and intermodality, improvement of the density and extent of the public transport network and actions to improve the comfort), proving that public transport is the key mobility issue in campuses located outside the city. Another key measure that is evaluated by the users is improvement in the infrastructure regarding disabled people. The above proposed measures confirm the results on the mobility problems that have been identified from the participants in the respective parts of the questionnaire and are in line with the findings in the literature on similar sustainable mobility plans in university campuses. In the next steps of the research statistical analysis will be carried out in order to extract more information from the survey.

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Public Transport and Demand Responsive Systems

Evaluation of Probabilistic Demands Usage for the Online Dial-a-Ride Problem

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Abstract. The objective of this study is to investigate if it is possible to reduce the operational cost of an online Demand Responsive Transportation System (DRT) by using probabilistic trip demands while leaving the optimization algorithm intact. The idea is that we use probabilistic demands in order to predict actual ones. If the prediction is accurate enough then the DRT's vehicle fleet reassigned in a better state. The innovation lies in the assumption that, given enough historical data on trip demands, the system's online nature can be reduced, resulting in a better solution (problem objective). The basic steps of the proposed methodology are: **(a)** Based on a real historical data set, a demand distribution probability created to describe online DRT's demands behavior. **(b)** During operation, for each incoming demand, create a set of additional probabilistic demands based on the distribution in (a) and calculate an initial solution. **(c)** Remove the probabilistic demands and optimize the solution further. **(d)** Comparatively analyze these solutions against those that would be produced without the use of probabilistic demands. The study revealed that using probabilistic demands improved the solutions in terms of cost (objective). Test data were recorded during an actual 30-day online DRT operation at the same location, the former municipality of Philippi in northern Greece.

Keywords: Online dial-a-ride · Probabilistic demands

1 Introduction and Literature Review

In this paper we propose a new version of the online regret based dial-a-ride algorithm presented by [1]. This version attempts to investigate if the solution can be improved using statistical data to introduce some predictability of future demands, while leaving the fundamental algorithmic scheme intact. In fact, an attempt is made to turn the problem from its pure real-time version into a "pseudo" static version, given the fact that actual demands are not known. The proposed algorithmic scheme was evaluated with data from an actual DRT system, operating in the former municipality of Philippi in northern Greece. The results indicate that the use of probabilistic demands improved the solution in the majority of the experiments performed.

The dial-a-ride problem is a well-known problem since its first introduction in the early 1970s and has been studied extensively. Molenbruch et al. [2] offer an extensive overview of the problem as well as of the proposed solutions. Healy et al. [3] showed

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that the DARP is NP-hard. Since then, the majority of research has been focused on the development of heuristic and metaheuristic real-time approaches. Uncertainty of (demand's location and time) in location and time of demands is a key issue in real-time DRT systems. To address this, significant research efforts focus on real-time problems with stochastic parameters. Ho et al. [4] deal with trip requests that are served with a given probability. Authors propose a stochastic extension of the traditional dial-a-ride problem, in a sense that the presence of certain users is given in terms of a probability. Schilde et al. [5] address patient transfer (ambulance). They propose a method to resolve situations that encompass dynamic (stochastic) as well as static requests using a fixed vehicle fleet. They show that using stochastic information on return transports leads to average improvement of around 15%. Xiang et al. [6] presented a flexible scheduling scheme to dynamically process various stochastic events, such as travel time fluctuation, new requests, customer absenteeism, vehicle breakdowns, cancellations of requests, traffic jams and so on. Their heuristic approach consists of a properly organized local search strategy and uses a secondary objective function to drive the search out of local optima. Diana et al. [7] proposed a probabilistic model that takes into account demand distribution over the service area, and quality of service. They compare their model to a simulation approach that requires knowledge of the complete daily schedule. Results showed that, generally, the probabilistic model produced better results in terms of the minimum number of vehicles required to service all requests. However, for the largest problem instance, the results were worse. Coslovich et al. [8] focused on unexpected users asking for service during a vehicle stop. Authors presented an algorithm, which follows a two-phase strategy for the insertion of a new request into an existing route. Bent et al. [9] presented a study for the dynamic stochastic vehicle routing problem, the paper proposes a multiple scenario approach (MSA). The driving idea behind MSA approach was to continuously generate and solve scenarios, which include both static and dynamic requests. Fu Liping [10] presented an approach to the dial-a-ride scheduling problems arising in paratransit service systems that are subject to tight service constraints and time varying stochastic traffic congestion. Author extents conventional heuristics, using probabilistic time windows.

Our research presentation comprises three sections. In Sect. 2, we present the proposed algorithmic scheme. In Sect. 3, we present numerical results and analysis. Section 4 contains concluding remarks and future research pointers.

2 Online Regret Dial-a-Ride Algorithm (OP-DARP) with Probabilistic Demands – Basic Concept and Description

2.1 OP-DARP Basic Concept

The proposed OP-DARP algorithm is a continuation of the OR-DARP (Online Regret dial-a-ride) algorithm presented by Lois et al. [7]. To facilitate the reader, we present a short review of the OR-DARP algorithm. This algorithm initially processes online demands quickly, while continuously optimizing the solution. It adds two sub-modules to the general regret online algorithm. The first module is the online insertion algorithm, a typical myopic insertion algorithm modified to handle online demands, to give an initial fast response for any incoming demand. The second module is the regret optimization algorithm modified to handle online demands as well. OR-DARP algorithm uses the original regret concept, where multiple trip assignment combinations are explored, and a combination that results in higher gains replaces a previously chosen solution (maximum gain principle). For the OP-DARP algorithm, we follow a slightly different concept. The fundamental assumption is that historical data on incoming demands allows an insight to the location and time of future demands. To implement this, we use probabilistic demands from a domain of possible inputs. The basic concept is as follows: For every actual incoming demand, we: (a) define the Time Horizon (TH), that is the time frame into the future where the actual demand's pickup time belongs, (b) produce and select via Monte Carlo Method, probabilistic instants from the data set. The selection of probabilistic demands is based on a previously calculated TH. Then we calculate a solution for the actual demand taking into account the selected probabilistic demands. After the initial calculation, the probabilistic demands are dropped and the solution is further optimized on the principles of the OR-DARP algorithm.

2.2 OP-DARP Algorithm Description

The defining feature of the algorithm is, as noted above, the introduction of probabilistic demands. The first, preparatory, step is the calculation of the probability distribution of the historical data. The day is divided in a number of fixed Time Horizons. Each TH defines the domain input of probabilistic demands, given the probability distribution. We select probabilistic demands from the Time Horizon that contains the actual demand's pickup time. The size of the TH is intuitively important. A wide TH can overload the algorithm with, possibly, insignificant information. A narrow TH may not offer sufficient information to make a difference. For this study, we examined three TH sizes (60,120,180 min).

The core of the algorithm follows two basic steps: (a) for each incoming demand, select appropriate probabilistic demands from the corresponding TH, using the Monte Carlo method and include them to calculate an initial solution (b) remove the probabilistic demands and optimize the solution further using regret optimization module.

For a more detailed description, see the following chart (Fig. 1).

3 Numerical Results and Analysis

To evaluate the OP-DARP algorithm performance, we used real data from a pilot project in the municipality of Philippi, that contain exact times of users' calls. Since the data spans 30 days of continuous operation, we can use it to build an appropriate probability distribution regarding the occurrence for every trip demand presented during the pilot testing for one day (24 h or 1440 min) time period. Figure 2 presents trip distribution for three different time windows (60 min, 120 min, 180 min) during entire pilot project duration.

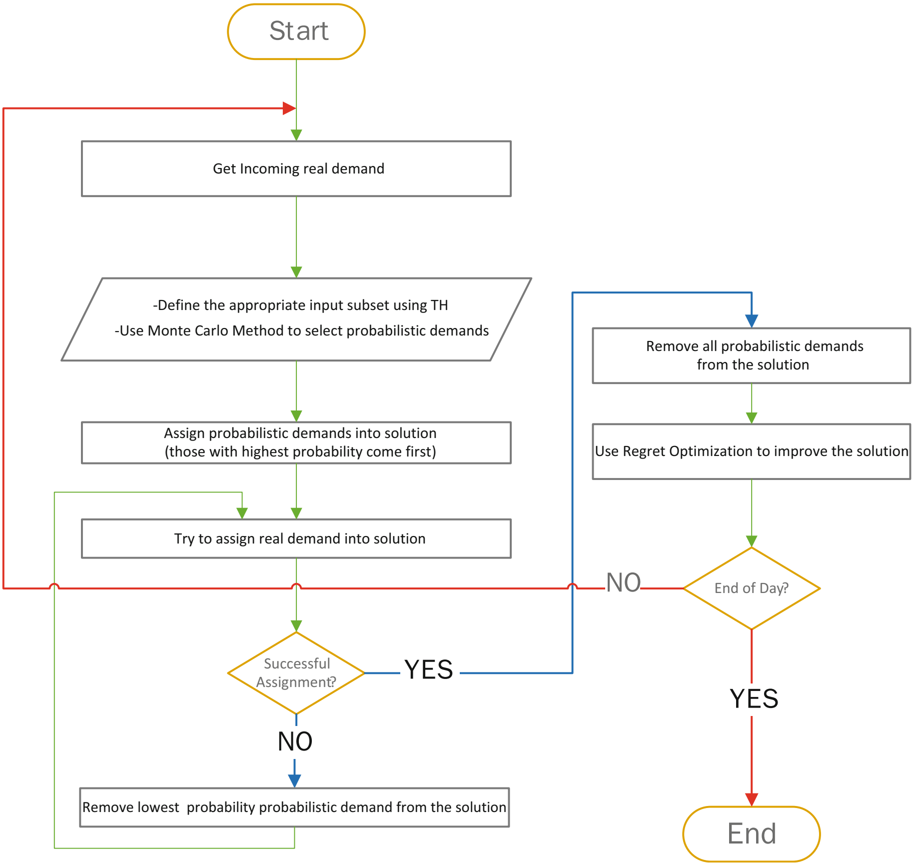
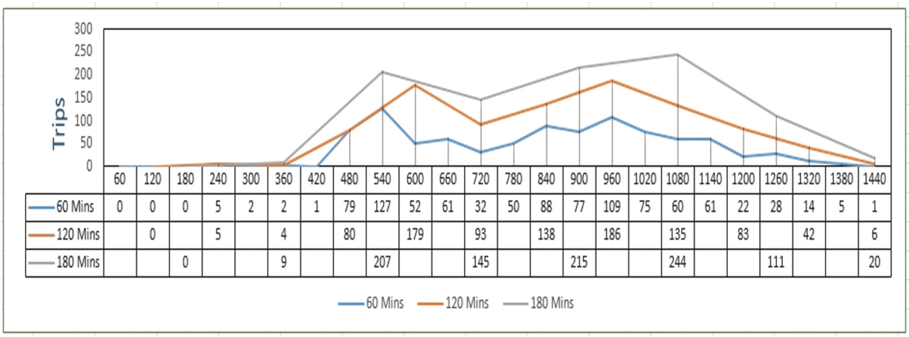


Fig. 1. OP-DARP algorithm flow chart.



	60	120	180	240	300	360	420	480	540	600	660	720	780	840	900	960	1020	1080	1140	1200	1260	1320	1380	1440
60 Mins	0	0	0	5	2	2	1	79	127	52	61	32	50	88	77	109	75	60	61	22	28	14	5	1
120 Mins		0		5		4		80		179		93		138		186		135		83		42		6
180 Mins			0			9			207			145			215			244			111			20

Fig. 2. Trip demands distribution.

We designed experiments to draw conclusions about the way that probabilistic demands affect solution quality in general. Data was analyzed to calculate the probability distribution for all trip demands that emerged during the pilot testing. Due to unsatisfactory fit for all known (Poisson etc.) probability distributions to our data, the empirical distribution was chosen. We designed two different sets of experiments to compare the performance of OP-DARP and OR-DARP algorithms. For the first set we used the busiest days of the month. Wednesday was the busiest day of the week for all weeks. Based on these observations we experimented with 5 Wednesdays. The second set of experiments, provide a comparison analysis for one month (Wednesdays excluded).

The first set of experiments. Basic parameters: Fleet size of 25 vehicles, vehicle capacity 12 seats, maximum pickup wait time 15 min, maximum trip demand ride time 1.5 time the absolute shortest path time, work period was one day (or 1440 min), three time horizons 60, 120, 180 min, Monte Carlo repetitions for each experiment were 100. Computational results after the application of the OP-DARP algorithm are presented in the Table 1, where: column C1 represents the experiment number (1 to 5). Each number is associated with one of the five Wednesdays during the pilot testing, column C2 represents the number of real demands for the experiment number denoted by column C1, column C3 represents the time step horizon, column C4 represents the average cost (the objective) produced by the repetitive runs of OP-DARP algorithm, column C5 represents the average vehicles number produced by the repetitive runs of OP-DARP algorithm, column C6 represents the standard deviation of all solution costs produced by the repetitive runs of OP-DARP algorithm, column C7 represents the percentage difference between the cost of OR-DARP (grey raw) and the average solution costs of the OP-DARP algorithm, column C8 represents the confidence interval (95%) for all solution costs produced by OP-DARP algorithm. Each grey row represents the solution produced by OR-DARP algorithm. Every framed cell represents the solution cost which is less than the solution cost presented by the grey row.

By examining Table 1 we conclude: (1) The OP-DARP algorithm gave better solutions for four out of five experiments in comparison with the OR-DARP algorithm. The maximum improvement percentage is 6.01%. However, in experiment #3, OP-DARP there is no gain. (2) The OP-DARP algorithm uses a significantly higher (1.5 to 2 times) number of vehicles than the OR-DARP algorithm in all experiments.

The second set of experiments. The basic parameters were similar to those of the previous experiments with one exception. The time horizon was always 120 min. Computational results are presented in the Table 2, its columns are self-explanatory.

By examining Table 2, we conclude that the OP-DARP algorithm improved the solutions for all days except for days 3, 14. Table 2 clearly shows that if computing power is not a problem, then it is worthwhile to use probabilistic demands.

Table 1. OP-DARP vs OR-DARP extensive comparison.

C1	C2	C3	C4	C5	C6	C7	C8
1	76	(OR-DARP)	627500	6	n/a	n/a	n/a
	76	60	599150	10.5	2599	−4.52%	1611
	76	120	613100	11.5	2902	−2.29%	1799
	76	180	619090	11.5	7053	−1.34%	4372
2	70	(OR-DARP)	700400	6	n/a	n/a	n/a
	70	60	658300	10	737	−6.01%	457
	70	120	659300	11.5	1475	−5.87%	914
	70	180	663900	10.5	5241	−5.21%	3248
3	99	(OR-DARP)	656100	5	n/a	n/a	n/a
	99	60	665600	10.5	1054	1.45%	653
	99	120	675300	12.5	421	2.93%	261
	99	180	658550	12.5	3109	0.37%	1927
4	101	(OR-DARP)	615000	6	n/a	n/a	n/a
	101	60	614390	10.4	2160	−0.10%	1339
	101	120	611300	11.8	994	−0.60%	616
	101	180	613790	11.9	619	−0.20%	383
5	73	(OR-DARP)	531500	6	n/a	n/a	n/a
	73	60	555940	9.9	2416	4.60%	1497
	73	120	533441	10.4	4941	0.37%	3062
	73	180	529450	9.2	1423	−0.39%	882

Table 2. OR-DARP vs OP-DARP, simple comparison.

Day of the month	OR-DARP cost	OP-DARP Average solution cost	% difference
Day-02	397400	390800	−2%
Day-03	402700	407433	1%
Day-06	355800	350867	−1%
Day-07	331700	323633	−2%
Day-09	440900	424467	−4%
Day-10	570000	557567	−2%
Day-13	387600	384300	−1%
Day-14	422600	444967	5%
Day-16	552400	550833	−0.003%
Day-17	821300	795467	−3%
Day-20	427100	418700	−2%
Day-21	529800	479017	−10%
Day-23	560100	556533	−1%
Day-24	554000	545000	−2%
Day-27	414000	405000	−2%

4 Conclusions and Future Work

So far, research in the DRT field focuses on algorithmic optimization methods and their improvement. The algorithms work usually on the time and location of demands as they occur. However, the effectiveness of an algorithm also depends on the information it has to work on.

In the study, we propose that the use of probabilistic demands can improve solutions. That improvement does not require a change of the optimization algorithm. It is a consequence of artificially reducing the system's online nature by introducing predictability of future demands. With our study, we provide some experimental evidence to support this. In the majority of experiments, the results show an improvement to the solutions - on average - in terms of operational cost. On the downside, the number of vehicles used increased notably. This is significant and particularly detrimental in cases of privately owned, fixed fleets. In cases that vehicles are hired or payed directly by the clients, it is irrelevant. In any case, further investigation is justified, preferably with a more extensive set of data for a larger area of operation.

Two issues emerged that require specific attention in further research. The first is the size of the Time Horizons. As mentioned above, Time Horizons describe fixed future periods defined by the time where the real demand may be realized. Probabilistic demands belonging to those future periods are incorporated temporally in the solution process. A small size (i.e. 30 min) means few probabilistic demands. A large size (i.e. 300 min) means more probabilistic demands. Our results on an appropriate TH, are inconclusive. We believe that, there is a need for further investigation. Also for this study, we used fixed Time Horizons. The day was divided in advance in an appropriate number of fixed Time Horizons. It would be interesting to see the effect of a "moving" Time horizon, adjusted to each demand's pickup time (i.e. one hour before demand's pickup time, one hour after demand's pickup time).

The second issue is the effects of using probabilistic demands with different optimization algorithms. For example, algorithms that try to find solutions in a larger solution neighborhood (i.e. tabu-search, simulated annealing). Investigation of such approaches is definitely warranted.

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Understanding Taxi Travel Demand Patterns Through Floating Car Data

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Abstract. This paper analyses the current structure of taxi service use in Rome, processing taxi Floating Car Data (FCD). The methodology used to pass from the original data to data useful for the demand analyses is described. Further, the patterns of within-day and day-to-day service demand are reported, considering the origin, the destination and other characteristics of the trips (e.g. travel time). The analyses reported in the paper can help the definition of space-temporal characteristics of future Shared Autonomous Electrical Vehicles (SAEVs) demand in mobility scenarios.

Keywords: Taxi demand · Travel demand · Floating car data

1 Introduction

Improving air quality and reduce congestion in urban areas has been a priority in many countries. In central areas, regulatory traffic control has been introduced, usually integrated with improvement of public transport provision. These solutions are effective, but more than 20 years has passed from the introduction of those schemes and the technological context is changing. One main technological change refers to the rising of Automated Electric Vehicles (AEVs) that have the potential to affect substantially congestion, energy use and emissions in central areas. These AEVs will facilitate the sharing mobility development, with expected relevant effects on urban livability. One issue in designing future SAEVs service is the identification of the number of shared autonomous vehicles and the number and the localization of stations for the pick-up and drop-off of shared vehicles and the feasibility of the service [1]. In order to help the definition of space-temporal characteristics of the SAEVs demand in future mobility scenarios, the analyses of current characteristics of car sharing and taxi services can be of great help. For such purpose, this paper analyses the current taxi services in Rome, using FCD collected in February 2014, from a sample of 310 taxi drivers out of a total population of about 7,700 taxi drivers operating in the municipality.

The paper is composed as follows. Section 2 reports a literature review, Sect. 3 presents the study area where the taxi service is analyzed. Section 4 reports the

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methodology adopted in the analysis, considering the data and the approach. Section 5 contains the main obtained results. Finally, Sect. 6 reports some conclusions.

2 State of the Art

Several studies have been carried out on the analysis of taxi services, thanks to the innovative technologies. One of them concerns Berlin's taxi services [2] and it's based on data collected from on-board GPS devices while operating taxis. In particular, the study analyses the travel behavior and vehicle supply of the Berlin taxi market using floating car data (FCD) for one week each in 2013 and 2014. Regarding spatial analysis, the study shows that most taxi trips take place either within the city center or from/to Tegel Airport, the most important Berlin's airport. Another study [3] concerns Washington, DC where the authors investigate the relationship between taxi pick-ups and drop-offs from GPS data considering land use and travel data for each zone in the city. Also in this case, the presence of three civil airports in the study area influences the taxi demand. The purpose is the development of a model to relate taxi demand with land use and accessibility. Harbin City [4] is a further example for taxi data analysis, in particular, the city was divided into traffic zones and the pick-up and drop-off locations are identified to build the origin-destination matrix of the trips. Other considered input data are travel distance, time and average speed in occupied and non-occupied status. The aim is to analyze travel demand distributions and the estimation of an entropy-maximizing model to estimate the traffic distribution. To reveal the travel patterns in Shangai, Liu et al. [5], analyze the trips of about 6,000 taxi. This study aims to identify spatial interactions among areas of the city and identify the structure of the travel flows.

The data collected from taxi trips are complex, contains geographical and temporal components and, in some cases, could contains other trip information. Consequently, can be hard to use queries to perform analyses (e.g., trip distance, trip distribution). Ferreira et al. [6] propose a possible solution of this computational hard problem using the trips data of New York City taxi, developing a model able to support visual exploration of big data related to origin-destination taxi trips. A similar analysis is conducted using FCD collected in Beijing and containing the taxi trips [7]. The data processed deals with the taxi stay location and the taxi operations. In order to analyze the travel length, the distribution of trip distance and the spatial distribution of the taxi, [8] use a dataset containing the trajectory data of 11,880 taxis in Beijing. The analysis is conducted considering both the travels with customer and the empty travels. The variables analyzed in [9] are the displacement of each trip the duration of each trip, the time interval between successive trips by the same taxi. The data are from five different cities and consider only the trips with customer.

3 The Study Area

The municipality of Rome extends over an area of 1,283.70 Km^2, with the 22.20% destined to urban activities. The area is divided in six zones according to the PGTU (General urban traffic plan). Four of the six zones are inside the main road ring (GRA).

The fifth zone is outside the GRA and includes urban perimeters of some relevance. The last zone is located in the west part of the city.

The population reaches 2.9 million of inhabitants, which daily generate 4.7 million of trips, while trips generated from outside Rome are about 800,000. Trips from outside is continuously growing (250,000 units more than 2004), confirming the population's tendency to go live outside Rome.

4 Methodology of Work

4.1 Supporting Data

GPS data used in this case study belong to CRAWDAD dataset 2014 [10]. The GPS position of each taxi is logged every 10 s and it has been possible to build a database of historical GPS traces through around 27 thousand GPS positions recorded per day, therefore 756 thousand for the entire month of February 2014. Each entry includes:

- ID (the taxi identifier),
- Date (date the record is logged),
- Timestamp (time the record is logged),
- Coordinates (geographical location: latitude and longitude).

4.2 Approach

The possible status of taxicabs was aggregated in the following categories:

1. to customer (driving to or waiting for a customer),
2. with customer (driving with a customer on board),
3. at rank (standing at a taxi rank),
4. outside rank (idle but not at a rank, for example returning to a rank).

The analysis of taxi demand from GPS traces is composed of several phases:

1. computation of distance between two successive GPS positions recorded (if the distance travelled by the taxi driver in 2 min is less than 10 m, it has been considered the vehicle non-moving, otherwise the driver is traveling),
2. individuation of the origin o and the destination d of each trip,
3. computation of progressive distance (to evaluate the length of a trip).

Other calculated values are the travel time (for each trip) and the waiting time of a taxi in a position (if the waiting time in a position is greater than 2 min we suppose that the position is a destination).

The activity *with customer* is the taxicabs status needed for this demand study. In order to individuate this kind of status, it's important to recognize all the times the vehicle is at a rank. A taxi cab is considered steady at a rank when the time previously calculated is more than 2 min and the coordinates are quite near one of 100 rank of the city. Hence, it's possible to establish the number of times a vehicle is steady at a rank and instead when it's steady because the driver is dealing with a customer (the costumer is entering or is leaving). Consequently, it can be found the trips with the activity *with customer*.

Once the data processing is applied, it has been possible to build a database based on the vehicles' status *with customer*, for the studied period. Each entry of the database contains:

- length of the trip,
- travel time,
- origin and destination of the trip,
- waiting time.

Finally, the origin-destination matrix based on the vehicles' status *with customer* is built.

5 Main Results of the Analyses

5.1 Temporal Patterns of Taxi Demand

A detailed distribution of taxi demand (the number of requests submitted per day and the number of requests submitted per hour) over the two weeks are presented in Figs. 1 and 2. For the demand side, the following happens:

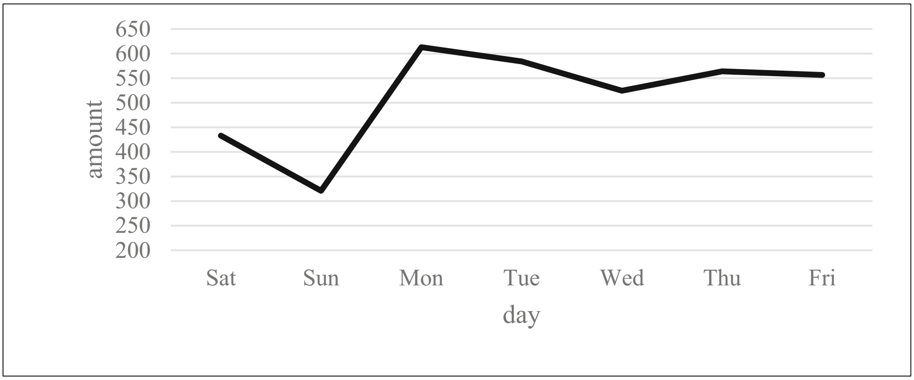


Fig. 1. Request submissions per day.

- taxi demand during weekdays (Monday–Friday) is generally higher than that of weekend (Saturday and Sunday),
- taxi demand during weekdays follows a clear pattern: a major peak from 8 am to 9 am, smaller peaks during the afternoon (the first peak at 3 pm and the second one at 6 pm) and very low taxi demand from 12 am throughout the night,
- Monday is demand-wise the busiest day,
- Saturday night records a peak around 11 pm and significant taxi demand throughout the night.

Besides Saturday night, the demand for taxi services during weekends is low.

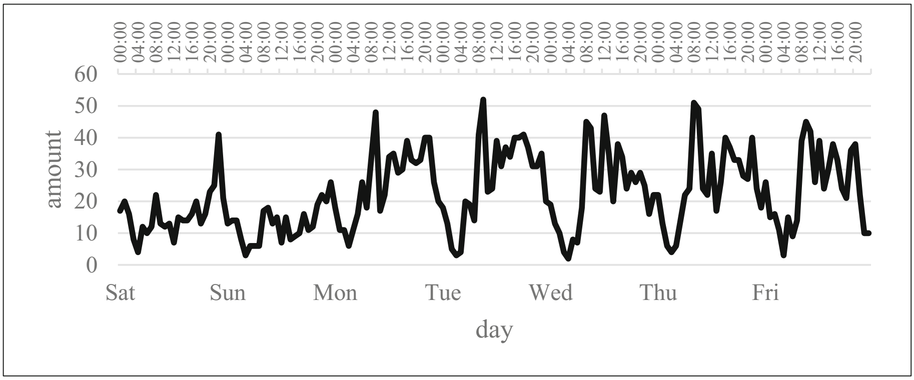


Fig. 2. Request submission per hour.

5.2 Trip Distances and Travel Time

The average trip distances, calculated adding the beeline distances between two consecutive geographical points (the points are recorded every 10 s), are at most weekday hours between five and fifteen kilometers (Fig. 3). However, the weekday morning (about 8 am), with average distances around twenty-five kilometers, form a notable exception. The day with the highest average trip distance is, on the other hand, Wednesday, with roughly 30 km. Relating to the average travel time (Fig. 4), it range from 7 to 31 min. The maximum average travel time is recorded Monday, between 8 am and 12 am, another peak is notable on Friday around 8 pm. The time analysis can be useful in defining the use of SAEV, assuming that the time that a user spends traveling with a taxi is comparable with the time that he/she would spend using the SAEV.

As to the distribution of trip distances (Fig. 5), there are few trips of less than one kilometer, whereas a trip distance between two and five kilometers is the most common. Longer distances are less and less likely: not even twenty percent of all trips are long between ten and twenty kilometers. On the other hand, trips longer than twenty kilometers are about the 13%.

5.3 Location-Based Taxi Demand

Origins and destination of taxi trips are generally spread all over the city (Fig. 6a). The majority commences and ends within the inner railway ring and in the EUR district, one of the most important financial and tertiary area of the city. Moreover, the data suggest that about the 15% of trips are from the city to the outside and vice versa. Figure 6b highlights these trips, remarking that they are mainly from/to Fiumicino Airport, the biggest Rome Airport.

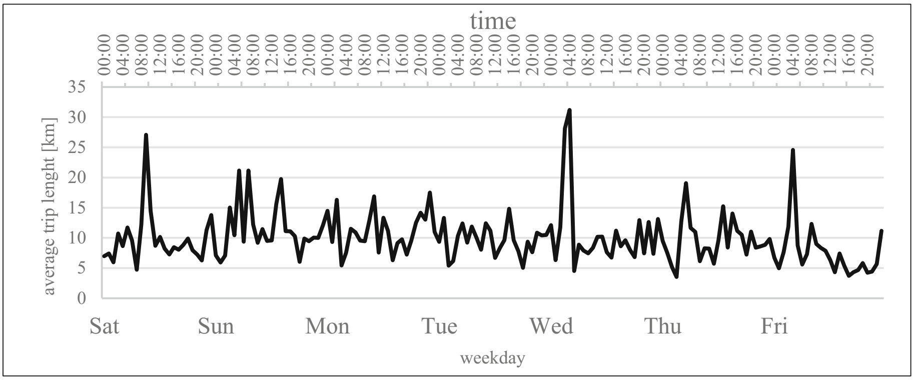


Fig. 3. Average trip distance at different times.

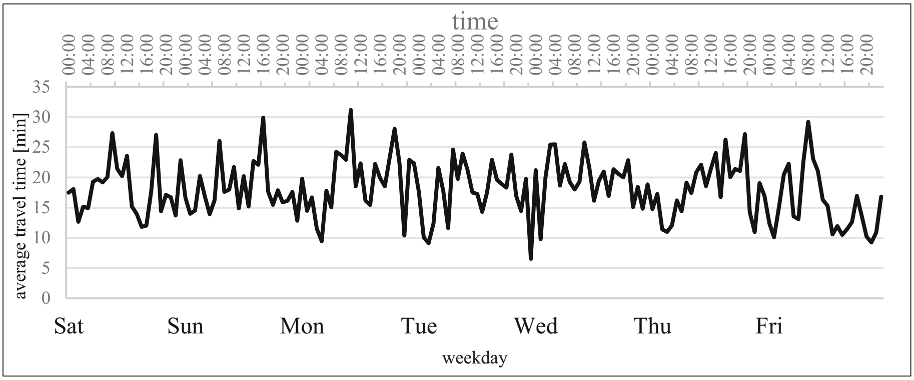


Fig. 4. Average travel time.

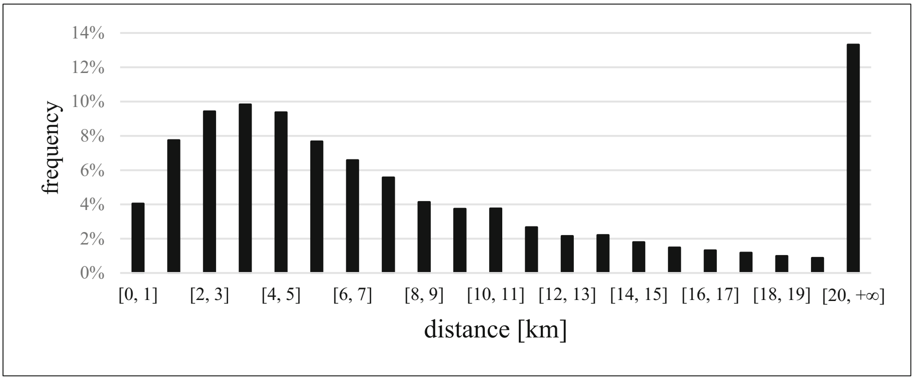
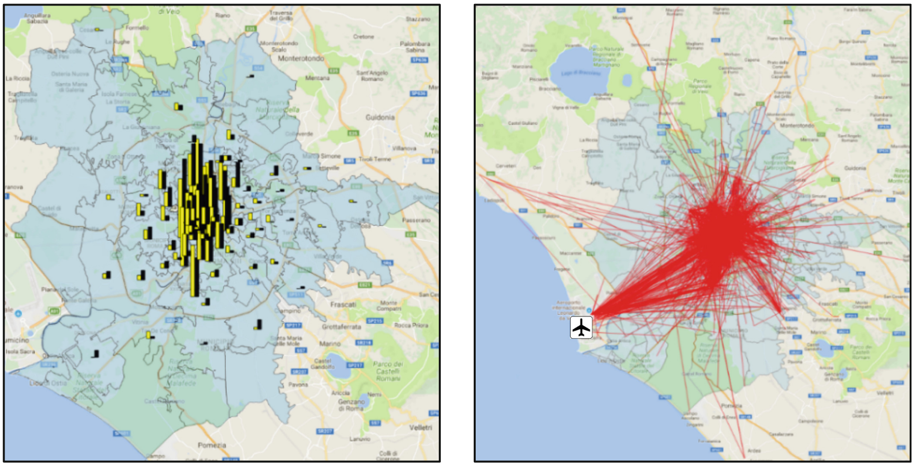


Fig. 5. Trip distance distribution.



(a) Origins and destinations per zone (b) Trip visualization

Fig. 6. Trips and origin destination relations (Map source: Google Streets).

6 Conclusions

In this paper, we presented an analysis of FCD related to the taxi trips in Rome. The data were collected in February 2014, from a sample of 310 taxi (on a total of about 7,700 taxi operating in the municipality). The data processing suggests that there is generally a demand peak on workday mornings and a several lower peaks over a longer time in the afternoon. From analyzed data, about 30% of the trips are taken in the morning from 5am to 8am while the remaining 70% are distributed over the rest of the day with two afternoon peaks, the first one at 4 pm and the second one at 6 pm. On weekends, the demand peaks shift towards the night and are generally lower than weekdays. On Saturday night, about 40% of the total number of trips occurs, with a peak at 11 pm. The remaining trips (60%) are distributed equally over the course of the day.

As far as spatial analysis is concerned, the majority taxi trips begins and ends within the Inner Railway Circle, the trips from/to the outside (mainly from/to Fiumicino airport) are about the 15%. As to the distribution of trip distances, there are few trips of less than 1 km, whereas a trip distance between 2 and 5 km is the most common. Longer distances are less and less likely: not even 20% of all trips are long between 10 and 20 km. On the other hand, trips longer than 20 km are about the 13%.

This analysis of Rome can be useful for the future SAEV services design, also using the taxi data (space-temporal distribution, number of trips, travel time, distance) as a proxy to try to define one component of the future demand for SAEV. Indeed, a first element to design the sharing service is the definition of the areas where the vehicles can be picked-up or dropped-off. To do this, can be selected as potential areas those where are registered high values of demand for taxi. Besides, the travel time evaluated with taxi data can be used to size the fleet of shared vehicles. It is noted that the actual zones of Rome covered with the vehicle sharing services are those with high taxi demand (central zones).

Further analyses are also in progress to use these data, with the aim to develop and test a model framework for forecasting taxi travel demand in relation to socio-demographic characteristic of different zones of the city.

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Critical Moment for Taxi Sector: What Should Be Done by Traditional Taxi Sector After the TNC Disruption?

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Abstract. The biggest change in urban mobility during recent years is introduction of TNCs (Transport Network Companies) like Uber and of course the most important impact of TNC disruption happened on traditional taxi services. It is a hot topic of discussion in many countries that how the current taxi industry should respond to TNC disruption. This paper will present the current situation regarding impact of TNCs on Taxis with examples from various countries. Reaction of traditional taxi sector will be analyzed and categorized within this paper as well. Main aim is to help better understanding of different reactions, their categorization and as well potential outcomes for traditional taxi sector to be sustainable in competitive business environment and take role as part of sustainable urban mobility puzzle. There are variety of responses already given by traditional taxi industry to the TNC disruption including 'Ignoring', 'Resisting' 'Competition' and 'Collaborate' with the new actors. Different options will be evaluated and discussed in this paper and recommendations will be presented to Traditional Taxi Sector.

Keywords: Transport network companies · Taxi · Regulation
Shared mobility

1 TNC Disruption and Impact on Traditional Taxis

The most important impact of TNC disruption happened on traditional taxi services among different modes of urban transport. The number of trips taken by regular taxis in San Francisco decreased 65% in just 15 months between 2012 and 2014. The average number of trips per taxi has been on a steady downward trajectory, from 1,424 per month in March, 2012, to 504 per month in July, 2014 [1].

In New York, the lack of supply relative to demand caused taxi medallions (permits) to sell for over $1 million by 2013. By 2015, however, the price of a medallion had fallen by about 25% in response to competition from TNCs [2]. In Chicago the average weekly medallion prices and number of transfers from 2008 through March 2015 peaked at about $400,000 in July 2012 and have trended downward slightly since then, in contrast to the upward trend from the beginning of the data in 2008.

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The market has become thinner over time, as well, with the number of transfers peaking at 538 in 2012 and decreasing to 91 in 2014 and only seven from January through April 2015 [2]. Similarly, Hong Kong Taxi Permit Trade value is down by HK$ 1 million and in Toronto it came down to 90000 Canadian Dollar from earlier 360000 [3]. In Dubai, which is an example of very protective market in terms of taxi regulation, traditional taxis lost around 15% of their trips to limousine segment after entrance of Uber and Careem which are allowed to work only with limousine segment [3].

In New York, TNC ridership doubled annually over the last three years to 133 million passengers in 2016, and is now approaching yellow cab ridership levels. After accounting for declines in yellow cab, black car and car service ridership, TNCs have generated net increases of 31 million trips and 52 million passengers since 2013 [4].

2 Methodology

This paper will be mainly based on survey for urban transport authorities, interviews with top level managers of taxi operating companies conducted within this study to better understand the taxi sectors reaction and collection of information from different sources including press releases and secondary data sources.

2.1 Case Study Collection

Collection of information from different sources including press releases, newspapers and other academic studies conducted.

2.2 Survey for Urban Transport Authorities

Set of questions developed related to impact of TNCs on Traditional Taxi Sector and the survey was conducted to different cities with different size, geographical backround, different mix of mode share. Survey was conducted via e-mail for the urban transport authorities of that cities who can present the full overview and the data was collected from that cities based on their own research and studies (e.g. travel survey, urban mobility master plans, other studies). Collected data went undergo internal (compatibility with other data from the same city) and external (compatibility with data from other cities) checks and adjustments. 6 cities from different regions of the world (Europe, Asia, North America and Middle East) were included into survey and 4 questions were asked. In all cities TNCs are existing and but none of the cities are measuring the modal share of TNCs of as of today. 4 of 6 cities didn't measure the impact of TNCs on Traditional Taxi Sector but 2 of them measuring without providing quantitative examples. 3 of 6 cities expressed their observed change in Traditional Taxi Industry after introduction of TNCs e.g. increase of Service Quality, new features, change in business model etc. Participating cities and their answers also categorized in below Table 1.

Table 1. Responses of urban transport authorities to survey questions.

	List TNCs operating in your city?	Mode share/Fleet size	Do you measure impact of TNCs on Traditional Taxis?	Is there any change you noticed with Traditional Taxi Industry after introduction of TNCs?
Brussels	eCab, Taxi.eu, Splyt, Taxibleus, Taxi2share, Collecto	N/A	No	N/A
Dubai	Uber, Careem	N/A	No	Yes
Frankfurt	Taxi-App, Taxi Deutschland, eG	N/A	No	N/A
Hong Kong	There are TNCs but exact number N/A	N/A	No	The taxi trade has all along strived to improve the quality of ordinary taxis
Kuala Lumpur	12 Active Operators	N/A	Decrease of demand for taxis due to poor quality of vehicles and service	Adoption of technology by drivers & companies to improve offering to taxi drivers such as by reducing vehicle rental, training etc.
Montreal	Uber, Netlift	N/A	Yes, still early but we have a partnership with Montreal University to evaluate the impact of the arrival of UBER in 2014	Yes. The industry is in a major change period since Montreal adopted its taxi policy. The upcoming of Uber added pressure to improve service. Many projects to improve customer service are and will be implemented

2.3 Interview with Top Level Executives of Traditional Taxi Sector

In addition to collection of data from different sources and survey to urban transport authorities, within the scope of this research below listed top level executives of taxi operating companies were interviewed. The list of executives were selected to represent different type of corporate structure and geographic balance. During the interview they were asked about their strategy after TNC Disruption in their respective city with providing different examples. Their answers were also categorized by authors according to their actions taken already after TNC disruption (Table 2).

Table 2. Interview with senior executives of taxi operating companies.

	A. Sabbagh	Tony Heng	Siti Faradillah	Alpay Kılıckaya
Position	CEO	G.Manager	G. Manager	Manager
Company	CARS	SMRT	Destination	Izmir Taxi
Area	UAE, Qatar, Kuwait, Bahrain, Malaysia, India	Singapore	Kuala Lumpur	Izmir
Organization type	Private Company	Private Company	Private Company	Chamber of Individual Taxis
Category	Compete/Collaborate	Compete/Collaborate	Resist/Compete	Resist/Compete

3 Responses of Traditional Taxi Operators to TNC Disruption

There are variety of responses already given by traditional taxi industry to the TNC disruption in different countries. Based collection of different case studies and the review of earlier studies, responses to transport authorities survey and interview with traditional taxi operators Responses can be basically categorized into 4: Taxi Companies who are 'Ignoring' the TNC Disruption, 'Resisting' to the TNC Disruption, developing 'Competition' against and 'Collaborate' with the new actors.

3.1 Ignore

Still in many countries taxi operators are ignoring and remaining to focus on their business. Taxi business remains regulated and controlled by stringent government regulation in that cities. Business model of TNCs was looking unviable as Taxi were never pitches as 'Alternative to Vehicle Ownership'. This way ignorance is not so common in the world today and it was a pattern for countries where TNCs didn't enter aggressively yet. But today with the growing penetration of TNCs this ratio went down. Also this is still an issue for mid and small size cities of the countries where TNCs are not very active as they see less market for them.

3.2 Resist

Drivers around the world protested against TNC players by blocking roads or stopping the work. Demonstrations all around the world received big attention from media, especially European cities witnessed lots of strikes and demonstrations which turned into violent in some cities for example in Paris. Not only the demonstrations but also several actions were taken by the taxi industry. Barry Korengold, president of the San Francisco Cab Drivers Association described Uber: "I think of them as robber barons. They started off by operating illegally, without following any of the regulations and unfairly competing. And that's how they became big—they had enough money to ignore all the rules" [5]. Taxi Industry representatives became more visible in media, they launched lobbying and communication campaigns and of course law suits in many cities against Transport Network Companies. Geradini [6] mentions that taxi companies are realizing that in the medium-term Uber's business model is likely to prevail and that it is therefore a matter of time before they will have to revisit their modus operandi. In the short-term, such an approach is, however, likely to be resisted because it would lead to job losses, as well as an acceptance by taxi companies that the business model they have so much decried is the right way to go. In cities like İzmir from Turkey and Kuala Lumpur from Malaysia traditional taxi operators also resisting against introduction of Transport Network Companies. They conduct lobbying activities especially for transport authorities for banning or limiting entrance of TNCs, keeping the existing regulatory framework capping number of available taxi numbers in the city and restricting new entries into market.

3.3 Compete

Competition against TNCs is the most common way today followed by many taxi operating companies and individual license owners. Many taxi companies also launched their own apps today against TNCs. Jaspal Singh [7] lists different actions taken by taxi operating companies. 9211 is a mobile app created by Mumbai Black & Yellow Taxi drivers to compete with transport technologies companies. Oride is the app created by Gradient Telematics Sdn Bhd (GRADIENT) representing over 90% of the corporate Taxis in Malaysia. It is an official app used by GABUNGAN – Association of all taxis companies. The "Tokyo Taxi Association-TAKKUN" app, launched in January 2014, is the most popular app to book a taxi in special zones/the Busan district. It has registered around 10,963 taxis. The it Taxi app is launched by the Italian taxi drivers' union (URI, Unione Radiotaxi Italiani). The app allows people to search for and book taxis on their mobile phones. The app is currently available in Italian, English and German and in over 30 cities in Italy. ihail app is owned by major taxi companies in Australia - Yellow Cabs, Silver Top Taxi Service, Black and White Cabs, Suburban Taxis and Cabcharge. Together the owners control more than 50% of all taxis in Australia [7].

According to Wallsten [2] in New York City and Chicago taxis responded to new competition by improving their quality. Uber has caused cabs to improve quality. In particular, in Chicago Wallsten suggest that complaints about things a driver might do to affect quality—use of air conditioning, "broken" credit card machines, rudeness, and talking on cell phones—all seem to have decreased along with Uber's rise. Sometimes credit card machines are "broken" (i.e., the driver refuses to use it) and sometimes they are really broken. A decrease in complaints about credit card machines could reflect better maintenance, better behaviour, or both. At the same time, complaints about cabs cutting in line, overcharging, and taking long routes do not appear correlated with Uber's rise.

Taxi Industry is advised in different academic researches as well to compete against Transport Network Companies. In a research done in China [8] the taxi industry is advised to focus on releasing new taxi-booking app to attract more consumers. The new app should offer appropriate discounts to consumers. By creating a network between every full-time taxi driver, taxi companies should make customers wait for responses for least time. Also, taxi drivers' punctuality and concentration level of driving should be considered when taxi companies select and train their drivers. If possible, taxi companies need to set stricter rules to standardize drivers 'driving behaviors. To monitor whether taxi drivers obey rules, the taxi companies can install closed circuit televisions in taxis, and they can get feedback from customers about drivers' concentration level of driving by reviewing the comments posted online and the ranking about drivers given by consumers. Considering that people are not familiar with what the taxi companies are doing or what they have done, taxi companies can promote their public reputation and advertise more to make people be familiar with their good social activities. Traditional Taxi Industry in Montreal is also in a major change period since Montreal adopted its taxi policy. The upcoming of Uber added pressure to improve service. Many projects to improve customer service are and will be implemented. Similarly in Kuala Lumpur adoption of technology by drivers & companies to improve offering to taxi drivers such as by reducing vehicle rental, training etc. In city of Izmir, Taxi Chamber launched first call and dispatch centre in Turkey as response to entrance of Transport Network Companies to Turkish cities.

3.4 Cooperate

In this example taxi associations or taxi operating companies accept the entrance of TNCs and make cooperation between them. Hailo is the best example of partnership between traditional taxis and new technology. The company is working with traditional black cabs in London. eCab is entering into partnership with taxi companies around the world. Main cab companies in Vancouver (Black Top Checker Cabs, MacLures Cabs, Vancouver Taxi and Yellow Cab) entered into partnership to provide its supply on eCab mobile app. Premier Taxis (Silver Cab) in Singapore entered into partnership with Grab Taxi. 3,000 Silvercab drivers will be added to the Grab mobile application to accept bookings. Grab also entered into similar partnership with Trans-cab [7].

Public Transport Council (PTC) and Land Transport Authority (LTA) Singapore authorized traditional taxi operators to implement dynamic pricing or surge pricing for trips booked through mobile applications in March 2017. There are 5 operators - Trans-Cab, SMRT, Premier, Prime and HDT Singapore Taxi, which operate more than 10,600 taxis in total. Grab has entered into partnership with taxi companies and will offer the fare option through the new JustGrab function in the Grab app. Users would require to choose the JustGrab button on the Grab app and will get either a taxi or private hire car at the same price quoted. Grab will take a 10% cut from cabbies assigned to JustGrab passengers, while Grab cabbies will pay a flat commission of 50 cents [9].

In Dubai, some of the conventional taxi fleet operators, for example CARS Taxi, also launched a business in limousine segment as Transport Network Companies are allowed only to work with limousines and there is shift of customer demand to limousine segment [3]. Dubai Taxi Corporation also started partnership with Uber and Careem with signing partnership agreement especially for limousine segment operations in Dubai.

There is also a 5th way of cooperation which is not officially announced there are negotiations reported between traditional taxi operator SMRT and GRAB in Singapore.

If successful, the deal will SMRT, the 3rd largest taxi operator of Singapore to sell the taxi business to leading Transport Network Company of South East Asia, Grab. The deal is also for SMRT to have shares at Grab and have seat at the board of directors of Grab [10].

4 Conclusion

Current research regarding advises to traditional taxi sector in terms of their strategy after TNC disruption is limited although the traditional taxi sector is the party impacted heavily by TNCs. Limited current research mostly advising to the taxi sector compete against Transport Network Companies but the strategy for this competition is missing. Competition against Transport Network Companies by traditional taxi industry is not an easy task as TNCs has strong competitive advantage in terms of technology, economy of scale, modern management and marketing techniques. It is also important to notice that traditional taxi sector continued their operation in many countries several years with heavy regulation in terms market entry and protection which limited their innovation capability and produced poor services together with less ability to response market changes. But also there are many advantages of traditional taxi services against TNCs mainly well trained drivers (in comparison to unprofessional TNC drivers), existing vehicle fleet, city knowledge etc. From this perspective traditional taxi sector should consider more about collaboration options with TNCs. Transport Network Companies today are reality and have many competitive advantage against traditional taxi industry. This option could bring benefit to both parties and they can act complementary other than competing each other and losing sources for this competition for the mid-term. Examples from Singapore or Dubai where traditional taxi sector were very strong can be taken as case study on this and could be studied by other cities to design further strategy. In addition to partnering with Transport Network Companies Traditional Taxi Industry should also look different ways to improve customer satisfaction and efficiency. This can be achieved through, Corporatization of individually owned taxi operators, increase of service quality and focus more on product differentiation and market segmentation and better integration with other modes of public passenger transport.

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Predictive Maintenance for Buses: Outcomes and Potential from an Italian Case Study

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Abstract. The paper deals with an innovative Predictive Maintenance (PdM) system to assess the quality of the engine oil for buses, tested in Ravenna within the European Bus System of the Future - EBSF_2 project, funded by the European Union. The system relies on a PdM software linked to oil sensors and filters, installed on a test fleet, and on an IT architecture, specifically designed. The system enables a continuous assessment of the oil quality, which is highly predictive of the engine performance, thus detecting potential breakdowns and planning the replacement of spare parts ahead of regular schedules; the system also detects which substances and problems cause the poor quality of the oil.

The paper describes the system, the testing scenarios, the performance assessment, and the main outcomes. Results also enable an assessment of additional, potential environmental benefits (especially mitigation of emissions toxicity and improvement of waste management). Additional features are also reported such as an algorithm to estimate the date when oil has to be changed. Such results are analysed and commented with the research objective to provide advanced knowledge for further research studies.

Keywords: Predictive maintenance · ITS · Lubricants · Bus · EBSF_2

1 Introduction

Preventive Maintenance (PM) for bus fleets "to reduce the likelihood of the in-service failure of components by anticipating their failures" [1 cited in 2] is applied in many bus maintenance departments. Unlike in the USA, where several regulations and standards require inspections of vehicles with specific reference to PM [2], in Europe this practice is still to be consolidated, especially among smaller transit operators, in which vehicle maintenance is managed via regulated but "reactive" procedures (i.e., restoring equipment to its proper condition after any given breakdown event). However, even less consolidated is Predictive Maintenance (PdM), which is the monitoring of the condition of the fleet equipment to forecast when maintenance is needed.

The goals of PdM are many: for operators, increased productivity thanks to reduced vehicle downtime, optimized maintenance labor and life-cycle costs of components and parts, reduced maintenance expenditures; for patrons, increased satisfaction due to a

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more reliable and safer bus service; and for the community, environmental benefits, mostly due to improved waste management and cleaner performance of components, especially engines [3]. PdM is essential to improve bus efficiency and, ultimately, raise its image, and it is therefore considered a core research area within the "European Bus System of the Future – EBSF_2" project. EBSF_2 (2015–2018) is a research project funded by the European Union with the aim of developing a new generation of buses across Europe, by validating highly advanced, innovative solutions. Since its inception, the EBSF_2 research program, evaluation methodology and implementation activities have been widely described [4, 5]. However, it is worth mentioning that 12 demonstration sites (from medium-sized cities to metropolitan areas across Europe) with more than 500 vehicles are involved in the testing activities, to assess under real operational scenarios the potential impact of several technological solutions, associated with different fields of innovation, among these a number on intelligent garage and PdM operations.

This paper describes the experience at one of these demonstration sites testing a technological innovation in the field of intelligent garage and PdM: the Ravenna case study. Here, a PdM system that monitors engine oil quality was under test on six urban buses, to assess the potential economic, operational, and environmental benefits of extending the engine oil's lifetime. More specifically, in the paper, the PdM system and the local test scenarios, are reported, the evaluation methodology described, and performance variations due to the introduction of the oil monitoring system (associated with various areas of impact – maintenance, operations, fuel consumption, costs, staff training) analyzed and commented on.

1.1 The Case Study Context

Famous worldwide for hosting eight UNESCO World Heritage Sites, the medium-sized town of Ravenna (around 170,000 inhabitants) is also the center of a large agro-industrial area) in northern Italy. The local motorized vehicle ownership rate is around 600 [(number of vehicles/number of inhabitants) x 1,000]; passenger cars are dominant, but bikes represent a very popular alternative mode of transport. The transit system is supplied by an interprovincial operator, START Romagna, across a 2,100-km network, which, along with the province of Ravenna, covers those of Forlì-Cesena and Rimini. The approximately 700-vehicle fleet serves almost nine million passengers per year, around 40,000 of whom travel across the Ravenna city center on a daily basis [6]. The fleet comprises different types of vehicles, the majority of which are diesel-fueled; the average age of vehicles is over six years.

The community has always been very concerned about quality of life, with specific attention paid to negative impacts due to pollution, particularly in the city center, where it jeopardizes citizens' health and the conservation of historic landmarks. Therefore, the governance of local mobility is based on enforcing a push-and-pull policy: disincentives for the use of private cars, for example by restricting passenger cars' access to the city center; and incentives to attract passengers onto transit by improving the bus service but, above all, by operating cleaner fleets.

Therefore, the need to meet the environmental requirements of the city is one of the drivers that prompted START Romagna to test an advanced PdM system.

2 The Predictive Maintenance System

A regularly scheduled maintenance process is crucial to providing a reliable and effective transit service, even when based only on reactive procedures. The underpinning concept is that regular efforts to maintain equipment in conditions as close as possible to the original accomplish more and at lower costs. If such efforts are also associated with preventive control procedures, and possibly with no service disruption, reliability and efficiency increase. This is the basic concept of "predictive" maintenance, and IT support enables continuous improvement of diagnostic operations, thus decreasing maintenance costs, breakdowns, use of spare parts and quantity of waste materials. The EBSF_2 Ravenna demonstrator serves as a case in point: an innovative PdM system for bus fleets under test. The system relies on maintenance software that analyzes data coming from sensors assessing engine oil quality, which detects potential breakdowns, allowing parts to be replaced in advance. The system also detects which substances, namely metals, and problems in general cause poor oil quality.

The potential of an advanced PdM process has been long recognized by START Romagna, which prior to EBSF_2 regularly scheduled reactive maintenance operations, though with no systematic check of oil quality and therefore with no potential to forecast failures. The need to switch from reactive to predictive procedures, focusing on oil quality, comes from acknowledging that constantly monitoring its status can be highly predictive of engine performance. For example, the detection of residual metals indicates that maintenance is necessary (ahead of schedule), whereas if the monitored quality is good, it is possible to postpone maintenance operations and therefore reduce costs. Moreover, lubricants, because of their hydrocarbon composition, contribute to CO_2 emissions. The PdM software tested in Ravenna provides real-time information on the quality of the engine oil through a sensor and an additional filter or purifier. Collected data enable a time-based trend assessment of the qualitative attributes of the engine oil (conductivity, temperature, amount of water) via a "quality index". This index describes the oil degradation levels and consequently predicts the time of replacement. It is also possible to detect unexpected contamination problems and avoid mechanical consequences to the buses; in this case, it is possible to intervene and extend the "life" of the oil by means of a cleaning filter. The IT supporting system enables data collection via an on-board system, under real operational conditions. More specifically, the oil quality sensor is connected to an on-board unit that gathers data from the sensor; the Controller Area Network (CANbus) through the FMS gateway manages the thresholds for data validation through embedded firmware and sends such processed data to the PdM software. Data analyses and trends are processed at the ground unit, over time.

2.1 A Core Components of the Predictive System

The components of the IT architecture are many, but one device plays the role of core component in the system: the Extended Oil Life System (EOLS) filters.

Typically, around 80% of engine failures are related to oil contamination, with indigenous full-flow filters unable to remove small particles of soot (carbon), heavy metals, liquid and gaseous contaminants below 10 microns. With higher levels of oil contamination, wear and tear on the engine increases, with physical damage to even the hardest metal surfaces. Chemical wear should also be considered, as it is caused by a reduction in lubricity and an increased rate of oxidation within the oil. When installed in synergy with the existing full-flow filter, EOLS can significantly extend the oil performance and decrease its use, as it prevents the accumulation of harmful contamination below 1 micron by filtering solid particles, significantly reducing acid formation and evaporating liquids and gases.

Therefore, in the Ravenna test, by combining filtration and evaporation in a single system, this Intelligent Processing Unit can help reduce all contaminant groups and deliver significant cost savings for operators by:

- reducing oil drain frequency and consumption, wear, and damage to the engine;
- decreasing disposal costs;
- minimizing filter replacement and ongoing consumable costs; and
- mitigating unpredictability in maintenance operations [7].

The filtration system allows a very slow oil flow (5 l per hour), with an oil pressure of around 2–3 bars and is based on a bypass oil circuit. Improved filtration is achieved by having the oil pass through a specifically designed device, a long-strand, protein-rich cotton medium. Such a medium reacts with the acid contaminants and removes them. Once filtered, the oil enters the heated evaporation chamber where liquid contaminants are evaporated and immediately vented. When these contaminants are removed, the clean oil is gravity fed back to the engine oil sump.

3 The Adopted Evaluation Methodology

As for any other innovative solution tested within EBSF_2, the assessment relies on the usual “before vs during implementation” comparison of results, with Key Performance Indicators (KPIs) measuring the performance variations in each case study and cross-case, as previously reported [4, 8, 9]. In this way, performance are assessed by comparing variations before (the NO EBSF_2 scenario) and during (the EBSF_2 scenario) the implementation of the PdM system. In the Ravenna case study, a selection of more than 20 KPIs is available, corresponding to different impact areas. PTs vary according to the KPIs they are associated with, and the expected improvements in the different performance fields range from 5 to 20%.

4 Test Scenarios and Results

The test scenario, that is, creating the conditions to test the PdM system, is based on a number of requirements: a suitable amount of vehicles to test; the potential to collect data not only from the “demo” vehicles but also from a number of control ones (to provide data to describe the “before” situation, without the PdM system to test, and enable performance comparisons); and, lastly, a suitable period to ensure sound availability of data. This last requirement determined which vehicle was tested with which oil change frequency: diesel buses 40,000 km (24,855 miles) and methane-fueled buses every 30,000 km (18,641 miles). A 12-month test total duration was judged suitable to provide a sound amount of data and was also coherent with the overall timespan of the EBSF_2 project (36 months). Buses under test operate on regular routes and in urban and suburban areas of Ravenna. Six vehicles were equipped with data collectors and lubricant sensors that send the information to the on-board data collection system. During the test, the sensors recorded the oil capability, conductivity, and trends, and gave an alert when values were out of range. Two of the vehicles were equipped with the additional purifier, to test the lubricant quality, compared with that of the vehicles without filters.

4.1 Operational Performance Results

Results from the testing activities are reported in Table 1, where a selection of KPIs is reported. General operational costs seem to rise (according to the variation in KPI "Operating costs per vehicle per 10,000 km"), whereas other cost items show a different trend: for example, KPI "Energy costs" and KPI "Costs per spare parts purchase" both decrease. A contributing factor can be the reduction in the oil consumption, which according to the KPI "Oil required per vehicle per 10,000 km" diminished by around 40%. KPI "Total and amortization costs per vehicle per 10,000 km" also decreased by 15%, far beyond expectation. Since this KPI includes the sum of two different items (i) total costs due to staff, energy, maintenance management, purchase of external goods and services, financial costs, depreciation, and tax expenditure, plus (ii) any additional costs due to amortization of a debt or other obligation linked to the PdM system under test, a decrease in its value is evidence of how this PdM system may contribute to improving the economic efficiency of the maintenance process.

In this kind of testing activity, all of the above might raise the typical research question: would the results have been different if tested on a larger scale or over a longer period of time? According to past experience, this may be particularly relevant if the emphasis is placed on economic and operational issues for smaller operators [8, 9]: expensive innovations can, in the end, become unaffordable. At the same time, it should be considered that, although six buses might constitute a small case, the test fleet can be considered appropriate and the results achieved scientifically sound for two reasons: (i) the test fleet is consistent with the usual experimental operations funded within European research projects focusing on innovation (such as EBSF_2), and with the size of the local operation (installing the equipment simultaneously on a larger number of vehicles would have certainly resulted in service disruption); and (ii) those involved in the test were average-performing buses, representative of the local fleet's performance and with homogeneous backgrounds and operational characteristics (driving cycle and types of route, commercial speed, schedule, frequency, etc.). The system, however, is engineered to process data from a larger fleet.

4.2 Conditioning Monitoring: Effective Prediction of Oil Replacement

To enable an advanced use of all the collected data coming from sensors and CANbus, a "Condition Algorithm" has been developed to estimate the date for the next oil replacement. The process is dynamic as based on the mileage travelled by each vehicle

Table 1. Test results, a selection of KPIs.

KPI	Units	NO EBSF_2	EBSF_2
Energy (fuel) consumption per vehicle and km	kJ/km	17000,00	17000,00
Operating costs per vehicle per 10,000 km (energy not included)	€/(vehicle × 10,000 km)	3.855,00	4.143,68
Energy costs per vehicle per 10,000 km (fuel, energy)	€/(vehicle × 10,000 km)	2.378,30	2.084,33
Costs of maintenance staff per vehicle per 10,000 km	€/(vehicle × 10,000 km)	454,00	543,00
Costs per spare parts purchase per vehicle per 10,000 km	€/(vehicle × 10,000 km)	1.150,00	1.130,33
Oil required per vehicle per 10,000 km	liters/(vehicle × 10,000 km)	10,25	6
Average maintenance time per vehicle per 10,000	h/(vehicle × 10,000 km)	12	12
Average daily time of vehicles at the depot (excluding maintenance)	h/day	14	14
Breakdowns per vehicle per 10,000 km	breakdown events/(vehicle × 10,000 km)	5,71	5,25
Total and amortization costs per vehicle per 10,000 km	€/(vehicle × 10,000 km)	4.687,59	3.981,19

where the PdM system is installed. Such collected values forecast the expected next oil replacement date and the mileage still ahead of this activity. Condition monitoring is the process of monitoring a parameter of condition in machinery, in order to identify a significant change which is indicative of a change in oil condition or a developing fault. To comply with this, the "Condition Algorithm" relies on the above mentioned oil quality sensors which directly develop a quality trend, and not just values of a given period, in absolute figures, to be further processed to trend forecast. More specifically, once a final quality limit has been determined (e.g. Sensor Loss = 18,8%), it is possible, by measuring the values at two different intervals of time, to calculate the unit percentage variation per month, Rate of Change or RoC, and consequently estimate the date for the oil substitution based on its surveyed quality and not according to regular scheduling. Moreover, when used in conjunction with the sensor data, a daily maximum RoC can be fixed (e.g. Sensor Loss = 2%) so that whenever sudden, exceeding values are detected, the supporting software (Fig. 1), prompted by the on-line sensors, issue an alert which enables immediately to check and stop (if need be) the vehicle. As a general example, for the 31/8/2017–14/9/2017 period the loss measured by the sensor was 9,67%; for the subsequent time period (15/9/2017–29/09/2017) the loss increased up to 10,83%. Consequently, the daily RoC percentage was 0,077. Processing these data on a regular basis, the forecast oil life was equivalent to 109 days, i.e. up to

January 10th 2018, thus rearranging the date for oil replacement operations. In the majority of applications, this PdM system highlights that the average life of oil can be significantly extended.

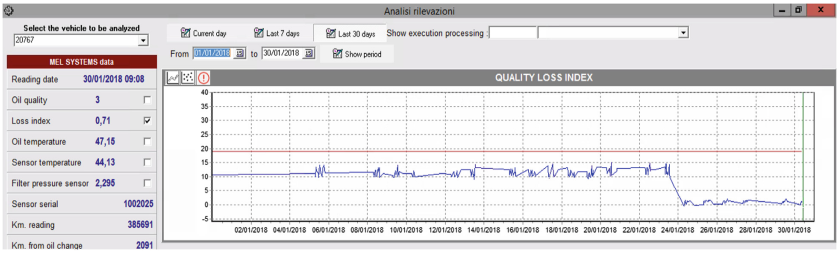

Fig. 1. A screenshot of the PdM software.

4.3 More Additional Benefits for the Environment

From these results of the Ravenna demonstrator, some conclusions on the possible environmental benefits in the fields of mitigating the toxicity of emissions can be drawn. The system, since reduces the content of harmful heavy metals by the oil filters, is able to decrease the overall toxicity of the emissions. To assess the extent of such a reduction, emissions were simulated by COPERT, for the two diesel-fueled vehicles equipped with the sensors and the oil filters. Initial results showed that a 5% reduction in heavy metals in the oil can achieve a 0.01% reduction in the CO_2 emissions related to lubricants. If upscaled to the whole fleet and regular urban operations, and assuming a more modest reduction of 10% of oil consumption (note that the reduction achieved thus far is higher, as reported in Table 1), then it is possible to save 0.56 tonnes of CO_2 emissions yearly.

5 Conclusions

One of the serious concerns for bus operators is how to cope with the high costs they expect to incur when introducing innovations into the service [8, 9]. Thus far, the reduction in spending on specific items, such as the costs of energy, or of the use of components, namely lubricants, are evidence that it is still possible to save and optimize the overall maintenance process, by innovating. One more lesson learnt in Ravenna is that this advanced IT-based PdM system proved to be efficient, reliable, and affordable, thus contributing to debunking the myth of the high costs associated with innovations. The system, thanks to the potential to forecast failures, contributes to improving the reliability of the service by reducing the amount of unexpected events. This also affects costs, as it is possible to save, thanks to the extension of the lubricant's lifetime: by the end of the test, it is expected that the frequency of oil changes on the vehicles equipped with filters will be even lower. From the environmental point of view, improved engine performance contributes to mitigating the harmfulness of CO_2

emissions from vehicles; at the same time, it diminishes the need to dispose of hazardous waste (fluid and/or solid), thanks to the potential to prolong the lifetime of spare parts and/or components. Affordability, therefore, is also supported by the environmental benefits achieved by upscaling the PdM system to the whole fleet and urban operations, as evidenced by the COPERT simulations and the assessment of the operator's potential to improve its local waste management process. Such environmental benefits actually represent, in the long run, an additional source of savings for the whole community.

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Electrification of Public Transport: Lessons from the ELIPTIC Project

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Abstract. ELIPTIC (2015–2018) is a project funded by the European Commission to develop 20 new concepts to demonstrate that the further take-up of electric vehicles can be done in a cost-efficient way, with tangible effects on the urban environment. The concepts are divided into three thematic pillars: (i) safe integration of electric buses using existing electric public transport infrastructure; (ii) innovative energy storage systems to increase operational efficiency, and (iii) multi-purpose use of electric public transport infrastructure.

ELIPTIC deploys such new concepts on eleven use cases across Europe and the outcomes are independently assessed according to a methodology specifically designed to deal with the two different types of case studies: demonstrators, assessed via a direct before-vs-during comparison of performance and feasibility studies, assessed via a dedicated SWOT analysis. ELIPTIC also relies on a User Forum involving public transport practitioners who assist in the development of the project. The assessment also includes a transferability exercise. The paper describes the ELIPTIC concepts under test and the assessment methodology, along with the outcomes from the assessment procedure, cross-revised with the feedback from the User Forum participants. To conclude, recommendations for the upscaling of electrification of public transit across Europe are drawn.

Keywords: Public transport · Electromobility · ELIPTIC

1 Introduction

Urban public transport is continuously under development, especially in the field of electrification. But the operators' overall perception of electrification seems to be affected by economic concerns [1–3], as electric vehicles are more expensive than the conventional "oil-based" ones. Operational conditions and characteristics strongly differ, according to the types of fuel or energy used, batteries, engines and operations [4]. Specific models to assess costs and benefits are required [5] to steer towards the most appropriate choices. Without these, decision-makers and operators are left to decide on the basis of the locally-perceived economic convenience, i.e. in terms of affordability of the innovation within the overall cost structure of urban bus operations,

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in which the expenditure for fuel may be not a decisive parameter. In ballpark figures, fuel expenses seldom exceed 15% of the total directly-operated expenditures [6, 7], and management efforts are generally directed to reduce labour costs, usually the higher percentage in the costs breakdown. It is not surprising, then, that fuel might be considered a minor item in the list of costs, and the need to switch towards more innovative propulsion systems not perceived as a priority, among some operators. At the same time research is a constant supporting source of evidence of benefits of cleaner fleets. In this, the European Commission has a major role in promoting research on more sustainable urban mobility policies; among the research projects in this field, a series of them are specifically dedicated to cleaner fleets, the last of which is ELIPTIC - Electrification of Public Transport In Cities (2015–2018), deploying different technical solutions to increase the electric option in public transport fleets.

2 Three Main Technological Pillars to Boost Electrification

A core goal within ELIPTIC is to highlight that the electrification of public transport and the optimization of the related infrastructure and rolling stock already operational, can become drivers to reduce costs and save energy. Evidence is collected via the development of innovative use concepts within 3 Thematic Pillars, each tested in one or more use cases across Europe (Table 1), as demonstrators (with operations tested in real urban scenarios), feasibility studies, or both . They include core technologies for the full up-take of electrification in Europe, more specifically:

- Pillar A - safe integration of electric buses using existing electric public transport infrastructure, through the assessment of potential replacement of diesel buses with trolley-hybrids or electric buses, with a focus on opportunity (re)charging operations (fast or overnight), exploiting tram or metro local infrastructure.
- Pillar B - innovative energy storage systems to increase operational efficiency, by the recovery of braking energy from light rail or tram networks, or the conversion of a dismissed rural line into a light rail one
- Pillar C - multi-purpose use of electric public transport infrastructure, via the possibility of supplying energy to other types of electric modes (commercial vehicles, passenger cars, taxis).

3 Evaluation of Results

Such variety of cases calls for specific requirements in the evaluation of results: cross-case comparability of results, and comprehensive analysis including more impact areas. To meet such requirements, the ELIPTIC assessment methodology for the use cases was aimed at evaluating the performance results achieved (the so-called “Impact Evaluation”, further described), by a series of more than 100 Key Performance Indicators – KPIs, divided into five main evaluation categories: *Operations*, *Energy*, *Economy*, *Environment* and *People*, each in turn subdivided into more impact areas.

Table 1. ELIPTIC Technological pillars and case studies.

ELIPTIC use cases	Pillar A Safe integration of electric buses using existing electric public transport infrastructure	Pillar B Innovative energy storage systems to increase operational efficiency	Pillar C Multi – purpose use of electric public transport infrastructure
Bremen (Germany)	Operation-optimized system of opportunity charging at bus depots[a/b]	Recuperation of braking energy from trams: Refurbishment of a flywheel energy storage system[b]	Extension of existing multimodal mobility hub stations[b]
London (United Kingdom)	Opportunity (re)charging of electric buses and/or plug-in hybrid buses (using metro infrastructure)[b]		Use of metro sub-station for (re)charging transport operator's electric utility vehicles and zero-emission taxis[a]
Barcelona (Spain)	Optimised braking energy recovery in light rail network[a]		Use of metro/tram infrastructure for recharging electric vehicles[b]
Brussels (Belgium)	Progressive electrification of hybrid bus network, using existing tram and metro infrastructure[b]	Optimised braking energy recovery in light rail network[b]	
Warsaw (Poland)	Use of /tram infrastructure for recharging electric - buses[a/b]		
Leipzig (Germany)	Opportunity (re)charging of electric buses (using tram infrastructure)[a]		Use of tram network sub-station for (re)charging electric vehicles[b]
Oberhausen (Germany)	Opportunity (re)charging of electric buses (via tram catenaries and sub-stations)[a]		Fast-charging stations for electric vehicles powered from the tram network[a]
Gdynia (Poland)	(a) Opportunity (re) charging of electric buses connecting the local agglomeration based on trolleybus infrastructure[a] (b) Replacing of diesel bus lines by extending trolleybus network with trolley-hybrids[a/b]	Optimised braking energy recovery in trolleybus network[b]	

(*continued*)

Table 1. (*continued*)

ELIPTIC use cases	Pillar A Safe integration of electric buses using existing electric public transport infrastructure	Pillar B Innovative energy storage systems to increase operational efficiency	Pillar C Multi – purpose use of electric public transport infrastructure
Eberswalde (Germany)	Replacing diesel bus lines by extending trolleybus network with trolley-hybrids (incl. automatic (de)wiring)[a]		
Szeged (Hungary)	Replacing diesel bus lines by extending trolleybus network with trolley-hybrids[a]		Multipurpose use of infrastructure for (re) charging trolley-hybrids and electric vehicles[b]
Lanciano (Italy)		Conversion of rural line into tram[b]	

[a]*Demonstrator*
[b]*Feasibility study*

The framework of such methodology was based on previous successful assessment procedures (developed within the CIVITAS Initiative and other EC-funded projects) and adapted to have the selected KPIs coherent with the three Pillars gist. Moreover, the methodology had to consider that along with the "conventional" demonstrators', also outcomes from the feasibility studies needed to be assessed. If for the former, a classical "before-vs-during" comparison of results can be performed, for the latter being no actual implementation, a different but comparable assessment is required.

The ELIPTIC evaluation process, therefore, relies on two specific tasks: the "Full Conventional Evaluation" for the use cases with demonstrators and the "Technical Viability Evaluation" for the use cases based on feasibility studies. Common to both is the creation of the "NO ELIPTIC", i.e. a reference scenario for each use case, built on the local KPIs values and additional information, to describe the situation prior to the ELIPTIC innovations. The "Full Conventional Evaluation" also includes the creation of an "ELIPTIC scenario" based on the performance of the ELIPTIC innovations, still built on via the local selection of KPIs. Such "before-vs-during" performance comparison also includes a Cost Benefit Analysis, to assess the cost effectiveness of the ELIPTIC measures. The "Technical Viability Evaluation" for the feasibility study use cases, banking on the NO-ELIPTIC scenario as a knowledge base, relies on the development of a SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis to highlight drivers, barriers and prospects of the ELIPTIC innovative concepts, thus enabling to stress elements of strength and weakness and potential opportunities and threats, useful to assess the possibility of a full uptake of the ELIPTIC innovations. Currently, results from the NO-ELIPTIC scenario are available for all the use cases, whereas the creation of the ELIPTIC scenario and the development of the SWOT analysis are in progress, as further reported.

A transferability exercise concludes the ELIPTIC assessment process; here a set of respondents (User Forum Members, high-profile experts and regular public transport users) are asked if they would like to theoretically transfer in their cities the innovation tested within ELIPTIC. The transferability methodology also relies on previous successful experiences developed in other EC-funded projects on the exploitation of advanced public transport systems and extensively reported elsewhere [8]. First results from a preliminary test including the possibility to transfer Pillar A innovation is further described.

3.1 The Role of the ELIPTIC User Forum

ELIPTIC also relies on a User Forum involving public transport practitioners, a group of 22 public transport operators and authorities from 15 countries have been selected on the basis of their substantial expertise and long-time experience in the sector. They assist in the development of the project by following the progress of the project and providing feedback on ELIPTIC activities, taking part in surveys about the state of electric public transport, and, participating in workshops, discussion and assessment exercises on major issues raised during the project. The mutual interplay between the ELIPTIC User Forum feedback and the ELIPTIC evaluation team provides a comprehensive analysis of the potential upscaling of electrification in Europe.

4 Core Performance to Upscale Electrification

For the ELIPTIC case studies, the "snapshot" resulting from the collection of the KPIs' NO-ELIPTIC values is the reference scenario. The recurrence in the selection of some KPIs can be interpreted as the ELIPTIC use cases general interest in the performance associated to such indicators, and the related impact areas as core fields to monitor in sight of the expected benefits due to the introduction of the ELIPTIC de-monstrators.

If the evaluation category *Operations* is considered, *Service* and *Supply* are the core impact areas; it is expected therefore that the demonstrators are likely to improve each related performance. It is also to notice the major relevance of indicators measuring the performance of *Driving staff* (man/vehicle per day), *Operation time* (monthly hours of service per vehicle) and *Service coverage* (travelled km divided by the number of operational vehicles per line, per day), all related to the *Supply* area. The resulting core KPI, i.e. *Service coverage* corroborates the relevance of performance associated to the consistency of the fleet to provide a reliable service. In the *Economy* Evaluation category, the interest is clearly on the basic expenditures (fuel and the costs for the use of the recharging infrastructure), with performance affecting the monthly *Fuel costs* ranked first. This can be interpreted in terms of expectations that introducing a change in the propulsion or in the energy provision might reduce costs.

Focusing on use cases within Pillar A, two more KPIs result of some importance, i.e. *Operating costs* (as the monthly expenditure due to staff, energy, maintenance, purchase of external goods and services, financial costs, depreciation, and taxes) and *Residual value of vehicles* (as the sale value of the vehicles after 15 years of operational lifetime). The former can be linked to the general concern to reduce the overall expenditures above remarked, but the latter is clearly related to uncertainties due to the introduction of new types of vehicles or technologies. That the introduction of a “novelty” might affect the cost structure is also highlighted by the relevance of KPIs *Electricity costs for vehicles* and *Investment for the network.* The main interest in the *Energy* Evaluation category is obviously linked to the KPI measuring *Electricity consumption*, whereas within the *Environment* Evaluation category, the focus is on the *Emissions* impact area, with major emphasis placed on those due to NOx and CO_2.

4.1 Potential and Barriers of Replacing Diesel Buses with Trolley Hybrids

The SWOT analysis is still in progress, but its first results on some Pillar A cases, where the replacement of old-generation diesel vehicles with hybrid trolleybuses is under study, highlights interesting directions in the acceptance of this technology. Strengths are represented by: (i) maintenance effort, assessed as lower compared to diesel buses, which require complex maintenance of the exhaust gas treatment system; (ii) the reliability of the technology, assumed to be equal to that of diesel buses; (iii) hybrid trolleybuses’ zero emission operation and higher energy efficiency, as compared to diesel and battery buses with opportunity charging, respectively.

A major barrier for the implementation of hybrid trolleybuses is the lack of full technological readiness. The traction battery as core component, although already available on the market, is not perceived as technologically ready, since necessary technical (e.g. capacity, size, operational temperature range) and consequently operational requirements (e.g. driving range, charging time) of the entire technology concept are not yet fulfilled in all scenarios. More critical still, the development of an automatic or semi-automatic wiring/de-wiring mechanism has not produced a satisfactory solution for all cases. In terms of operations, implementation efforts are similar to those for battery buses with opportunity charging. This strength, however, is coupled to the precondition that a trolleybus catenary system is already installed, which is the case in all the hybrid-trolleybus scenarios. Unfavorable modifications imposed by the implementation of hybrid trolleybuses, such as adjustments of the line routing to match catenaries, as well as related schedule changes and break-time extensions are considered as minor barriers for the concept viability. Another drawback is the currently low off-catenary driving range under extreme weather conditions.

On a financial basis, a major barrier for the concept viability arises from the investment criteria, which are not fully met in all cases. Critical in this regard are the higher procurement costs of new hybrid trolleybuses compared to diesel buses. Equipping conventional trolleybuses with additional batteries, however, represents a much lower initial cost. A potential threat arises, thus, from the scarce availability of funding for new vehicles and extended catenary infrastructure. Especially subsidies, an important funding source, are rarely available or not available at all. Finally, the extension and modification of the catenary system faces, in some cases, threats in regulation and acceptance. Required authorizations in this regard may be a slow and expensive process in some cities, thus hindering a fast implementation of the concept.

4.2 The ELIPTIC User Forum Contribution

The objective of the ELIPTIC User Forum has been to enlarge the assessment and validation of the ELIPTIC concepts and results, through independent expertise. For example, the User Forum members are called to respond to surveys about the state of electric public transport in their cities. This process is a major innovative contribution to advance the knowledge on the topic, as it merges practice with scientific know-how. For example, when asked about the driving forces to enhance an electric mobility strategy in their city, the highest priority for was found to be CO_2 reduction, emissions regulations, improving public image, and political pressures. User Forum members were also surveyed about the most relevant KPIs for integrating an electric public transport solution, which resulted to be: *Vehicle capital costs*, *Charging time*, *Durability of traction batteries*, *Electricity consumption* and *Operating costs*. According to the respondents, the criteria they would select when making a business case for integrating electric mobility are: overall availability, costs of components, improvement of air quality, integration into existing schedules and operations, and climate protection. Eventually, when asked for the strengths, weaknesses, opportunities and threats of their selected charging approaches, User Forum members identified the following items:

- Strength: Existing grid (the synergies of combined solution and no additional connection)
- Weakness: Training and skills (additional trainings and personnel qualification will be required)
- Opportunity: Costs and finance (cost reduction of new technology due to the power distribution infrastructure already being in place)
- Threat: Contracting and permits (contracts with the public transport operators are not adapted and long time periods to get licenses for civil works are needed).

4.3 First Results from the Transferability Exercise

This preliminary exercise investigated the different key drivers that would encourage the adoption of electric technology in cities across Europe and as well as the key barriers that hinder this procedure. Respondents were requested to participate in an online preliminary survey focused on Pillar A innovations, meant to fine tune the following full transferability exercise including all the pillars. A total of 58 respondents (transport operators and authorities, academicians and public transport users), from different parts of the world, took part in the exercise. More specifically they were asked whether they would theoretically transfer the hybrid trolleybuses (HTs) in the city to replace diesel buses and top five pros and cons are reported in Fig. 1, ranked per relevance

All the key drivers seem to be linked with the improvement of the environmental conditions, and mainly through the reduction of noise and emissions. On the other hand, the key barriers identified are mostly related to the technological and economical aspects of operating hybrid trolleybuses which could be attributed to its few applications since this technology is assessed as not yet mature enough. Due to low demand, its cost is still very high, which makes this technology as an option disregarded by some transport operators and authorities. In addition, lack of funds undoubtedly hampers its implementation as well.

Key Drivers	Points	Key Barriers	Points
HTs have superior air quality performance if compared to conventional buses (diesel buses and conventional trolleybuses)	95	Wiring/dewiring is not possible everywhere since wiring roofs cannot be installed everywhere	27
HTs are generally perceived as environmentally-friendly and innovative by the citizens	93	Initial capital costs are high	24
Road transport contributes one-fifth to the EU's total emissions; hence, HTs can help in reducing this	91	No funding is currently available to start HT operations; therefore, it is necessary to rely to the usual company financing program	24
HTs are less noisy if compared to conventional buses (diesel buses and conventional trolleybuses)	90	There are too many environmental constraints which limit the acceptance of HTs among the citizens (cut trees to accommodate wiring; landmarks preservation affects the length of no-wiring routes, etc.)	24
HTs promote sustainable transport and mobility	90	Catenaries are required	23
		In the end, the service is not that flexible (wiring is a constraint)	

Fig. 1. Top 5 recurring key drivers and barriers for all respondents

5 Conclusions

The ELIPTIC participants' concern for the economic aspects is clear: higher procurement costs of hybrid trolleybuses compared to diesel buses, relevance of operating and capital costs, lack of funding, just for mention some recurrently highlighted aspects, stress once again the need to make electrification more affordable for operators. One more recurring issue is that non-oil based traction systems are still not perceived as technologically ready (e.g. batteries for hybrid trolleybuses) or not meeting some specific supply requirements (for example, higher driving range). Under the infrastructural point of view, if the possibility to rely on the existing grid is hailed as a point of strength, at the same time changes to refurbish catenaries or operate substations are lamented as barriers for wider application of the electric option within the local transit supply. However, general willingness to switch to more environmentally-friendly propulsion systems is reiterated by the ELIPTIC participants as a way to fight climate changes. All of the above is more or less confirmed by the preliminary transferability exercise. The general perception of electrification seems, therefore, to be based on a mix of pros and cons, which are natural when engaging in innovation, but of no real help in a decision-making process on the possibility to include (more) electric modes in a local transit supply. This stresses the need to provide more and more advanced scientific knowledge to steer policy decisions towards the most suitable solutions.

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Conjoint Analysis for the Optimization of a Potential Flexible Transport Service (FTS) in the Region of Zagori, Greece

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Abstract. Flexible Transport Services (FTSs) are usually recommended as an appropriate solution for the service of travel needs of low demand areas and/or vulnerable people. The flexibility in terms of their design characteristics (e.g. booking procedure, pricing, Level of Service [LoS], etc.) raises the problem of their determination (levels) towards the creation of an optimum future Flexible Transport Services (FTS) ('product'). By applying the Choice Based Conjoint Analysis (CBCA) deriving from the marketing research discipline, we calculated the 'utility' value of the defined levels, the 'importance' values of their characteristics and the preferences' shares for selected alternative scenarios of services. As case study area, we chose the underserved traditional and historic settlements of the mountainous region of Zagori (Zagorochoria) in Greece, close to the city of Ioannina. A field research survey was conducted for the collection of data, both by personal interviews and self-completion online. The analysis of the results is demonstrating a positive acceptance of Flexible Transport Services (FTS) and is indicating travel cost as the most important characteristic.

Keywords: Choice Based Conjoint Analysis · Flexible Transport Services (FTS) · Demand responsive transport · Rural area · Mountainous area · Zagori

1 Introduction

Flexible Transport (or demand responsive transport systems) includes services that are flexible in terms of routes, timetables, vehicles' type, booking procedure, pricing and payment methods, etc. [1, 3]. Their flexibility and demand responsiveness, enabled by the new technologies, allow them to offer a viable travel solution, serving the modern and flexible urban lifestyle's travel patterns, as well as wherever and whenever conventional public transport cannot be sustained or doesn't even exist - in particular serving vulnerable and special population groups [6], off-peak time periods, or areas of low demand, e.g. mountainous, isolated, rural or island areas, new suburban areas. The investigation of the people's preferences towards the possible creation of a FTS and the estimation of the demand for using it, has been realised in the past by conducting stated-preferences' questionnaires surveys [1, 3, 5]. In the frame of this paper, we apply

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the conjoint analysis method [2, 4], in order to define the service's characteristics levels that could optimise as whole the transport service against respondents' preferences. We choose Zagorochoria, a complex of historic mountainous villages, close to the city of Ioannina, as our study area, in order to investigate the creation of a flexible transport service that will cover both residents' and tourists' travel needs.

2 The Area and the Existing Transport Services

2.1 Basic Characteristics of the Area

The villages of Zagori, the so-called 'Zagorochoria' comprise a distinct and special historic and cultural group of settlements that are located in the north-western edge of Pindos. The area can be divided in three basic geographical parts, the central, western and eastern Zagori. The villages are scattered in the whole area belongs to the Municipality of Zagori. According to the most recent census of 2011 the permanent population of the Municipality is 3.724 persons, while the De Facto population is 3.804 persons. The largest percentage of the population are people over 70 years old and the mean age is 52,4 years. Only 31% of the population are people that are working, while 41% is comprised of retired persons.

The villages of Zagori share a common shape, they are all monocentric. Around of their centres, a network of walking pathways is being developed. The road network of the Municipality consists of 416 km. In the eastern Zagori area, the road network's condition is rather bad, so the access through the Egnatia motorway is not so easy. The distances between each one of the settlements and the closest main city, Ioannina, are ranging from 24 to 80 km.

Several poles of historic and environmental interest are gathered in the area of Zagori. There are plenty of old stone-bridges, byzantine churches and monasteries scattered in Zagori area that are dated from 12^{th} until 19^{th} century. In every village at least one traditional and religious related fest ('panigyri') is usually taking place yearly. In the wider area of Zagori, there are also some bioreserves of international significance that have been included in the Natura 2000 network.

2.2 Travelling from Ioannina to Zagorochoria (and Vice-Versa)

There is a Public Transport service available connecting Ioannina with the Zagorochoria using coaches (the so-called local interurban 'KTEL'). There are also some coach lines connecting the settlements of Zagori themselves. The cost of the coach ticket is varying between 3€ and 5€. Based on the timetables, it can be concluded that the frequency of the services is extremely low (namely, a settlement is served once in a week and only in the working days). The coaches are departing from Ioannina in very early morning hours, while the return trips from the villages to the city begin after noon, making a daily trip ('aller-retour') to them rather difficult, if not impossible. Apparently, the similar case for the residents of villages is not feasible by definition, since their night stay at Ioannina is required in order to use the morning service.

There are also some fixed 'high school' bus (coach) services from the villages to Ioannina provided by KTEL, however none other user than the students is allowed to use these services. Due to the helical and curved road routes, a conventional car vehicle cannot speed very much, having to accelerate and slow down often, consuming this way more fuels than in usual circumstances and making the travel cost not affordable in some cases. In addition, elderly people that comprise the majority of population of the villages are not able to drive, so the only existing travel option except for the coach is the expensive taxi service, whose cost from a village to Ioannina city is ranging from 50 to 70 euros, according to the distance. It can be easily understood that the existing level of public transport service doesn't encourage tourism without the usage of private cars.

3 Survey's Method and Sample's Profile

3.1 Survey Method: Data Collection and Questionnaire Design

The questionnaire survey was conducted in spring of 2017 in thirteen certain and indicative settlements of the Municipality of Zagorochoria. Data was collected by both personal interviews of the settlements' residents and by disseminating an online questionnaire addressed to the residents of the city of Ioannina and the tourists/visitors of the area. The dissemination was realised through social media and by distributing at hotels a leaflet on which a QR code (link to the questionnaire) was shown. In total 300 questionnaires were gathered, out of which 170 by the settlements' residents (distributed according to the population of each village), 90 by the citizens of Ioannina and 40 by tourists. The structured questionnaire included certain sections of questions and in particular the following: (i) travel behaviour, e.g. number of trips to Ioannina weekly, preference towards usage of FTS, factors affective FTS mode choice, number of possible trips using FTS, etc.; (ii) socioeconomic data, e.g. residence, smartphone usage, gender, age, income, physical mobility status (e.g. disability, etc.) (see Fig. 1).

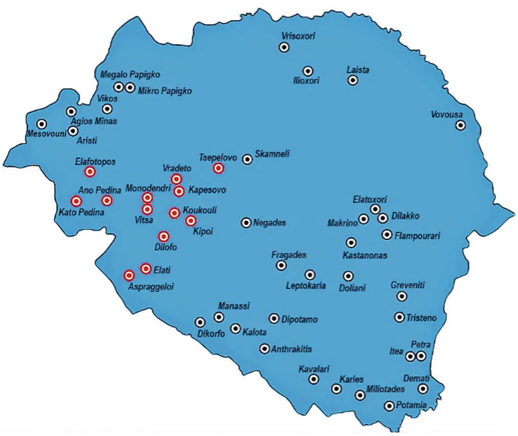

Fig. 1. Settlements in which the questionnaire survey by personal interviews took place.

3.2 Survey's Analysis Method

Choice Based Conjoint (CBC) Analysis method was chosen in order to fulfil the scope of the survey. For this reason, Sawtooth software was used. According to the CBC analysis, the respondent has to choose one out of the presented sets of attributes that suits better to his/her preferences. This is a statistical technique within the marketing research methods that enables the determination of a combination of limited number of attributes of one product or service that can have a major influence in the respondents' choices. Every time that a product or service has to be designed, its main distinct attributes (characteristics) have to be defined. According to the type of the attributes, certain levels for them could be determined. For the FTS under examination, we defined the following attributes and levels to be tested (see Table 1).

Table 1. Attributes and levels of a future FTS (DRT) serving Zagorochoria.

Attributes	Levels		
1. Booking of service	Booking one day in advance		Direct dial
2. Delay *(deviation of departure time from the desired departure time)*	None	1 h	2 h
3. Travel time *(increase compared to the travel time by car or taxi)*	**+0%**	**+25%**	**+50%**
4. Travel cost increase *(x bus ticket cost)*	**2**x cost	**3**x cost	**4**x cost

Concerning the suitable number of questions (tasks) to be addressed, the default suggestion of Sawtooth is 8 tasks with 3 different scenarios for each one of them (in total 24 different possible choices). In our exercise, we have withdrawn the scenarios ('prohibitions') that harm or favour solely either the passenger (direct dial; none delay; +0% compared to the travel time by car; 2x bus ticket cost) or the operator (Booking one day in advance; 2 h delay; +50% compared to the travel time by car; 4x bus ticket cost). By validating the formula below, we can check the appropriateness of the survey design towards the production of reliable results (8 tasks; 3 concepts per task and 3 stages at maximum → 8 > 6):

$$\frac{Number(Tasks) * Number(Concepts)}{Number\ of\ maximum\ level\ in\ attributes} \geq 6 \tag{1}$$

3.3 Respondents' Profile and Selected Survey's Descriptive Statistics

The sample is constituted of 300 people, equally distributed between men and women, out of which 170 are residents of the 13 villages, 90 residents of the main closest city of Ioannina and 40 visitors/tourists.

Concerning the age distribution of the sample, 23% refers to persons over 65 years old, who are mainly residents of Zagorochoria. 18% are people among 46 and 55 years old, while the ranges 56–65 y., 36–45 y. and 26–35 y. have 16% each. Age group of 19–25 y. reached 11% and concerns, mainly, students living in Ioannina. When respondents were asked which factor would influence more their choice to use the FTS or not, 48% (143) replied the travel cost, 40% (120) the travel time, 9% (28) the travel deviation in terms of the desired trip departure, and 3% (9) the booking procedure. 82% out of the total respondents stated that are smartphone users.

In the question related to the number of trips from Zagorochoria to Ioannina (and/or vice-versa) that respondents would make using FTS if such one would exist, 21 answered (0) trips, 14 replied (1) trip, 107 said '2 times' (namely 1 trip 'aller-retour'), 128 responded '4 times' (namely 2 trips 'aller-retour'), 27 people would use it 6 times (3 trips 'aller-retour'), 2 respondents would use it 8 times and only one for 10 times.

In particular, concerning the willingness of the Ioannina's tourists to visit Zagorochoria, 28 out of 40 expressed their intention to do it.

In the (see Table 2), entitled 'Utility values of the attributes' levels', detailed information is provided concerning the number of respondents' answers to questions related to: (i) income, (ii) occupation, (iii) residency (namely: Zarogorochoria, Ioannina, tourists/visitors), (iv) reduced mobility (disability or any other physical constrain/difficulty), (v) willingness to use FTS if there was such one, (vi) residency of people living in the Zagori area, (vii) transport mode(s) they use at least once during a week to travel from Zagorochoria to Ioannina (and vice-versa).

4 Results of Choice Based Conjoint Analysis

1. **Utility of levels**: The higher the utility is, the more desired the certain level of an attribute is. Levels with high utility have a greater positive impact on the products' choice by the respondents. The total sum of the attributes should be equal to zero. It should be pointed out that a negative value does not necessarily indicate that an attribute is not desired. In fact, this may be acceptable, but given all other attributes, the levels that have positive values will be more preferred (see Table 2).
2. **Importance index of the FTS attributes**: The CBC analysis using the Sawtooth software has resulted in the 'importance' index (%) of all attributes. Travel cost increase seems to be the most significant attribute according to the respondents' answers. The attribute of travel time increase, the 'time delay' (in relation to the desired trip departure) and the 'booking type of service' follow as less important. Slight differentiations can be observed among the values of importance resulted by the residents of the various settlements (villages) (see Table 3).
3. **Simulation**: Based on the utility's results of the attributes' levels and on the results of attributes' importance, a simulation was conducted concerning the reaction of the respondents against a possible creation of a DRT service. In the first scenario, three services with different optimal (=positive utility) combinations of levels were defined. The second scenario focuses more on the increase of travel cost, while the third one assumes higher travel time increase. The results, i.e. the share of preferences for all services of the three scenarios (9 in total), are presented in the following table. For example, in the 1st scenario, the first service is mostly preferred (64.5%) (see Table 4).

Table 2. Utility values of the attributes' levels.

Levels of attributes		No.	Booking of service		Time delay (in hours)			Time increase % compared to car			Cost increase (x bus ticket)		
			1 day in advance	Direct dial	0	1	2	+0	+25	+50	x2	x3	x4
	Total sample	300	−9.5	9.5	22.7	0.9	−23.6	76.5	−11.6	−64.9	91.4	10.6	−102
Transport mode used at least once weekly	Drivers	145	−8.5	8.5	21.4	2.6	−24.0	78.9	−12.2	−66.7	91.2	9.6	−100.8
	Non-drivers	155	−10.3	10.3	24.0	−0.8	−23.2	74.2	−11.1	−63.2	91.6	11.5	−103.1
	Cars' passengers	98	−11.1	11.1	27.2	−1.5	−25.7	73.0	−10.4	−62.6	90.7	7.9	−98.7
	Non cars' passengers	202	−8.7	8.7	20.6	2.0	−22.6	78.2	−12.2	−65.9	91.7	11.9	−103.6
	Bus users	53	−9.4	9.4	27.9	0.5	−28.4	73.4	−13.2	−60.2	87.4	16.6	−104.0
	Non bus users	247	−9.5	9.5	21.6	1.0	−22.6	77.1	−11.3	−65.8	92.3	9.3	−101.6
	Taxi user	1	−4.1	4.1	47.7	9.9	−57.5	67.7	−21.2	−46.6	77.0	18.1	−95.1
	Non taxi users	299	−9.5	9.5	22.6	0.8	−23.5	76.5	−11.6	−64.9	91.5	10.6	−102
	Motor drivers	27	−5.1	5.1	15.5	2.9	−18.4	99.0	−12.5	−86.5	85.7	−4.4	−81.3
	Non motor drivers	273	−9.5	9.5	23.4	0.7	−24.1	74.3	−11.5	−62.7	92.0	12.1	−104
	Motor passengers	9	−6.8	6.8	55.6	−1.3	−54.3	37.3	−4.9	−32.5	103.3	3.7	−107
	Non motor passengers	291	−9.7	9.7	21.7	0.9	−22.6	77.8	−11.8	−66.0	91.1	10.7	−101.8
Willingness to use	Definitely YES	57	−16.8	16.8	29.9	−1.3	−28.6	71.9	−10.2	−61.7	78.4	17.6	−96
	Probably YES	186	−7.6	7.6	21.8	2.7	−24.5	72.2	−11.3	−60.9	98.1	9.2	−107.3
	Probably NO	45	−8.0	8.0	21.5	−3.6	−18.0	91.7	−11.5	−80.2	82.0	8.6	−90.6
	Definitely NO	12	−9.5	9.5	7.5	−0.4	−7.1	107.6	−24.6	−83.0	84.6	6.7	−91.3
Residency	Zagorochoria	170	−9.9	9.9	22.7	−0.9	−21.8	72.9	−12.1	−60.8	90.8	20.4	−111.2
	Ioannina	90	−8.9	8.9	22.0	4.4	−26.4	80.2	−10.7	−69.4	93.8	−3.5	−90.3
	Visitors/tourists	40	−8.9	8.9	24.3	0.4	−24.7	83.5	−11.8	−71.7	88.7	0.5	−89.2
Villages of Zagori area where survey took place	Vradeto	4	−30.0	30.0	31.02	−0.75	−30.27	46.40	−11.86	−34.54	84.56	28.65	−113.21
	Elati village	8	−23.4	23.4	45.19	−8.36	−36.84	43.47	2.62	−46.09	70.24	41.05	−111.29
	Elafotopo	7	−24.2	24.2	63.54	−12.91	−50.63	59.69	−10.13	−49.56	55.17	17.78	−72.95
	Koukouli	6	−18.7	18.7	44.26	−2.31	−41.94	39.80	0.41	−40.22	91.57	13.14	−104.71
	Ano Pedina	21	−9.3	9.3	10.54	−1.87	−8.67	63.84	−12.38	−51.45	113.35	20.19	−133.55
	Kato Pedina	6	−10.2	10.2	38.75	−4.73	−34.02	82.10	−19.81	−62.30	73.76	14.86	−88.63
	Monodendri	20	−11.5	11.5	13.09	−2.58	−10.51	99.90	−12.69	−87.21	82.77	0.73	−83.51
	Tsepelovo	36	−7.6	7.6	19.34	3.42	−22.77	69.25	−14.64	−54.61	93.98	32.15	−125.53
	Asprangeloi	23	−5.9	5.9	13.6	−0.61	−12.99	88.31	−15.02	−73.30	99.76	0.45	−100.21
	Vitsa	15	−2.2	2.2	22.02	−1.24	−20.78	75.91	−19.12	−56.79	90.43	29.55	−119.98
	Dilofo	3	−3.0	3.0	54.98	−9.79	−45.18	58.99	−6.34	−52.65	74.37	35.03	−109.40
	Kapesovo	9	−3.0	3.0	23.39	2.99	−26.39	75.69	−4.00	−71.70	87.48	21.85	−109.33
	Kipoi	12	−4.3	4.3	19.70	4.47	−24.17	70.59	−9.05	−61.54	91.61	32.09	−123.70
Gender	Women	150	−10.2	10.2	23.8	0.0	−23.8	75.9	−11.3	−64.6	92.6	6.2	−98.8
	Men	150	−8.7	8.7	21.6	1.8	−23.4	77.1	−12.0	−65.1	90.2	15	−105.2
Occupation	Students	27	−18.7	18.7	40.8	0.9	−41.6	49.5	0.0	−49.6	91.7	−2.3	−89.4
	Employed	156	−8.3	8.3	21.7	1.5	−23.2	81.0	−13.1	−67.9	90.6	8.5	−99
	Retired	95	−10.0	10.0	20.5	−1.1	−19.5	73.8	−13.3	−60.6	92.7	20.2	−112.9
	Unemployed	22	−4.4	4.4	17.4	4.5	−21.9	88.7	−8.4	−80.3	91.5	−0.1	−91.4
Income	Income <500e.	116	−9.4	9.4	25.5	1.4	−26.9	71.4	−9.6	−61.8	92.1	11.4	−103.4
	Income <1000e.	116	−10.8	10.8	22.2	−0.1	−22.2	76.8	−11.2	−65.6	91.6	8.3	−100
	Income >1000e.	22	−9.4	9.4	15.0	1.8	−16.8	87.2	−14.3	−72.8	91.1	7.2	−98.3
	Unknown	46	−6.1	6.1	20.6	1.6	−22.2	83.4	−16.6	−66.9	89.5	15.8	−105.3
Status	Reduced mobility	40	−8.7	8.7	19.3	−2.1	−17.2	76.2	−13.9	−62.3	98.3	11.0	−109.3
	Not reduced mobility	260	−9.6	9.6	23.3	1.3	−24.6	76.5	−11.3	−65.2	90.4	10.5	−100.9

Table 3. Importance index of the FTS attributes.

Importance	Booking of sevice	Time delay	Time increase	Cost increase
Total sample	4.7%	11.6%	35.3%	48.4%
Drivers	4.3%	11.3%	36.4%	48%
Non-drivers	5.2%	11.8%	34.3%	48.7%
Cars' passengers	5.5%	13.2%	33.9%	47.3%
Non cars' passengers	4.3%	10.8%	36%	48.8%
Bus users	4.7%	14.1%	33.4%	47.8%
Non bus users	4.7%	11.0%	35.7%	48.5%
Taxi user	2.1%	26.3%	28.6%	43.0%
Non taxi users	4.7%	11.5%	35.4%	48.4%
Motor drivers	3.4%	8.5%	46.4%	41.8%
Non motor drivers	4.9%	11.9%	34.2%	49%
Motor passengers	2.5%	27.5%	17.5%	52.6%
Non motor passengers	4.8%	11.1%	36%	48.2%
Definitely YES (DRT usage)	10.2%	13.3%	34.1%	42.4%
Probably YES (DRT usage),	5.7%	10.8%	32.1%	51.4%
Probably NO (DRT usage)	4.9%	10.1%	42.8%	42.2%
Definitely NO (DRT usage)	4.5%	3.2%	47.8%	44.5%
Residents of Zagorochoria	4.9%	11.1%	33.4%	50.5%
Residents of Ioannina	4.5%	12.1%	37.4%	46.0%
Visitors/Tourists	4.5%	12.3%	38.8%	44.5%
Vradeto	15.00%	15.32%	20.23%	49.44%
Elati village	11.72%	20.51%	22.39%	45.38%
Elafotopo	12.11%	28.54%	27.31%	32.03%
Koukouli	9.37%	21.55%	20.01%	49.07%
Ano Pedina	4.65%	4.80%	28.82%	61.73%
Kato Pedina	5.11%	18.19%	36.10%	40.60%
Monodendri	5.75%	5.90%	46.78%	41.57%
Tsepelovo	3.78%	10.53%	30.97%	54.73%
Asprangeloi	2.96%	6.65%	40.40%	49.99%
Vitsa	3.52%	10.70%	33.17%	52.60%
Dilofo	1.11%	25.04%	27.91%	45.94%
Kapesovo	1.50%	12.44%	36.85%	49.20%
Kipoi	2.17%	10.97%	33.03%	53.83%
Women	5.1%	11.3%	35.5%	48.9%
Men	4.4%	11.9%	35.1%	47.8%
Students	10.8%	22.3%	24.1%	42.8%
Employed	4.7%	11.2%	36.7%	47.4%
Retired	5.2%	10.9%	34.1%	49.8%
Unemployed	3.2%	10.8%	42.0%	44.0%
Income <500e.	4.8%	13.2%	32.5%	49.5%

(*continued*)

Table 3. (*continued*)

Importance	Booking of sevice	Time delay	Time increase	Cost increase
Income <1000e.	5.7%	12.4%	33.4%	48.5%
Income >1000e.	5.6%	8.3%	40.0%	46.1%
Unknown	3.4%	10.1%	37.3%	49.2%
Reduced mobility	4.3%	9.1%	34.6%	51.9%
Not reduced mobility	4.8%	12.0%	35.4%	47.8%

Table 4. Combinations of attributes' levels of FTS for the simulation scenarios.

	Service	Booking of service	Time delay	Travel time increase	Travel cost increase	Share of preference
Scenario 1	1	Direct dial	1	0%	2x	64.5%
	2	Direct dial	0	0%	3x	28.5%
	3	Direct dial	1	0%	3x	7.1%
Scenario 2	1	1 day before	1	25%	3x	47.7%
	2	Direct dial	0	0%	4x	48.7%
	3	Direct dial	0	25%	4x	3.6%
Scenario 3	1	1 day before	1	25%	2x	45.7%
	2	Direct dial	1	25%	2x	24.4%
	3	Direct dial	0	50%	3x	29.9%

5 Conclusions

Any better and improved level of service of the existing public transport system serving the area of Zagorochoria would be welcomed and acceptable, since it could cover more effectively the travel needs of tourists and visitors, the vulnerable residents of the settlements, including mostly the elderly and students, as well as those employees that do not own a car or have not access to it. The suggested flexible transport service could tackle the barrier of low travel demand that cannot sustain a conventional service with fix route and timetable of high trips' frequency. At the same time, it can provide demand responsive services that can better address the random travel needs of people throughout a whole day. According to the analysis conducted, it was resulted that respondents give primarily emphasis on the travel cost and secondarily on the travel time. Moreover, the direct dial option is much more preferred than the alternative of booking one day in advance. The potential creation of the flexible transport service is appreciated positively almost by the majority of the respondents. The Conjoint Analysis used enabled us to identify the most preferred levels (values) for the most crucial service's attributes (characteristics) we had defined at the beginning. The next step of planning the service in real practice should consider these insights balancing them with the limitations and availability of the existing human and funding resources.

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Theoretical View on the Designing of Prototype of Business Model for a Transport Company

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Abstract. The term "business model" is associated with the "dot-com" firms and its exponential growth in late 90s, but in contemporary economics it is a transversal matter to any organization according to Osterwalder et al. (2004). There are many definitions of business model, but there is a common point in all of them: a business model is created to represent a certain service or product in order to create value to stakeholders and to be purchased by a company's customers. The aim of the paper is to define the theoretical way for building a successful business model, which can be useful for a passenger transport company. As a result of theoretical research the authors developed recommendations for building a prototype of business model for a company, which is operating in transport industry.

Keywords: Business model · Business model canvas · Strategy
Transport company

1 Introduction

In recent years, the business model has been the focus of substantial attention by both academics and practitioners. Michael Lewis refers to the phrase *business model* as "a term of art." [1]. The diversity of explanation of it causes some substantive obstacles for understanding the nature and elements of the model and finding what constitutes a good model. And also there is misunderstanding and confusion in terminology such as business model, strategy, business concept, revenue model, and economic model. Some academics and practitioners often use terminology interchangeably. The *aim* of the paper is to define the theoretical way of building successful business model and to apply it for designing of prototype of a business model, which can be useful for a transport company.

Research Methods
During the preparation of the given paper a systematic literature review as a research method has been used and three research questions were formulated. This involves collecting published articles related to a topic, analyzing data and reporting what can be learned through considering these collectively. The aim of literature review is to concretely examine the literature that has accumulated in regard to a concept of business model.

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Research subject is a prototype of business model.

Research object is a set of literature in the fields of strategic management and corporate governance.

The theoretical prototype of business model is developed based on the study of contemporary scientific and economic literature in the field of strategic management and corporate governance. The following resources were used in this paper: journal databases, subject specific professional websites, and books. The following criteria for searching information were used: relevant to the topic, peer reviewed, and taken from well-known scientific databases.

The paper focuses on studying the following issues:

– The nature of a business model;
– Strategy and business model: how they are connected?
– How to build successful business model for a passenger transport company?

As a result of literature review the authors developed recommendations for building a business model for a company which is operating in transport industry.

2 The Nature of “Business Model”

There is no generally accepted definition of the “business model” in overall. It is described in different ways with similar characteristics. The diversity of explanation of it causes some substantive obstacles for understanding the nature and elements of the model and finding what constitutes a good model. And also, there is misunderstanding and confusion in terminology such as business model, strategy, business concept, revenue model, and economic model. According to Morris, Schindehutteb, and Allen a business model can be identified as economic, operational and strategic, that have special set of decision variables. In the operational type, the model reflects itself as an architectural configuration. In this type the focus is on design of infrastructure and internal processes that help the company to create value. The authors wrote: “business models are a brief idea of how the interconnected complex solutions in the field of venture strategy, architecture, and economy are determined to create sustainable and competitive advantage in certain markets” [2].

Therefore, Stewart and Zhao [3] defined the model as a “in what way company make money and takes its profit stream over time”. In the opinion of Mayo and Brown [4] business model is associated with design of the main interlinked system for creating and sustaining competitive business. Definition of the strategic type of business model shows overall direction on the company’s market position, interactions in the organization and opportunities of growth [2]. In the opinion of Slywotsky [5] a business model is “the way how the company select its customer, defines and variate its offerings, defines the tasks which do itself and which it outsource, puts its resources, goes to the market, make tools for its customers and make a profit”.

By the opinion of Teece [6] business models have been related to trading and economic behavior since pre-classical times. The business model became very important when Internet appeared in the 1990s, and it has been gathering momentum since then. Zott, Amit and Massa noted that “from that time, the definition of the business model have been researched by huge number of scholars and business practitioners, as written in some publications, books, articles, and in book chapters in the business press and scientific journals" [7]. American researchers Johnson, Christensen and Kagermann [8] described that the business model includes 4 (four) interlocking elements that, taken together, built and bring value:

(1) *Customer value proposition* (CVP) – is most essential. It can be said that successful company in the one, which can create value for customers – it is, the approach to help customers to absorb an essential job done.
(2) The second one is *Profit formula*. This is the formula which demonstrates and characterizes how the company makes value for itself with providing benefit and value for the customer.
(3) The third one is *Key resources*. For this part the researchers added the main resources of the company 'assets', which are people, equipment, products, channels, technology, facilities and brand required to deliver the value proposition to the targeted customer.
(4) The last one is *Key processes*. All prosperous firms have operational and managerial processes that enable them to bring value in a way they can successfully repeat and develop in scale.

In overall these 4 (four) elements can be presented as each of building blocks of any business. The first element 'customer value proposition' and the second 'profit formula' describe value for the company and the customer, accordingly; the third 'key resources' and the fourth 'key processes' determine how that value will be passed to both the company and the customer. Maggreta [9] noted that the great strength of business model as a "plan tool" is its holistic perspective and she presented a business model as "a scientific method starting with hypothesis which is tested".

In order to understand better the business model and its role, it is essential to understand how it is situated in the firm. According to the analysis of the researcher Osterwalder [10] the business model is a conceptualization of the money earning logic of a firm. Here the place where conceptually explained business model come into play. In the opinion of Fensel, using ontological approach for business modelling, one can create a shared and common understanding of what the firm has to do in order to earn money and simplify communication between people and heterogeneous and widely spread application systems [11].

The business model and the triangle are the target for continuous forces. Among other these influences: competitive forces, customer demand, legal environment, technological change and social environment. The main person who will be duty for these external forces by responding is the manager's role in designing or adapting a firm's business model. Once it can be seen that how a business model applies to where it is worked and where it can be fit within that model it will be able to use the same powerful way of thinking to define, sharpen, and grow of business. And as a company progresses, it should use strategies to adjust its model and adapt to changing times.

Based on the analysis of the nature of business model, the following research questions were developed in this paper:

RQ1: What is the successful business model?

RQ2: How to re-interpret the strategy through the lens of the business model?
RQ3: What procedures should be done to build successful business model?

3 Strategy and Business Model: How They Are Connected?

Mintzberg and Lampel [12] described the strategy as an elephant of which we can only grab hold of some part or other. Different views include that strategy is about providing a company vision, designing an organization that achieves a fit between internal strengths and weaknesses and external threats and opportunities [13], positioning the company in the market, defining a set of goals and objectives [14], the steps to achieve them and the way to measure them [15]. Osterwalder [16] is his dissertation argued that the business model and strategy talk about similar issues but on a different business layer. He explained business model as the strategy's implementation into a conceptual blueprint of the company's money earning logic. In other words the vision of the company and its strategy are translated into value propositions, customer relations and value networks (Fig. 1).

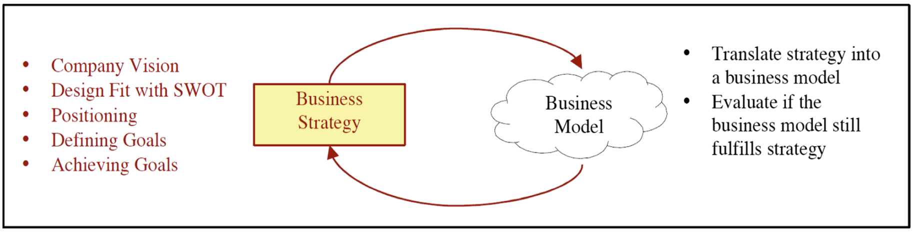

Fig. 1. When business model translates into business strategy [16].

Moreover, some authors debate the using of term 'business strategy' and 'business model' as they are used interchangeably [9]. Often they use it to refer to everything they believe gives them a competitive advantage [17]. Yet, a review of the literature shows that the view that business models and strategy are linked but distinct is more common [18]. A practical distinction describes business models as a system that shows how the pieces of a business fit together, while strategy also includes competition [19]. In general, however, business model literature seems to fit the former definition better, because most of it focuses on describing the elements and relationships that outline how a company creates and markets value. Strategy and business model are interlinked with each other and in each case it should be checked whether business model fulfill the strategy. Otherwise, model will not meet expected outcomes.

4 The Business Model Canvas: The Way for Making Money

According to Osterwalder, Pigneur and Tucci [16] a business model can be explained through 9 (nine) basic building blocks that illustrate "the logic how the firm makes money". Osterwalder developed what is arguably the most comprehensive template on which to construct "assumptions or hypotheses", as he wrote "a business model is really a set of assumptions or hypothesis" [10]. His nine-part "business model canvas" is essentially an organized way to lay out a company's assumptions about all elements of its activities. They are:

Customer Segments: Customers are the heart of any business model. There are various types of customer segments, here are described some examples: mass market; niche market; segmented, diversified market, etc.)
Value Propositions: Customization: making services and products for the individual needs of customers are also creating value. It's necessary to describe not the goods themselves, but exactly, what they do, what problem they solve.
Channels: It is important to take into account absolutely all channels: first contact, conviction, delivery, after-sales service, advertising, etc.
Customer Relationships: This building block portrays the sorts of connections an organization sets up with particular client sections.
Revenue Streams: This block represents the money an organization creates from every client segment. An organization must ask itself, for what value every client segment is genuinely eager to pay?
Key Resources: This block describes the most essential resources (assets) required to make a business model work: physical, natural, financial, intellectual, human). These assets enable an enterprise to make and offer a value proposition, achieve markets, keep up associations with customer segments, and earn revenue.
Key Activities: Like key resources, they are required to make and offer a value proposition, achieve markets, keep up customer relationships, and gain revenue.
Key Partnerships: It describes the system of suppliers and partners that make the business model work.
Cost Structure: It shows all costs acquired to work a business model. This building block describes what the most vital expenses brought while working under a specific business model.

5 Building Prototype of Business Model

Building prototype of business model involves relentless inquiry best the way to create the new, discover the unexplored, or achieve the functional. Successful innovations require a deep understanding of customers, including the environment, daily routines, concerns and aspirations. Mapping the existing business model is one thing, designing another innovative business model. Ideas for business model innovation can come from everywhere, and each of the nine business models building blocks can be a starting point. Transforming of business model innovations affect multiple building blocks. It can be distinguished four the epicenter of the business model innovation: Resource-driven, Offer-driven, Customer-driven, and Finance driven [16]. Basing on literature review describing the ways of building a prototype of business model the authors presented business model which can be implemented for a transport company (Fig. 2). Brief explanation of each of 9 (nine) building blocks of this prototype of business model have been made:

<table>
<tr>
<td rowspan="2">Key partners:
-commercial agreements with partners, or make joint venture.
-agreement with transport operators, terminal management, local authorities</td>
<td>Key activities:
-improving comfort level of the terminal.
-special tariff for routes.
-coordination of schedules
-reduction of transfer distance.</td>
<td rowspan="2">Value proposition:
-improving the quality of transportation services for passengers by making intermodality of transportation for the service and reducing price.</td>
<td>Customer relationship:
-discounts.
-rewarding system.
-restructuring spaces in the terminal.</td>
<td rowspan="2">Customer segment:
-All.</td>
</tr>
<tr>
<td>Key resources:
-infrastructure of the terminal.
-knowledge of market split.</td>
<td>Channels:
-information and sales desk in the terminal.
-Internet based service and communication channels.</td>
</tr>
<tr>
<td colspan="3">Cost structure:
-related with restructuring the terminal
-related with integration of new services</td>
<td colspan="2">Revenue streams:
-advertisement
-tickets
-renting facilities
-parking place
-subsidies</td>
</tr>
</table>

Fig. 2. Prototype of business model for a passenger transport company

(1) Key partners – it is recommended to establish agreement with partners, transport operators, terminal management and local authorities.
(2) Key activities – are, improving comfort level as transport experience of the passengers will effect on operation.
(3) Key resources – these are infrastructure of the terminal and knowledge of market split.
(4) Value proposition – is, improving the quality of transportation services for passengers by making intermodality of transportation for the service and reducing price.
(5) Customer relationship – the prototype of business model is the way of attraction and retaining of the passengers.
(6) Channels – it depends on customer which way is more comfortable, and it is better to have information and sales desk in the terminal.

(7) Customer segments – all type of customer should be included for diversification of services.
(8) Cost structure – the main one will be expenditure to provision of transport services and integration of new one.
(9) Revenue streams – revenue can be earned from advertisement of products and services in the terminal, selling tickets, renting facilities, for instance, shops and parking places; in some cases – receiving subsidies from government.

From authors' point of view these criteria are specified in building blocks will help company to achieve its strategic goals. But, it should not be forgotten that strategy differs in each type of company and it should be reflected in the business model.

6 Conclusions

Basing on the results obtained in the given research, the following most general conclusions can be made in accordance with the formulated research questions (RQ1 and RQ2) in the Introduction section.

1. Successful business model shows more attractive and successful way than the existing alternatives. It can make more value for the discrete group of customers. Or can be the alternative which destroys existing and will be the standard for the future generation of entrepreneurs to beat.
2. It is assumed that strategy should be translated into a business model. It should be evaluated whether the business model still fulfills the strategy. However, the business strategy defines the company's vision, positioning, goals and ways of achieving them are the main points the company should decide on. Developing a good understanding of the organization's strategy environment helps to conceive stronger, more competitive business models.
3. Ideas on creation of successful business model innovation can come from everywhere, and each of the nine business models' building blocks can be a starting point. Transforming of business model innovations affect multiple building blocks. Four types of the business model innovation can be distinguished: Resource-driven, Offer-driven, Customer-driven, and Finance driven. These ways of building business model are the most productive and which company should implement if it is willing to win the business competition or set its roots in the market.

Basing on the above mentioned conclusions, the authors believe that the following recommendations could be useful to managers and owners of transport companies to build new business models and to improve the existing business models determined by the enterprise management. Recommendations reflect what should be done for building successful business model (RQ3). In order to build successful business model, it is necessary:

(1) To choose the type of building blocks which are: Resource-driven, Offer-driven, Customer-driven, and Finance driven.
(2) To design a business model canvas using building blocks.

(3) Specific criteria for transport industry should be developed, for-example: schedule coordination; existence of short distance services; tariff integration; joint marketing initiatives; collaboration with transport service agents; and barriers: logical, physical and institutional.
(4) Prototype of business model should be built basing on the above mentioned 9 (nine) building blocks: customer relationship, value proposition, key partners, key recourses, key activities, channels, customer segments, cost structure, revenue streams.

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Investigating Potential Synergies Among Social Entrepreneurship and Public Transport Through Experts' Consultation in Greece

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Abstract. Not all of the travel needs are adequately covered by the existing commercially oriented Public Transport (PT) services, while public funding is gradually being reduced. At the same time, disruptive global societal and market trends create new social challenges at local level. By activating the catalyst group of social entrepreneurs, new innovative solutions, with high social impact and value, could be applied filling the existing gaps in uncovered needs. At the moment, Social Entrepreneurship has not really been leveraged in PT in Greece, despite its potential. The involvement of the social entrepreneurs and social innovators towards the creation of more attractive, inclusive and sustainable PT related service for all, comprises an emerging and crucial topic. This was explored in the Greek national context by consulting professionals and experts coming from the mobility sector and social economy field, in the frame of an interactive, participatory workshop. The aim of this structured interaction that was based on the methods derived from collective innovation and focus group processes, was (i) the identification of potential synergies among Social Entrepreneurs and Public Transport, and (ii) the identification of potential barriers that such initiatives may face. Indeed, participants explored the fields where social entrepreneurs could be involved for the provision or the improvement of PT services and came up with some policy recommendations to overcome the identified barriers.

Keywords: Social entrepreneurship · Social innovation · Social economy Collective innovation · Public transport · Urban mobility

1 Introduction

Nowadays, PT sector faces a lot of challenges. Not all of the travel needs are adequately covered by the existing commercially oriented PT services, people are being more socially and environmentally concerned, and the available public funding is gradually being reduced. Thus, the involvement of the Social Entrepreneurs (SE) and the introduction of Social Innovations (SI) in PT, towards the creation of more attractive, inclusive and sustainable services for all, becomes an emerging and crucial topic. CIPTEC ("Collective Innovation for Public Transport in European Cities"), a CIVITAS/H2020 research project, aiming to bring new thinking and innovative

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solutions for PT, explored, among others, the potential of filling in the gap between supply and demand in PT sector, by activating the stakeholders' groups of SE and SI. This investigation consists of both desk and qualitative field research. The latter includes experts' consultation through interactive participatory workshops based on methods derived from social sciences, in particular focus group and collective innovation processes. In the frame of the CIPTEC SE/SI activities, four workshops were organised at local/national context (NL, IT, GE, EL) and one recap workshop at European level. The aim of this paper is to present the methodology, approach and results of the Greek local SE/SI workshop, which focused on exploring synergies potential among SE/SI and PT, identifying barriers that such initiatives may face, and suggesting policy recommendations on how these could be overcome.

2 Transport, Social Innovation and Social Entrepreneurship

Social Innovations are defined as *"new ideas (products, services or models) that meet social needs, create social relationships and form new collaborations"* [1]. Normally, SI go through four steps, as they start as early-stage ideas and afterwards they may be piloted of prototyped. If the above process is proved successful, the new model will be introduced into the implementation stage, as a new policy or venture. The final stage is the scaling of this new approach in order to achieve greater real impact [2].

Nowadays, global societal and market trends create new social challenges both at local and European level. Transport and mobility are related with two main societal challenges: (i) the increasing need to serve people's accessibility to workplaces, health, education and cultural places, especially of those who live in isolated areas with lack of transport modes or those who have mental and/or physical disabilities, and (ii) the need to minimize pollution and negative impacts of traffic congestion within the metropolitan areas and larger cities [3]. In order to tackle these challenges, SI could comprise a key factor. Several practical fields for introducing SI in transport and mobility, which focus mainly on neighborhood/city or regional level, have been indicated [3]. These SI initiatives were grouped into the three categories, in particular: (i) Inclusiveness and access dimension (e.g. increased access to basic needs, people with reduced mobility), (ii) Greening mobility and transport (e.g. usership, electric mobility and multimodality) and (iii) Slow transportation (e.g. cycling, walking).

The social enterprise is defined as *"an operator in the social economy whose main objective is to have a social impact rather than make a profit for its owners or shareholders. It operates by providing goods and services for the market in an entrepreneurial and innovative fashion and uses its profits primarily to achieve social objectives. It is managed in an open and responsible manner and, in particular, involves employees, consumers and stakeholders affected by its commercial activities"* [4].

Apart from the investigation of SI initiatives, PT stakeholders could activate the group of Social Entrepreneurs in order to cover the unmet citizens' needs by providing services with high social value and impact. The consideration and adoption of SI and SE concepts can contribute in addressing effectively social and economic challenges.

3 Current Situation of Social Entrepreneurship, Social Innovation and Public Transport in Greece

According to the Greek legislation, the following institutionalized forms of Social Enterprise exist: (i) Women agro-tourist cooperatives [5], (ii) Limited Liability Social Cooperatives (Koinonikos Synetairismos Periorismenis Efthynis [KoiSPE] [6], which provides a framework to support work integration of people with mental health problems, and (iii) Social Cooperative Enterprises [Koinoniki Synetairistiki Epicheirisi (KoinSEp)] [7], which is distinguished into three types according to its special purpose, in particular (1) Inclusion, (2) Social Care, and (3) Collective/Productive purposes. The few existing KoinSEp Social Enterprises (530 out of which 30–50% are being active [8]) are trying mainly to address the basic needs of living, such as: accommodation, food, clothing, medical care for vulnerable groups [8]. Although the use of term SE is rapidly being increased, the business fields of SE are not so widespread, compared to the traditional entrepreneurship. The tendency of the wider public to interpret SE as a part of the non-profit and/or voluntary sector, focusing only on work integration for disadvantaged people is one of the various reasons.

Public Transport is usually defined as passengers' transport systems and services, which are under the control of public or private providers. These are operating with vehicles, typically with a high capacity (large number of seats), which are shared by passengers. In Greece, the provision of PT services is rigid, as many and significant restrictions are placed, concerning several aspects of the business service provision. Not only the PT sector is regulated by Public and Private monopolies throughout the whole country, but there are also limitations set by national Laws for the determination of routes, timetables, vehicles, payment systems, pricing, etc. Taxi services market is also rather regulated. These restrictions limit the entering of new players, such as the Social Entrepreneurs in the transport services market.

4 Consulting Greek Experts Through an Interactive Workshop on the Potential of Social Entrepreneurship and Social Innovation in Public Transport

4.1 Defining the Workshop's Objective and Recruiting Experts

Although the concept and business sector of SE in Greece is gradually being developed, its application in the field of PT and transport in general has not been examined both at research and business level. A participatory workshop with a special focus both on SE and PT was organised for the first time, in October 2017, at Thessaloniki Greece, within CIPTEC project. The Greek local SE/SI participatory workshop was aiming at the identification of potential synergies among SE and SI and the PT sector. Participants were asked to explore how Social Entrepreneurs could be involved in the provision or the improvement of PT services (regardless the regulation limitations imposed in the Public Transport market by the current institutional framework), and to identify potential and crucial barriers that such initiatives may face [9].

For this purpose, the key stakeholders (actors/bodies) involved in the provision of mobility services, the promotion of the social entrepreneurship and the creation of social innovations in Greece, were listed. In addition, Greek individuals that are scholars and experts on the fields of SE/SI or/and professionals with real business involvement, were also identified. The recruitment of workshop's participants was realised by addressing invitations to these relevant bodies and persons coming from both the social economy and mobility field: in particular, Social Innovators acting in the transport sector, researchers in the fields of SE/SI, Mobility experts/professionals and representatives of Public Transport Operator and Authority, representatives of SE, and representatives of associations which promote the SE/SI. This way, the interaction between the two fields, mobility and the social economy, was possible.

4.2 Structure and Methods of the Participatory Workshop

The methodological approach used for the workshop was mainly based on the "focus group", which has been used over the past century for several purposes, especially in social sciences [10], as well as on collective innovation methods (brainstorming, Dot-voting). In contrast to group interviews method, group's interaction is one the main parts of the "focus group" method [11]. In the beginning of the workshop, participants were divided into three heterogeneous groups, taking into account their gender, professional and educational background. They introduced themselves presenting the activities of the organisations they are coming from and exchanged briefly personal views and experiences on the workshop's topic. The workshop was composed by two sessions, organised in the form of **open discussion tables**. In each one of them, two members of the organizing team were acting as facilitator of the table discussion and as rapporteur, keeping notes and reporting any interesting and useful information and idea expressed by the participants. Both roles are quite important, as the latter one reports the whole session and the first one balances the time allocated to the participants, so that all are given the floor to speak. During the **first session**, participants were asked to identify **potential synergies among SE and PT**, focusing mainly on: (i) the mobility of vulnerable population groups (e.g. PT buddies, "last mile" transport, etc.), (ii) information provision to vulnerable social population groups, (iii) mobility 'for all' (overcoming the 'transport poverty'), and (iv) environmental protection.

In the **second session**, the composition of the groups was partially re-arranged. A core group of 3-4 participants remained in their seats, ensuring the continuity of the discussion already conducted in the initial groups. Participants, as members of their new groups, were asked to identify the **most crucial barriers** for the development of SI and the launching of Social Enterprises within PT, addressing the challenges that were identified in the previous session. Afterwards, they were also asked to formulate a framework of key suggestions on policy measures that could favour the entering of SE in the PT sector in Greece. Finally, after the recap presentation of all sub-groups' workshop's outcomes, during a plenary discussion, participants evaluated them (the outcomes) in order to reveal the most interesting and crucial ones.

Both sessions were implemented by using the "**brainstorming**" method, which stimulates creative thinking and helps to quickly gather a large number of ideas from the groups. By using this method participants of each sub-group had enough time to think on each specific issue/question, discuss and report views on a big white piece of paper [12]. In addition, for the evaluation of the workshop's outcomes, the "**Dot voting**" method was used. This is a well-established method used to allow delegates to state their preferences with stickers [9].

4.3 Workshop's Results

The results of the two workshop's sessions are presented in the Tables below. Table 1 includes the SE and SI concepts that were co-created during the first session of the workshop. Particular emphasis was placed on the needs of vulnerable groups with regards to the use of public transport, mainly concerning people with physical and mental disabilities, children and prisoners. One of the leading SI concepts is about leveraging the experience of social entrepreneurs to implement complementary mobility services to be run in parallel with the mainstream ones (e.g. "walking bus").

Table 1. Co-created SE & SI concepts.

No.	Co-created SE & SI concepts
1.	First-Aid educational programme (training seminar) in order people/passengers to be prepared to encounter any emergency situation during a trip by Public Transport
2.	Improved access to health-care services and hospitals by special transport services, as some hospitals and health centers in Greece are located in the suburbs of the cities and are poorly served by frequent PT services
3.	Employing persons of local ghetto (areas) communities or people that are related with them, as drivers in certain PT social enterprises. The whole initiative will help the improvement of social inclusion of these areas and their citizens
4.	"Last mile" solutions in order to be easier for the passengers to reach their final destination without using their private car
5.	Gamification applications for improving travelling experience by PT services
6.	Demand responsive transport for special cases, which is a special type of transport, e.g. for those who want to transfer, for instance, a large package or a pet which are not allowed to be transferred by the conventional PT vehicles
7.	'Walking buses' for reducing private car use – "walking school bus" is a group of children walking to school with one or more adults (usually parents)
8.	"Hot-spot" with lockers for couriers on the buses or at the stations for transferring small packages
9.	"Ticket on hold", in which a person could pay for more than one ticket, and the amount over the ticket price will be used for the travelling of people who can't afford paying for the fare
10.	'Travel buddies' for people with mental or physical disabilities by giving incentives such as "a free ride", "lower ticket price", etc.
11.	Electric vehicles for temporary use, for people with disabilities, elderly, pregnant women, at specific large areas e.g. airport, ports, parks, shopping centers etc.
12.	Community shares, a model that was applied in UK, where the community is a shareholder of a social enterprise in several fields (e.g. awareness raising, supporting services for the elderly or people with disabilities, transport services)

Table 2 indicates the most crucial barriers identified by the participants, in the case of developing Social Innovations or/and launching Social Enterprises for tackling the challenges identified in the previous session.

Table 2. Identified barriers for the introduction of SE & SI in the PT sector.

No	Identified barriers for the introduction of SE & SI in the PT sector
1.	The existing regulatory framework for PT in Greece
2.	Limited access to finance (bank loans, etc.)
3.	Traditional view of social entrepreneurship sector in Greece, as part of the voluntary sector
4.	Absence of a 'social experimentation' culture
5.	People unawareness about the social entrepreneurship sector and its potential to tackle societal challenges
6.	Lack of lobbying by the local communities in large scale, so that their mobility and accessibility needs to be acknowledged
7.	Absence of high concentration of ownership (low number of taxi vehicles per owner)
8.	Problems related to the economic sustainability of the municipal transport services
9.	Inherent weakness of the Community Transport's legal entity form in UK
10.	Lack of institutions and agencies supporting the establishment of new social enterprises
11.	Low existing and perceived level of safety and security for the adoption of the proposed type of courier transfers (see "Hot-spot", as indicated in concept 8 of the Table 2)
12.	Experimenting with a new initiative in practice and improving it gradually in the continue, is not so popular compared to the detailed planning and designing
13.	Incomplete tax policy and delays in the launching phase of a social enterprise due to bureaucracy
14.	Lack of networking and collaboration among social enterprises

Finally, Table 3 includes the key suggestions on policy measures that could favour the entering of SE in the PT sector in Greece and the development of relevant SI. The implementation of radical changes in the current Greek tax legislation and the encouragement of a deregulation of the Greek transport market to favour the entry of new social businesses were mainly highlighted by the participants.

5 Discussion and Conclusions

In Greece, Social Entrepreneurs have not included yet PT into their fields of interest. Among the reasons for that, it seems to be the current Greek legislation on transport market, which is characterised by monopolies and restrictions in the PT operation and taxi services. Moreover, the main concern of the social entrepreneurs in Greece in the last few years was to provide basic services, covering by priority the key people's needs for living.

The local participatory workshop of experts, organised in Thessaloniki, comprises the first attempt in Greece to explore the prospects of creating synergies among PT and the social entrepreneurship field. Individuals having scientific and/or professional

Table 3. Identified policy recommendations.

No	Identified policy recommendations
1.	**Changes in tax policy/legislation:** As it was mentioned in the barriers' table, the current tax policy/legislation in Greece does not provide adequate incentives to the entrepreneurs in order to adopt a special social enterprise legal form. As a consequence, participants proposed changes in the tax policy/legislation for encouraging new social enterprises to be developed and enter into the market
2.	**Deregulate Greek Transport market:** The abolition of monopoly and the restrictions in the PT operation and the taxi services market will allow and enhance the entering of new players, such as the social enterprises in the PT and taxi sectors. Furthermore, participants highlighted the need of harmonizing the Greek legislation with the European Directives (and Regulations, e.g. Reg. 1370/2007) as soon as possible, focusing especially on the authorization of the circulation of Electrically Power Assisted Cycles (EPAC). It was also claimed that the newly created embryotic eco-system of social entrepreneurship could lobby and push towards the liberalization or/and deregulation of the transport market, at least with regards to the services provision to certain vulnerable population groups or/and disadvantaged areas. Besides, this may have significant social impact and in this sense it lies within the areas of interests for the social entrepreneurs
3.	**Project-based funding:** As highlighted in the previous session, one of the greatest barriers that social enterprises face in Greece is the lack of access to finance. In other words, it is almost impossible to secure financing in Greece, so the project-based funding may comprise the safest way to secure funding from abroad
4.	**Support the development of social entrepreneurship by changing perceptions and raising awareness:** Participants mentioned the significance of raising awareness, informing people about the opportunities in social entrepreneurship sector and changing their perceptions for the third sector of economy
5.	**Services and facilities for supporting social entrepreneurship:** The existence of a conducive ecosystem that could help social enterprises to be developed and enter into the market will influence and encourage more people to work on this sector. For instance, the development of professional supporting agencies, such as incubators, could encourage interested people to invest in social entrepreneurship sector, as some of them may have not - from the very beginning - the essential capacity and skills on how to launch a social enterprise. What is more, such an incubator could mentor its members in order to develop a successful business plan, access the markets, get prepared for public contracts' calls, etc.

interest on Social Entrepreneurship and Social Innovation investigated with experts coming from the mobility sector, the passengers' needs that are not adequately covered by the conventional PT services. Apart from the core activity of a PT Operator (PTO) that is the circulation of the PT vehicles, there are plenty of other supplementary and supporting services that are (or could be) provided by external parties and entities, such as the social enterprises, enhancing the PTO's operation, as it was revealed through the consultation of experts. The early-stage concepts of social entrepreneurship and social innovation that were co-created by the experts, cover a variety of aspects, indicating certain 'umbrella' fields as crucial or promising for the social entrepreneurs:

1. *Services or initiatives related to the human factors*: first aid training (No1), employing persons of ghetto communities (No3), Gamification (No5).
2. *Re-designing or offering alternative transport schemes or/and services*: access to health-care services (No2), last mile solutions (No4), DRT (No6), Gamification (No5), "Hot-spot" with lockers (No8), electric vehicles (No11).
3. *Special services targeted to vulnerable population groups*: access to health-care services (No2), DRT (No6), 'walking buses' (No7), Ticket on hold (No9), travel 'buddies' (No10), electric vehicles (No11).

As far as the barriers' identification is regarded, these are related to several aspects, such as: (i) the *regulatory framework* (No1, No9), (ii) the *monetary aspects* (No2, No8, No13), (iii) the *business culture and public awareness related to social entrepreneurship* (No3, No4, No5, No6, No12, No14), and (iv) *structure of the mobility market and social entrepreneurship field* (No7, No10).

The relevant stakeholders/actors cannot influence directly the barriers related to regulation, finance and tax policy issues or market structure. However, the business culture and the public awareness matters can be managed by the SE/SI actors, themselves. Considering the three 'umbrella' fields of potential concepts that were revealed, it can be pointed out that the majority of the concepts can be put into action by the social economy actors, either individually or in cooperation with the PT authorities and operators. Apparently, the feasibility examination of each concept, separately, has to be linked with a certain local context and thus, it was out of the scope of this paper.

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Modeling Transit User Travel Time Perception in a Post-Economic Recession Era: The Case of Athens, Greece

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Abstract. Travel time perception modeling and analysis is required for the planning, design and evaluation of public transportation systems. Often, changes in socioeconomic conditions may have an impact to the perception of public transportation travelers as for their perception of travel time components. Using stated preference data from Athens, Greece, this paper investigates perceived travel time characteristics in a post-economic recession era, using logistic and linear regression models. Two types of models are developed. The first type attempts to identify parameters that affect traveller preferences towards walking and waiting for a shorter or longer period. The second type investigates the contribution of individual in-vehicle and out-of-vehicle travel time (perceived) components to the total perceived travel time. Results are compared to those obtained by a recent, pre-recession study undertaken by the Athens Public Transport Organization. Findings suggest changes in traveler perceptions on the importance of waiting and walk access/egress time.

Keywords: Perceived travel time · Public transport · Stated preference survey
Logistic regression · Linear regression

1 Introduction

Passenger trips incur both monetary and non-monetary costs with the latter involving attributes such as travel time, convenience and personal habits. For planning purposes, passengers are assumed to choose modes and routes that minimize their so-called generalized travel cost [1]; this is the weighted sum of actual and/or perceived monetary and non-monetary costs corresponding to their trip. In the case of public transport, monetary costs typically include trip fares and park and ride costs, while non-monetary costs refer to the passenger's perception of travel time, convenience, security and so on [2]. Perceived travel time refers to the traveler's experience and understanding on the duration of different trip stages; depending on travel conditions, personal preferences and trip characteristics, time perception of travelers may vary significantly from actual conditions [3].

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Perceived travel time is an integral part of generalized cost, and, therefore, its valid estimation is required for decision making and various planning tasks, including route planning, mode choice investigation, transit assignment etc. As habits and travel conditions affect travel time understanding, it is anticipated that major socioeconomic changes could affect that perception. The Greek economic crisis of the recent years has been such a case of abrupt change in the social and economic life of a country. In this context, this paper investigates factors affecting travel time perception in a post-economic recession environment and compares findings to those of pre-crisis research for the case of the Athens public transportation system. A Stated Preference survey is exploited for that purpose. Data are analyzed and findings from appropriate statistical models are compared. The remainder of the paper is organized as follows: the next section offers a literature review and highlights the contribution of the paper. Subsequently the methodology and survey process are presented and then derived models and results are discussed. A comparison of the study's outcomes is offered and the paper concludes win major findings.

2 Background

Modeling and analysis of travel time perception has been widely investigated by the research community, with several of them focusing on public transportation users. Among relevant publications, Li [4] examined the perception of travel time and evaluation of the urban commute experience. Waiting time perception using hazard-based duration models was analyzed by Psarros et al. [5]. Sjöstrand [6] derived weights of different perceived public transport travel time components in Malmo, Sweden. Persson [7] attempted to compare mode choices for public transport users of two cities in Sweden and determined weights of travel time components for that purpose. Perceived travel time as part of generalized travel cost for rural public transportation travelers was modeled by Kumar et al. [8]. Socioeconomic impacts on travel time savings for the case of Tunis public transportation system were examined by Dhibi and Belkacem [9]; age, sex and income were those parameters found to affect that perception. Ceder et al. [10] used fuzzy logic and cumulative prospect theory to model perceived out-of-vehicle time in two public transport terminals, in Auckland, New Zealand. Parthasarathi et al. [11] linked perception time variation and network structure using data from the Twin Cities metropolitan area. An agent-based method was applied by An et al. [12] for capturing the perception of travelers' waiting time. Car driver perception of bus travel time in the Netherlands was investigated by van Exel and Rietveld [13]; the authors reported a ratio of 1:2.3 between actual and perceived travel time. Perception distortions of travel time were modeled by Gonzalez et al. [14] for the case of a Spanish tram network, while Varotto et al. [15] used a discrete choice model for describing travel time perception in transport mode choices. Yu and Jayakrishnan [16] used information entropy for representing reliability of perceived travel time in transportation planning activities. Recently, Gao et al. [17] identified mode specific perceptions of travel time and crowding in Shanghai's public transportation network.

A decade ago, the Athens Public Transport Authority (OASA) conducted a pre-crisis survey to investigate the characteristics of the passengers' trips) [18]. Part of that research focused on the way passengers perceive their travel time when using public transportation similar to our research. Consequently, it is important to update as well as to enhance these models in a period of different economic status. In this context, we intend to investigate factors affecting perceived travel time in an era of economic crisis and compare outcomes to pre-crisis findings.

3 Methodology

A Stated Preference (SP) survey based on questionnaires was undertaken for the purposes of this study. The survey included both face-to-face interviews and web-based collection of questionnaires. A total of 288 valid questionnaires were collected. The structure and content of questionnaires is shown in Table 1. In the first section, the participants were asked to provide information about their most recent trip, using public transportation. This included their travel purpose, point of departure, and statements on total travel time, in-vehicle, waiting, walking and driving time (when public transport was accessed by private vehicles), the number of modes used for their trip. It is noted that recorded travel times were perceived values, as respondents were not expected to be prepared and provide actual values for each step of their trip. The respondents also indicated their perception of a transfer burden in terms of perceived travel time. The content of the second section included questions focusing on the socioeconomic attributes of respondents, such as sex, age, income and frequency of public transportation usage. In the third section, respondents were requested to choose between alternative scenarios related to their preferences when using public transportation. These scenarios combined out-of-vehicle (walk, wait etc.) and in-vehicle travel time alternatives for public transport trips.

According to some basic descriptive statistics, 45.83% of survey participants are male, while 54.17% are female. Most respondents belong to the age between 30 and 65 years, while almost 37% of them are regular public transport users and more than 60% are middle class people, belonging to the average income category.

Data collected from the questionnaires were coded in variables to conduct the statistical analysis. First, correlation among the independent variables was tested. It was found that none of those variables used in models were correlated each other. The variables eventually used in models are depicted in Table 2.

Two types of models are developed as part of this work. The first type attempts to identify parameters that affect traveller preferences towards walking and waiting for a shorter or longer period. Scenarios depicted in Table 2 attempt to represent such conditions of a comparison of individual out-of-vehicle and in-vehicle times; logistic regression is used to identify influential factors of alternative scenarios. Logistic regression is suitable for this purpose since the dependent variable is binary depicting the preferences for more or less walking and waiting. The second type exploits answers of respondents in an effort to investigate the contribution of individual in-vehicle and out-of-vehicle travel time (perceived) components to the total perceived travel time; linear regression is used for that purpose, as the same kind of regression was used in OASA's model of perceived time in 2007 [18].

Table 1. Questionnaire structure and content.

Section	Description	Values
Information about passengers' most recent trip using public transport	Fare	Single ticket, daily ticket, 5 day ticket, monthly card
	Trip purpose	Work, education, entertainment, other
	Trip origin	Home, work, education, other
	Total travel time	Any
	In vehicle time	
	Walking time	
	Driving time	
	Waiting time	
	Type of modes used	Bus, electric bus, metro, train, tram, other
	In vehicle passenger's condition	Sitting, standing, both
	Perceived time cost for transfer	Any
	Number of transfers between modes	
Socioeconomic attributes	Age	
	Sex	Male, female
	Frequency using public transport	Daily, 3-4 times a week, 1-2 times a week, 2-3 times a month, seldom
3. SP Scenarios	Income	Low, average, high
	Travel time perception	2 alternatives

4 Results

In this context, factors affecting perceived walk access time (dependent variable - scenario A) are presented in Table 3.

Per Table 3 findings, travellers using single fares or whose travel purpose is "work" tend to prefer to walk for longer rather than riding public transportation. On the other hand, travellers with fare cards opt for lower walking times and longer travel times. Travelers whose transfer burden is perceived to be larger as well as travellers willing to wait less and spend more time in a vehicle are also willing to walk less.

Table 4 depicts results for perceived waiting time (dependent variable - Scenario B).

Table 4 results show that travellers who opt to walk less prefer to wait less and spend more time in the vehicle. Also, travellers at an age between 46 and 65 years prefer to spend more time waiting rather than boarding a vehicle for a longer time.

Table 2. Variables used in statistical analysis.

Variables	Description	Values
Fare120	Fare	1: 70 min 1,20€ single ticket, 0: otherwise
Fare1500		1: 15,00€ monthly card, 0: otherwise
PurpWork	Trip purpose	1: trip purpose is work, 0: otherwise
OriWork	Trip origin	1: trip origin is work, 0: otherwise
InVehicle	In vehicle time	Any
NTrans	Transfers between means	
Walk	Walking time	
Drive	Driving time	
Wait	Waiting time	
TotalTime	Total travel time	
TTrans	Perceived time cost for transfer	0: 0 min, 1: 5 min, 2: 10 min, 3: 15 min, 4: 20 min, 5: 25 min, 6:otherwise
Age65		1: passenger's age between 46 and 65, 0:otherwise
AWalk	Scenario for walk time	0: 10 min walking and 25 min in vehicle, 1: 5 min walking and 30 min in vehicle
BWait	Scenario for waiting time	0: 10 min waiting and 25 min in vehicle, 1: 5 min waiting and 30 min in vehicle

Table 3. Logistic regression results for perceived walk access time.

AWalk	Fare120	Fare1500	PurpWork	OriWork	TTrans	BWait	Constant
B	−0.764	1.113	−0.775	2.250	0.210	1.500	−1.188
Sig.	0.011	0.024	0.006	0.001	0.041	0.000	0.003
Exp(B)	0.466	3.042	0.461	9.491	1.234	4.483	0.305

Table 4. Logistic regression results for perceived waiting time.

BWait	AWalk	Age65	Constant
B	1.270	−0.770	−1.485
Sig.	0.000	0.023	0.000
Exp(B)	3.560	0.463	0.227

Overall, constant terms in models have a negative sign. This implies that there exist some unobserved factors, which could support the preference of travellers towards longer out-of-vehicle travel times; this is could be part of additional research in the future.

Apart from logistic regression model, linear regression was used to relate perceived total travel time with individual travel time components, as those were stated as part of the survey. A regression through the origin approach was intuitively selected, as total perceived travel time is zero if all perceived travel time components are equal to zero [19]. Results are summarized in Table 5.

Table 5. Linear regression results

TotalTime	InVehicle	Walk	Drive	Wait	NTrans	R^2
B	0.561	0.770	0.755	0.770	5.952	0.881
t	8.419	4.270	4.205	4.765	4.740	
Sig.	0.000	0.000	0.000	0.000	0.000	

As can be seen from Table 5, all individual perceived travel times seem to contribute to the total perceived travel time, along with the number of transfers. Obviously, the contribution of out-of-vehicle components has an increased impact compared to in-vehicle travel time. For example, one (1) minute of in-vehicle perceived travel time corresponds to 0.561 min of total perceived travel time while one (1) minute of waiting time corresponds to 0.770 min of total perceived travel time. Similarly, a transfer between modes seems to have a contribution of almost 6 min to the total perceived travel time.

In general, travelers have a better perception as for their in-vehicle travel time, which is usually close to reality [20]. Therefore, assessment of the impact of out-of-vehicle time components is usually based on in-vehicle travel time. Based on linear model outcomes, it can be straightforwardly derived that the impact (weight) of waiting and walking time correspond to 0.770/0.561 = 1.37 min of in-vehicle time while driving time corresponds to 0.757/0.561 = 1.35 min of in-vehicle time. For transfers, this weight is equal to 5.952/0.561 = 10.61. It must be noticed that the comparison concerns only perceived travel times and their contribution to the total time, as long as real travel times are not compared with the perceived ones.

It is worth comparing the weights of the perceived travel time obtained from this research to those found in the literature. Of importance is the pre-crisis survey undertaken by the Athens Public Transport Authority (OASA) in 2007. Results are summarized in Table 6.

Table 6. Weights derived by perceived waiting time surveys.

	In vehicle time	Walk time	Waiting time	Driving time	Number of transfers
Current research	1	1.37	1.37	1.35	10.61
OASA (2007)	1	2.13	1.18	–	10

As can be seen from Table 6, derived weights for time elements and the number of transfers are in line with those found in the literature, and verify to an extent past findings. The only exception is related to driving data, for which, to the authors' knowledge, relevant past work information could not be found. In a more direct comparison, the walking time weight is significantly lower in our study. This implies that people in an era of crisis may be more tolerant towards walking to a bus stop (rather than using their private vehicle for example). On the other hand, waiting time weight is slightly increased, meaning that people feels that waiting contributes more to their perceived travel time than in the past. These may be explained by the fact that the impact of the economic recession to the Athens public transport system was severe, with considerable cutbacks in operations, a subsequent decrease in frequencies and a poor maintenance of bus stop infrastructures. As such, waiting times have increased, some lines (and stops) were cancelled, bus stop environments have become less pleasant and more crowded, and often passengers decide to walk further to access bus lines with higher frequencies. So, there is a relatively low level of satisfaction as far as waiting times are considered, due to the passengers' anticipation of waiting more and in a worst environment than before during their trip. That fact leads to an a priori feeling of heavier contribution of waiting time to total travel time. In addition, in the recession years and afterwards, non-motorized trips in Athens have increased because of heavy taxation in fuel and private vehicle usage, as well as because of a heavy promotion of sustainable, health oriented travel habits. It therefore seems that travellers in a post-recession era have more incentives to walk compared to the past. On the other hand, degrading operations have negatively affected waiting time weights to a lesser extent compared to walking time weights though. Additionally, our sample consists of mostly relatively young people (71.53% aged between 15 and 45 years old) and passengers who use public transportation at daily basis (36.81% of the total ones). So, there is a higher possibility for them to be more familiar and tolerant with the public transportation means. Consequently, lower weight in perceived walking time, which difference is significant, compared to the one in pre-crisis era might have occurred in this research. The relative lack of older passengers in our sample may also lead to higher weight in waiting time, since older people tend to walk less and wait more contrary to younger ones who are usually more impatient.

5 Conclusions

This paper investigated perceived travel time of public transport travellers for the case of Athens, Greece. The analysis undertaken was based on data collected in a period after the country's economic recession and findings were compared to relevant pre-crisis research. It was found that individual travel time components are affected by factors such as the fare type, trip purpose, departure point, perception on transfers and age. Also, waiting time seemed to play a role towards the preferences on travel time component of walking. The comparison of findings with pre-crisis work indicated an increase in the impact of perceived waiting time to the perception of total travel time and a decrease to the related impact of perception about access/egress walk time. This is attributed mostly to the degradation of operations of the Athens public transport network and a forced change of attitude for passengers due to fewer incentives in using motorized modes of travel.

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The Aesthetic Integration of a Tramway System in the Urban Landscape - Evaluation of the Visual Nuisance

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Abstract. Visual nuisance is one of the environmental consequences caused by the operation of a railway transport system and especially that of an urban surface system, such as a tramway. It constitutes a design and construction parameter of the system and it entails the system's aesthetics as a whole, since that determines the degradation or improvement of the landscape in which the tramway is to be integrated in. It is of interest to the system's users but mainly to all the residents of the urban area that the system will be running through.

The structural elements of a tramway system, associated with visual nuisance, are the stops, the depot(s), the electrification installations, the interior and exterior of the vehicles, the track superstructure, the covering materials of the tramway corridors, the signaling equipment and finally the way the tramway infrastructure is separated from the rest of the traffic.

By studying the current approaches for evaluating visual nuisance as is conducted in large transport projects today, a lack of an objective evaluation method can be observed.

In this paper a methodology is proposed for evaluating the visual nuisance caused by the integration of a tramway system in an urban area. It is mainly of interest to the evaluators of urban railway systems, as it can replace their intuitive subjective choices with a rather objective common approach to the evaluation of visual nuisance. It is also of interest to the designers as it provides them with a list of best practices for the reduction of visual nuisance.

The findings of this research may be applied at the design stage of a new tramway system, at the evaluation of an existing system or finally for the evaluation of corrective interventions aimed at upgrading an existing system.

Keywords: Visual nuisance · Tramway projects · Tramway aesthetics

1 Introduction

Visual nuisance is one of the environmental consequences caused by the operation of a railway transport system and especially that of an urban surface system, such as a tramway. It constitutes a design and construction parameter of the system and it entails the system's aesthetics as a whole, since that determines the degradation or improvement of the landscape in which the tramway is to be integrated in. It is of interest to the

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system's users but mainly to all the residents of the urban area that the system will be running through.

The evaluation of new tramway projects and the comparison of different possible solutions within a proposed system, require in an increasing amount the evaluation of the resulting visual nuisance [1, 2].

By studying the current approaches for evaluating visual nuisance as is conducted in large transport projects today, a lack of an objective evaluation method can be observed. The aim of this paper is to propose a methodology for evaluating the visual nuisance caused by a tramway system. The results of using this method on the Athens existing tramway system are also presented [3, 4].

The findings of this paper may be applied at the design stage of a new tramway system, at the evaluation of an existing system or finally for the evaluation of corrective interventions aimed at upgrading an existing system. They are mainly of interest to the evaluators of urban railway systems, as it can replace their intuitive subjective choices with a rather objective common approach to the evaluation of visual nuisance. They are also of interest to the designers as it provides them with a list of best practices for the reduction of visual nuisance.

2 Proposed Methodology for Evaluating Visual Nuisance

2.1 Methodology and Assumptions

The methodology presented in this paper is based on assigning points to each of the structural elements of a tramway system and then evaluating the entire system based on its overall score [5]. More specifically this methodology, for evaluating the total Visual Nuisance, required the following steps to be taken:

1. The structural elements of a tramway system that contribute to visual nuisance were identified and recorded
2. The different available aesthetic solutions for each of the structural elements were identified and recorded. These aesthetic solutions were then categorized qualitatively into five (5) categories
3. A number of Visual Nuisance Points (VNPs) was attributed to each of these aesthetic categories (0 to 4)
4. The weighting factor concerning the contribution to visual nuisance of each of the structural elements to the entire tramway system was identified.
5. A formula for estimating the overall level of Visual Nuisance (VN) that is caused by the operation of a tramway system was proposed.
6. The overall VN score that is derived from the application of this formula, may be used to evaluate a tramway system as a whole.

This methodology assumes that regardless of any subjective visual pleasure caused at the sight of some structural elements, every structural element of the tramway system, except the ones that are concealed, causes visual nuisance. Furthermore, the structural elements of the tramway systems are considered to be independent to one another. This means that any changes in the visual aspects of one structural element do not affect any other structural element, but only the system as a whole. Lastly, the existing landscape is considered as "ideal". This means that the former state of the landscape is not taken into account. This methodology investigates the best practices for the systems themselves and does not go into any comparison with the former state of the landscape.

2.2 Structural Elements of a Tramway System and Related Aesthetic Solutions

The structural elements, which were considered to contribute to the visual nuisance caused by a tramway system, are the exterior image of the rolling stock, the interior image of the rolling stock, the stops, the electrification system, the tramway superstructure covering materials, the tramway corridor separation techniques, the signaling equipment, and the depot(s).

The different currently available aesthetic solutions for reducing visual nuisance of each of these structural elements are given in Table 1. In order to rank these solutions in qualitative categories three criteria were taken into account. These were the concealment of the structural element from the line of sight of observers, the limitation in number or in size of the different parts of the structural element, and the providence during the design of the structural element for the reduction of its visual nuisance, meaning a design that considers the aesthetics of the element as a priority.

Based on the fulfillment of the above criteria each option for the construction of each structural element was placed in a category (O, A, B, C or D) as shown in Table 1. Category O is achieved with the total concealment of the structural element. Categories A through D correspond to the effectiveness of each solution in reducing the visual nuisance of the structural element from most to least effective.

Each of these categories was given a qualitative description that corresponds to a number of Visual Nuisance Points as shown in Table 2.

2.3 The Impact of Each Structural Element on the Visual Nuisance of the Tramway System as a Whole

In order to ascertain the impact of each structural element on the visual nuisance of the system as a whole (Table 3), a series of interviews were conducted.

The twelve (12) interviewees were all engineers of various disciplines, including architects, urban design engineers and traffic engineers. No ordinary users or observers where interviewed. The twelve interviews resulted in the weighting factors. To this end, the interviewees were presented with the suggested methodology. Each of the structural elements was given a grade from 3 (least impact) to 10 (most impact) by the interviewees based on the impact that particular element has on the visual nuisance caused by the system. Lastly, the mean grade for each structural element was calculated. The mean grade was then divided by a reference value (the minimum grade of 3) and rounded to the nearest decimal point.

Table 1. Available aesthetic solutions per structural element of a tramway system.

Structural element – Aesthetic solution	Aesthetic category
Exterior image of the rolling stock • Modern vehicles which are designed exclusively for the system they are made for, while taking into account the existing character of the urban area that the system will be located in	A
• Modern vehicles with an innovative design that does not take into account the existing character of the urban area	B
• Conventional vehicles without any distinctiveness in their design	C
• Placement of advertisements on the sides of the vehicles (advertisements take up less than 40% of the total available space)	C
• Placement of advertisements on the sides of the vehicles (advertisements take up more than 40% of the total available space)	D
• Use of train sets that are longer than 65 m	Degrade by 1 category
Interior image of the rolling stock • Innovative design, with large open spaces and no advertisements	A
• Large windows and adequate open spaces at eye level, limited use of advertisements	B
• Small windows or obstruction of the passengers' sight with many elements at eye level or extensive use of advertisements	C
Stops • Mainly small and discreet stops. Limited size of structural elements and mainly use of glass or thin metallic parts	A
• Stops with a distinctive design that are integrated in the urban area in which they are constructed. The design takes into account the reduction of visual nuisance through the use of transparent or thin parts	A
• Stops with a distinctive architectural design, with the use however of large structural elements that hide part of the sky or the urban area	B
• Conventional stops with large structural elements. No effort to reduce visual nuisance	C
• Placement of advertisements on the surfaces of the stop (over 50%)	D
Electrification system [6, 7] • No use of catenary wires and electrification poles. Ground level electrification (free catenary system) [7]	O
• Effort to limit the amount of catenary wires per track	B
• Effort to limit the amount of electrification poles, use of existing buildings to support catenary wires	B
• No effort to reduce the amount of catenary wires or electrification poles	C
Tramway superstructure covering materials [8] • Use of cover elements (turf or colored stones) that have a visual continuity with the surrounding landscape, meaning that the cover materials appear to be a continuation of the surrounding ground	A

(*continued*)

Table 1. (*continued*)

Structural element – Aesthetic solution	Aesthetic category
• Use of cover elements or colored stones without however taking into account the visual continuity with the surrounding landscape	B
• Tramway corridors with no covering materials	C
Tramway corridor separation techniques [8] • Separation (from the other means of transport) with the use of small structural elements that are designed to improve the area's aesthetics (vegetation or well-designed elements)	A
• Separation with the use of small structural elements, poles or fences	B
• Separation with the use of large structural elements, poles or fences or other solid non-transparent elements that are over 1 m in height	C
• Placement of advertisements on the structural elements used for separation	D
Signaling equipment • Effort to limit the use of signaling equipment or use of a distinctive design of poles and signs	B
• Use of conventional signaling poles	C
Depot(s) • The depot is placed outside of the urban area	O
• The depot is placed within the urban area but there is consideration for its aesthetics	B
• The depot is placed within the urban area but there is no consideration for its aesthetics	C

Table 2. Visual nuisance points per aesthetic category.

Aesthetic category	VNP
Solution Category O - Concealment of the structural element from any observers	0
Solution Category A - No option for concealment – Effort to limit the size of the element that is observable and simultaneous significant effort for an aesthetically pleasing design of the element	1
Solution Category B - No option for concealment – Either an effort to limit the size of the element that is observable or significant effort for an aesthetically pleasing design of the element	2
Solution Category C - No option for concealment – No effort to limit the size of the element that is observable and no effort for an aesthetically pleasing design of the element	3
Solution Category D - Increase of visual nuisance through the use of larger structural elements or use of additional elements that are not functionally necessary and obstruct the sight of an observer (advertisements, large non-transparent elements)	4

Table 3. Impact of each structural element on the visual nuisance of the system as whole.

Structural element	Weighting factor
Exterior image of rolling stock	3
Interior image of rolling stock	1.3
Stops	2.7
Electrification system	2.8
Tramway superstructure covering materials	2.7
Tramway corridor separation techniques	2.3
Signaling equipment	1.4
Depot(s)	1.4
Sum	**17.6**

2.4 A Proposed Formula for Evaluating the Visual Nuisance Caused by a Tramway System

The level of visual nuisance VN that is caused by the operation of a tramway system may be evaluated using the following formula:

$$VN = \frac{\sum_i (w_i \, x \, VNP_i)}{\sum_i w_i} \tag{1}$$

Where:
VNP_i: The Visual Nuisance Points of every structural element *i* of the tramway system under examination. They are dependent on the qualitative category of the aesthetic solution chosen to reduce the visual nuisance caused by structural element *i*.

w_i: the weighting factor that defines the level of influence every structural element *i* has on the visual nuisance caused by the system as a whole. It is dependent on the size of the structural element, its construction site, its final location and the influence it exerts on the perception of observers.

The resulting value of Visual Nuisance may be used to evaluate the tramway system using three (3) qualitative categories (I, II or III) as shown in Table 4.

3 Evaluation of the Visual Nuisance Caused by the Athens Tramway System

Figure 1 shows the structural elements of the Athens Tramway System used for its evaluation. Figure 1a shows the exterior of the Sirio type rolling stock used by the Athens Tramway, a modern vehicle without however a design intended specifically for Athens. Figure 1b shows its interior, which contains large spaces and window and is void of advertisements. Figure 1c shows a typical stop which uses thin metallic elements and glass. In Fig. 1d depicts a signal, while there is no novelty in its design, its size is limited. Figure 1f shows light use of catenary wire, however in several areas that the tram coexist with the trolley the mesh of catenary wire is excessively thick.

Table 4. Evaluation of the total visual nuisance caused by a tramway system.

Total VN value	System evaluation
≥ 1.75	**Visual Nuisance Qualitative Category I** - The tramway system has reduced to a large extent the visual nuisance it causes. It has taken this parameter into consideration at the design level and has chosen effective solutions in partially or totally concealing the structural elements from observers. At the same time a priority was given to its tasteful design. It has a low negative impact on the image of the urban area while at the same time it includes visually pleasant elements
1.76 −2.75	**Visual Nuisance Qualitative Category II** - The tramway system has partially reduced the visual nuisance it causes. It has limited the size and intrusiveness of some elements and has improved their aesthetics. It has a medium negative impact on the image of the urban area. There might be the need for individual corrective actions in some of the areas in which it operates
2.76 −4.00	**Visual Nuisance Qualitative Category III** - The tramway system has taken few or no measures in reducing the visual nuisance it causes. Its structural elements limit the line of sight of observers to a large extent, while their design is neutral or unpleasant. The railway system has a high negative impact on the image of the urban area and is in need of corrective actions to limit the visual nuisance it causes

Figures 1g and 1h show areas where the tramway superstructure is covered with turf and vegetation is used for its separation with the rest of the traffic. The depot is typically inside city limits, in an area however of low population and of varying uses. Table 5 summarizes how the Athens Tramway System and its various structural elements have scored using the aforementioned method.

Fig. 1. Structural elements of the Athens Tramway [5].

Table 5. Visual nuisance caused by the Athens Tramway system.

Structural element (SE)	Aesthetic category – VNPs	Weighting factor w_i	Total VNPs
Exterior image of rolling stock	B – 2 VNPs	3	6
Interior image of rolling stock	A – 1 VNP	1.3	1.3
Stops	A – 1 VNP	2.7	2.7
Electrification system	C – 3 VNPs	2.8	8.4
Tramway superstructure covering materials	A – 1 VNP	2.7	2.7
Tramway corridor separation techniques	B – 2 VNPs	2.3	4.6
Signaling equipment	B – 2 VNPs	1.4	2.8
Depot	B – 2 VNPs	1.4	2.8

Using the aforementioned formula we get that:

$$VN = \frac{\sum_i (w_i \, x \, VNP_i)}{\sum_i w_i} = 31.3/17.6 = 1.78 \qquad (2)$$

Based on Table 4 the Athens Tramway System is placed by a small margin in category II, meaning that some corrective action could reduce the visual nuisance that it causes.

4 Conclusions

Firstly, it may be concluded that of all the structural elements of a tramway system, the exterior image of the rolling stock, the electrification system, the stops and the tramway superstructure covering materials play the most vital role in how intrusive a tramway system is to the aesthetics of an observer (both a user and an outside observer).

Moreover, this paper presents a relatively objective method for evaluating the visual nuisance caused by a tramway system as a whole.

The findings of this paper may be applied at the design stage of a new tramway system, at the evaluation of an existing system or finally for the evaluation of corrective interventions aimed at upgrading an existing system.

The application of this method on the Athens Tramway System was presented. This system was found to cause medium to low visual nuisance.

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Redefinition of Public Transport in the Alto Minho Region, Portugal – An Overview

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Abstract. Mobility redefinition is essential in any City/Region, towards attaining sustainable mobility in terms of the triple bottom line dimensions (economic, social and environmental). Therefore, it is urgent to improve and to create a more inclusive system towards enhancing public transport, based on population needs and using viable infrastructures and alternatives. Aiming to identify recent keys mobility systems, this paper presents an overview of various solutions adopted in public transports area, in some regions of the world with points in common with Alto Minho' Region and/or to the Region headquarters (Viana do Castelo). Furthermore, it is intended to identify and discuss those innovative combinations of transport modes currently employed, that could positively impact the Alto Minho Region transportation system. The overall assessment will support the definition of the main criteria to design a novel and efficient transport system, fully adapted to this region characteristics and population's needs. Thus, the purpose of this paper is to propose a viable and efficient public transport system that meets the region's sustainability requirements, along with the opportunity to involve the population, the transport companies and the different stakeholders, as well as the policy makers.

Keywords: Alto Minho region · Public transport · Mobility patterns Future solutions

1 Introduction

Regions, all over the world, are changing their mobility patterns towards assuring a better future for their citizens, especially by working on the redefinition of the economic, social and environmental dimensions, towards enhancing sustainability [19]. The pressure towards changing mobility solutions is high, especially

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due to the imperative necessity of reducing the oil consumption or even to moderate/mitigate the effects of climate changes [16]. Notwithstanding, policies take time to be implemented [20], as well as to measure their financial and social impacts. These impacts seem to be the most important goals for policy makers [4], together with the undeniable environmental consequences and the energy scarcity. A balance must be achieved between the mobility system design and its acceptability [6] by the population. Therefore, it urges to improve and create a more inclusive system to enhance public transport usage, adjusted to the population needs, being globally inclusive in order to avoid social exclusion (people unable to have a car and/or to drive) and predicting the usage of viable infrastructures and/or concrete alternatives.

The main purpose of this article is to present a new approach to the public transport design in the Alto Minho Region, properly balancing the demand paradigm and the smart sustainable transport solutions. The article is organized as follows: Sect. 2 describes the methodology used. Then, some mobility solutions are explained and justified its suitability on the Alto Minho's context, in Sect. 3. In Sect. 4 the Alto Minho Region is characterized, particularly on its land use, on some population indicators and on its mobility modes. Based on these Sects., Sect. 5 presents future mobility solutions to be considered in the Alto Minho Region public transport system design. Conclusions and directions for future research are outlined in the last section, Sect. 6.

2 Methodology

The research methodology used in this paper is exploratory and was based on the analysis of several case studies with common convergence points and similarities to the Alto Minho Region. The usage of those similarities ensures a convergence point, which substantiates the adoption of the same type of environmental friendly solutions, considering its reputability and feasibility to this region, as well as avoiding potential inadequacies in implementation [5] that would not be foreseen otherwise. Each case study was characterized and assessed in geographic and social levels, in addition to its travel patterns and transport combination modes. The case studies assessed with common points to the Alto Minho or/and its headquarters (Viana do Castelo) are the following: **Alentejo Central** has poly centric characteristics, i.e., in addition to the Region headquarters, has a number of medium-to-small cities as Alto Minho; **Burgas**, **Thessaloniki** (**Greek case**), **Médio Tejo** and **Ljubljana** have a population matching with the Alto Minho; **Leiria** is a medium-to-small size Portuguese City, with a Polytechnic Institute as Viana do Castelo; **Karditsa** and **Elefsina** (**Greek cases**) and **Tomar** have a population which match Viana do Castelo; **Larissa** (**Greek case**), **Ljubljana**, **Ponta Delgada** and **Tomar** have an area that matches with the one of Viana do Castelo.

3 Literature Review

According to Wegener [20], mobility in a holistic view promised the end of rural regions isolation; auto mobility for all, including the elderly, the poor, the handicapped; and the availability of efficient transport systems. Table 1 resumes the main objectives and solutions implemented in cities all over the world towards promoting sustainable mobility.

The review work suggests that the implementation of sustainable mobility measures, in small and medium-sized Portuguese cities, is dependent on the improvement of collective public transport services, on the promotion of cycling through the construction of safety cycle paths and conservation of the pedestrian networks [2]. In addition to the general suggestions about cycling and walking, a global inclusive transport solution is mandatory for the Alto Minho Region. A more equitable approach could include an on demand transport system, with technological support. Knowing that supporting government policies will be essential [16], as well as involving the users, the stakeholders and the operators in the design and definition of the new transport system.

4 Alto Minho Characteristics

In this Sect., the Alto Minho Region is described, to a further evaluation of its population and mobility profile, enabling an appropriate planning mobility solution, according to its geography, population and mobility factors.

Alto Minho Region has ten Municipalities, it is located in the North West of Portugal and is bordered by Spain from the North and East, by Braga District from the South and by the Atlantic Ocean from West. The region has 2 216 km^2 of area and is highly forested (71% of its territory), followed by an agricultural area (about 20%) and the urban areas as housing, commercial and industrial, represent only about 7% of the land use, equivalent to 145 km^2 [7]. In total there are around 250 000 inhabitants [14], for a 106.9 inhabit/km^2 [18] density, hence the Alto Minho Region is characterized for being territorial disperse and with a low population density. The major population zones are the Municipalities' headquarters areas, which present the highest potential to generate/attract trips, as well as along the coastline and nearby rivers.

In this region, key movement patterns are made mostly between neighboring and within the Municipalities [7]. Regarding daily movements as home to work and home to school movements', the car is the main transport mode used (67.70%), followed by the public bus (16.60%); and with 15% the walking mode; cycling, train and other modes fulfill few then 1% of the users [7]. It must be noticed that the rail network only exists in the Viana do Castelo – Valença line, going through four of the ten Municipalities; and the bus has insufficient schedules and frequency, especially in the smaller Municipalities where those can be almost non-existent. Mostly of these travels are made by car and in the Alto Minho Region there are just over 126 000 registered vehicles [3], representing one car for each two persons. There is a dependency on the individual transportation mode, therefore the pendular movements are dominated by these vehicles

Table 1. Mobility objectives and solutions proposed by each Region/City

City/Region and characteristics	Future mobility objectives and solutions
Alentejo Central Region has 14 Municipalities, 7 400 km^2 of area and 170 000 inhabitants. In this region apart from walking, everything is based on the car. The public transport network is mainly used by those who cannot use a car and in short distance travel [8]. Alentejo Central participated in a project to support the development of Sustainable Urban Mobility Plan (SUMP) in poly-centrist regions – Poly-SUMP [17]	. Create a Regional Sustainable Mobility Plan; . Living neighborhood - integrated urban planning; . Improve pedestrian networks; . Maintain rail road clean; . Redesign public transport network; . Incentive green mobility system; . Have a zero-emission corridor policy
Burgas has 205 467 inhabitants. In 2012, Burgas City started the implementation of a bike-sharing service and was the first Bulgarian City to include the practice as part of an integrated urban mobility policy [11]	. Implement an electronic rental system; . Promote cyclist's low modal share; . Create cycling infrastructure for mobility behavior change; . Planning long-term campaigns, as Bike2Work, to foster a local cycling culture
Greek cities: Thessaloniki with a special role on a national level, due to its location and population size; Larissa is a development center in Thessaly Region, as does Karditsa in the Western part of the same region. Elefsina plays a particular role in the function of the urban agglomeration of the Greek capital [4]	. Ring Roads; . Redevelopment of road sections; . Parking Policy; . Improve and promote public transport; . Promote cycling
Leiria has 565 km^2 of area, 126 897 inhabitants and a Polytechnic Institute. Biclis (Leiria city bikes) was created in the scope of the project T.aT. (Students Today, Citizens Tomorrow) [10] and it was also implemented the project U-Bike [13]	. Create bike stations and parking; . Have bikes available for public usage; . Develop an interface between transport system and users; . Reduce road accidents; . Promote the soft modes
Ljubljana the 2016 European Green Capital, has 275 km^2 of area and over 280 000 inhabitants, once dominated by car transport. Nowadays, the focus is the public transport, as well as pedestrian and cycling networks, encouraged with the participation of the residents [9]	. Modify the traffic regime on the main traffic arteries; . Implement various projects as: "BicikeLJ", "One is not enough" and "A to B: Ljubljana"; . Electric vehicles in the city center free of charge; . Connect stakeholders and knowledge

(*continued*)

Table 1. (*continued*)

City/Region and characteristics	Future mobility objectives and solutions
Médio Tejo Region has 13 Municipalities, 3 344 km^2 of area and 247 330 inhabitants. Regarding Portuguese context, an innovative demand transport project was developed in this region. It is an important reference for the dissemination of flexible transportation and for eventual replication in other regions of the country [15]	. Increase public transport network working areas; . Improve the existing transport offer regarding the territorial area and time periods, throughout the day and all year long; . Cover areas where public transport does not exist or is insufficient
Ponta Delgada has 232 km^2 of area and 68 809 inhabitants. Private car is the major mean of transportation, thus the congestion has increased in recent years. Public transportation is limited to intercity and city buses (minibuses) and represents 17% of commuting transport [12].	. Re-qualification of side walks; . Develop a plan for pedestrian corridors and bike lines; . Implement a limited car circulation; . A car-sharing and car-pooling systems, which transform the generally low occupancy car into a high occupancy vehicle
Tomar has 351 km^2 of area and 39 682 inhabitants. Three future mobility scenarios were proposed and analyzed, as well as a sustainable mobility index proposed for the decision-making of the authorities of small and medium-sized Portuguese cities that want to improve the quality of life of their citizens through sustainable mobility [2]	. A bike sharing system that will bring benefits for residents and visitors; . New stops for the public bus; . Create electric vehicle charging stations; . Encourage pedestrian mobility, especially for visitors/tourists

in all the Municipalities. The majority of neighboring Municipalities movements represent usually short trips, it must be noticed that 66% of those trips last less than 15 min., 28% last between 15 and 30 min., and only 6% last more than 30 min. [7]. Regarding to all the Alto Minho population (workers or non-workers) 88% of the daily movements are made inside the same region [7]. Moreover, such represents 112 640 daily trips made by the individual transportation mode. In the region, there are public transport services by **road** (in a 480 km of total main and secondary roads, with 1.1 km/km^2 of spacial length and an average of 1.4 $stops/km^2$); by **rail** (in four Municipalities, with 49.8 km and 12 main stations); and in Viana do Castelo City a port infrastructures and water transport: **ferry-boat**; a **cable car**, making the connection between the center and the touristic attraction Santa Luzia Mountain; and small **electric buses** circulating in the streets of the Historic Center. Regarding **cycling** there are 1291 km of cycling roads. There are free parking zones in public areas in all the Municipalities and with charging fees in seven of them [7].

Ensuring progress towards a more sustainable and inclusive development, as it is a political priority in the European Union, the *Comunidade Intermunicipal do Alto Minho* (CIMAM) defined the Sustainable Urban Mobility Action Plan (SUMAP) for the Alto Minho Region, in 2016 (further details in [7]). A SUMP was created for the Viana do Castelo Urban County Center (further details in [1]), in 2010. Both Plans, despite the diagnosis and/or the strategies definition phases, have not been implemented.

5 Future Mobility Design in the Alto Minho Region

Defining the future mobility and the future of public transport system in any region worldwide, not only requires an extensive and fully understanding of the user experience but also of the infrastructure investment required to support it. Thus, focused in the SUMAP and SUMP objectives together with the Table 1 indicators, a future public transport system for the Alto Minho Region is outlined. This future public transport system clearly has its advantages and will also enhance and promote a more sustainable mobility ecosystem.

The world's environmental situation and the car dependency requires a reversion on the usage of this dominant transport mode. To many people, sustainable mobility requires a radical change in the way travel decisions are made [6]. Hence, during the transition to a new system or paradigm, it will be important for the public transport system to be able to respond rapidly to these changes [16]. Available public transports, cycling and walking have become less attractive, and this in turn has resulted in the greater use of the car [6], whilst the former modes are healthier and allow the promotion of a more active transport, i.e., a healthy life style. In the Alto Minho Region most of the jobs or work places are near to where people have their residences, the average time traveled by car, in most of the situations, is less than 15 min. These distances and time travel would not be much different if they were done using the public transport system or even when using shared transport modes. Thus, allowing the implementation of new services with high innovative levels, reducing or minimizing the necessity of using the car. Then, in urban areas the average trip length would be kept below the limits required for maximum use of the walk and the bike modes. Given this region characteristics and the existent public transport solutions, an on demand responsive transport system is clearly a feasible and applicable future transport solution. The redefinition of the public transport network working areas and schedules and the proper inter modal infrastructures are essential towards guarantying the decrease usage of the car as well as enhancing the adoption of new collective transportation solutions. Furthermore, to promote other sustainable and innovative offers such as cycling and electric vehicles, as well as car-pooling and car-sharing initiatives, implemented in a first phase in the major attraction zones of the region. It is also important, as concluded from the analysis of the case studies, to define and implement a "Regional" SUMP with all its implications; to improve the pedestrian networks and roads, with enhanced security;

to create more bikes infrastructures and a bike sharing program; to develop an interface between the collective and individual transportation systems and the users (for ticketing, with routes choice and timetables); to increase the train frequency; and demotivate the use of the car for the short trips, which are the prominent in the region.

The implementation of these recommendations, to become fully successful, need to have the support and the involvement of the CIMAM, the collective transport companies that exist in the region and ultimately the involvement of all who use and have transportation responsibilities.

6 Conclusions

The economic, environmental and social challenges faced today, are obliging the public decision-makers to adopt innovative mobility policies all around the world. Therefore, it is almost impossible, or impracticable, to adopt new mobility solutions without doing any type of benchmark analysis with similar regions. An overview of eight sustainable mobility City/Region case studies has been presented, together with the study of common points between each one of them and the Alto Minho Region and/or the Region headquarters. The set of mobility solutions identified are weighted and adjusted to the Alto Minho Region, aiming to redefine the public transport, promoting social inclusion, and healthy and ecologically life styles. Briefly we highlighted the conception of a Regional SUMP; increasing the bus and train frequencies and bus coverage areas; creating the inter modal terminals; improving the pedestrian and the cycling networks, as well as promoting a sharing program; implementing initiatives as car-polling and car-sharing, in addition to electric vehicles; developing of an on demand responsive transport system and an interface between transport system and users. Nevertheless, the involvement of all the stakeholders and the proper stimulus created by the policy makers is viewed as critical for the implementation of the solutions proposed, as well as to fully adopt a sustainable life style where mobility is seen as a major contributor.

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A Criteria-Based Evaluation Framework for Assessing Public Transport Related Concepts Resulted from Collective Intelligence Approaches

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Abstract. Public Transport (PT) is a key factor towards sustainable urban mobility. The increase of its modal share requires the continuous adoption of new innovative and user-centric solutions covering the existing and emerging needs of citizens. Which concepts and ideas should be promoted and financed by priority? The paper aims to present the quantitative evaluation of the innovative PT-related ideas resulted from the collective intelligence processes (crowdsourcing and co-creation) that were applied in the frame of the CIPTEC project (H2020). An online questionnaire survey was addressed to experts in order to evaluate quantitatively twenty selected concepts by rating them, against three distinct assessment criteria: utility, feasibility and innovativeness. The analysis enabled us to understand how the collected rates are varying, in the case of examining the distribution of either each innovation or each criterion individually. As an overall conclusion, it could be claimed that although the outcome of the collective intelligence process might not be always as innovative as it was initially planned, its advantage of being in line with both the PT demand and supply side needs and priorities, ensures its utility and feasibility and subsequently, the increased possibility for its adoption and market uptake.

Keywords: Public Transport · Evaluation · Assessment · Questionnaire survey Criteria · Collective innovation

1 Introduction

During the last decades, governments and policy makers have targeted to make the European cities more sustainable, liveable and inclusive, both in a social and a physical sense. Towards the achievement of this target the shift to more sustainable and collective transport modes seems crucial, with the improvement of Public Transport services be on the top. By introducing new innovative concepts/services, new passengers may be attracted. However, the selection of the most appropriate concepts towards this goal is one of the main issues that an organisation should deal with.

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This paper aims to present the quantitative evaluation of the PT-related early-stage ideas resulted from the collective intelligence processes that were applied in the frame of the CIPTEC, by using descriptive statistics.

2 Survey Design

2.1 CIPTEC Collective Intelligence Processes' Outcome

In the frame of CIPTEC project, two collective intelligence processes (crowdsourcing and co-creation) were exploited in order to support, among others, the generation of innovation and the emergence of new ideas. In more details, eight co-creation workshops were organised at local level in Thessaloniki, Southern Tuscany, Frankfurt and Rotterdam/The Hague and five different crowdsourcing campaigns were designed and ran (four campaigns in local languages of the aforementioned cities, while the fifth one was launched in English and addressed to all European citizens). Both of these user-centred processes aimed to support the generation and evaluation of innovative ideas, concepts, practices proposed by the citizens [1].

In general, a lot of interesting ideas emerged (486 ideas derived from crowdsourcing and 165 ideas resulted from co-creation workshops). By shortlisting them through evaluation procedures tailored case by case, 20 concepts were selected to be further examined and evaluated [1]. The full names of these twenty ideas/concepts, as well as their corresponding abbreviations are listed below:

(1) Development of a "social-bus" app (SOCIALAPP), (2) Development of an "environmental trip" app (ENVAPP), (3) Innovative solutions for on-board and at bus stops passengers' counting (PASSCOUNT), (4) Use of data mining tools for enhancing service operation and performance (DATAMIN), (5) Use of E-Ink technology for the screens of info-panels (EINK), (6) Umbrella brand concept (UMBRBRAND), (7) Public Transport funding by the beneficiaries of the system (PTFUND), (8) City marketing from a Public Transport perspective (CITMARK), (9) Mobility as a Service and platform with real-time travel, comfort and multi-modal information (MAAS), (10) Flexible pricing options (FLEXPRIC), (11) Green platforms and "green technologies" systems at Public Transport stops providing comfort and pleasure to the passengers (GRTECH), (12) "Public Transport seats" application (PTSEATSAPP), (13) Public Transport Widget indicating the accessibility of places of interest by Public Transport (PTWIDGET), (14) Advanced e-ticketing system (ADVETICKET), (15) Mobile phone charging locker (MOBCHARLOCK), (16) "On demand" transport services using minibuses (demand responsive) (ONDEMAND), (17) Bus Lane with Intermittent Priority (BLIP), (18) Real-time journey planner on app including management of customer requests (RETIJOURNAPP), (19) Integrating Public Transport use in Entrance Tickets of Events (PTEVENTICK), (20) Fully equipped Public Transport making travel time exploitable time (FULLEQUIPPT) [1].

2.2 Survey Method

An online questionnaire survey was conducted, in order to validate quantitatively the twenty aforementioned selected ideas against three distinct criteria: utility, feasibility and innovativeness. The selection of the appropriate set of criteria comprises a significant step. Based on "FAN" method from the Synectics problem-solving tool [2], a proposed set of criteria to assess any innovative idea should include attractiveness, novelty and feasibility. In addition, "SNIFF" test for innovation decision-making includes Strategy, Need, Impact, Feasibility, Feel (SNIFF) [3]. Another evaluation framework for innovative urban and interurban freight transport solutions used the following criteria: financial viability, costs and benefits to society, integration of stakeholders' opinions [4]. New, creative ideas should be evaluated in terms of their feasibility, effectiveness, efficiency and profitability [5].

In order to ensure that the questionnaire would be comprehensive and "attractive" for the participants and receive as many answers as possible, it was decided to keep the number of criteria low. Finally, taking into account the related literature and considering possible combinations of evaluation criteria, the three (3) aforementioned criteria (utility, feasibility, innovativeness) were selected as more appropriate for the scope of the survey, namely the evaluation of ideas resulted through collective intelligence approaches.

The evaluation questionnaire was designed in such way to allow both the analysis through descriptive statistics using 10-point scale and the application of the Analytic Hierarchy Process (AHP). Participants were asked to rate each one of the aforementioned ideas/concepts, in terms of their feasibility, utility and innovativeness by using a 10-point scale, with 0 being the minimum and 9 the maximum rating/score.

Relevant scientific debate on which point scale (e.g. 0 to 5, 0 to 7, 0 to 10 or 1 to 10 scales) is more appropriate, does exist. The human mind can absolutely judge and distinguish about seven distinct categories and can compass its attention about six objects at the same time, so any increase in the number of responses above 6 or 7 might be ineffective [6]. The 5-point scale increases the response rate, as it seems to be less confusing for the respondents [7]. The 1 to 10 scale produces more missing data than 0 to 10 scale, while the 0 to 10 scale with 5 stated as midpoint (0–5–10 scale) has lower number of missing data [8]. In order to facilitate the application of AHP, the 0 to 9 (10-point) scale had to be selected [9]. Apart from the evaluation of the ideas/concepts, the questionnaire included also some demographic and personal questions in order to shape the profile of the respondents.

The questionnaire was distributed online (through e-mails, social media, etc.) by the CIPTEC project partners to experts. The survey was conducted in June 2017. In total, 97 fully completed questionnaires were collected from respondents, originating from several European countries. In order to ease potential respondents and make them more willing to participate, the questionnaire was provided in five languages (English, Greek, German, Dutch and Italian).

The main objectives of the survey were (i) the examination and discussion of the ideas/concepts' scoring in absolute values against each criterion in order to conclude on the effectiveness and potential of the collective intelligence methods towards the generation of valuable results and (ii) the examination of the variations of the collected answers both in terms of each innovation and each criterion. In addition, the analysis of the answers assisted us to analyse innovative concepts and ideas against each criterion separately, enabling comparisons between the innovative concepts and ideas and allowing also the selection of the most suitable ones, according to the priorities that will be set by a decision maker any time.

3 Results

3.1 The Profile of the Respondents

The sample is constituted of 77 men and 20 women with an average age of 49 years old. In more details, the majority of the participants (50.52%) were between 45 and 64 years old, while the 35.05% of the participants were between 25 and 44 years old. Concerning the allocation of the respondents in the various working sectors, 32 persons are working in PT sector, 18 persons in Businesses/Industry and 15 persons in the academic sector. Fewer are those who are working for the government, organisations of civil society and at other sectors.

Regarding the PT use the vast majority of the participants (89.69%) referred that they are PT users. Participants were also asked to assess themselves in relation with their current knowledge on Transport issues. Almost half of them (52.58%) stated that they have received extensive formal education/training on Transport issues, while 30.93% of them answered that they are getting updated frequently on the topic and/or part of their education/professional activities are related to this topic.

3.2 Descriptive Analysis of the Survey's Results

For each innovative concept/ideas the participants were asked to answer three questions: *"How useful each concept/idea is?", "How feasible the implementation and the operation of each concept/idea is?" and "How innovative each concept/idea is?"*, particularly by evaluating their **utility (util.), feasibility (feas.) and innovativeness (inv.)**. The results (util., feas., inv.) for each criterion separately and the total results (all) of the three criteria in combination for each one of the concepts/ideas are presented in Table 1. The calculated Mean of each innovative concept/idea represents the arithmetic average of the grades given by the 97 respondents in each one of the four cases (for each criterion separately and for the combination of them). The total score, namely, the sum of the three distinct scores – for utility, feasibility, innovativeness was calculated and the innovations were ranked starting from the highest **Mean** value of total score (see column: '**Mean (all)**') to the lowest one. The **Standard Deviation (Std. Dev.)** represents the degree of variation of the collected answers. In more details, a low Std. Dev. value prompts to a high degree of consensus among participants, while a high Std. Dev. value prompts to a lower degree of consensus among experts.

In terms of the results, "MAAS" is ranked in the first place, while "RETI-JOURNAPP" and "FULLEQUIPPT" complete the three top-ranked concepts. The Std. Dev. values of these three innovative concepts/ideas are quite similar, indicating that

Table 1. Results from the survey for the three criteria separately and in total.

Innovation	Mean (all)	Std. Dev. (all)	Mean (util.)	Std. Dev. (util.)	Mean (feas.)	Std. Dev. (feas.)	Mean (inv.)	Std. Dev. (inv.)
MAAS	19.55	5.530	7.26	2.128	6.33	2.164	5.97	2.439
RETIJOURNAPP	18.68	5.409	6.90	2.028	6.55	1.963	5.24	2.768
FULLEQUIPPT	18.32	5.687	6.97	2.079	6.51	2.122	4.86	2.784
PASSCOUNT	18.28	5.241	6.40	2.383	5.92	2.003	5.97	2.275
CITMARK	18.26	5.026	6.79	2.010	6.80	1.801	4.67	2.625
ADVETICKET	18.25	6.630	6.42	2.605	5.57	2.462	6.27	2.644
DATAMIN	18.10	5.797	6.58	2.304	6.32	2.182	5.21	2.398
PTWIDGET	17.86	5.918	6.04	2.384	6.65	1.915	5.18	2.610
PTEVENTICK	17.80	5.407	7.03	2.138	6.96	2.150	3.81	2.807
BLIP	17.60	6.523	6.41	2.503	5.19	2.663	6.01	2.671
GRTECH	17.11	5.914	5.93	2.442	5.91	2.146	5.28	2.617
FLEXPRIC	17.00	5.656	6.54	2.213	5.97	2.413	4.49	2.471
PTSEATSAPP	16.61	6.330	5.85	2.607	4.98	2.586	5.79	2.445
ONDEMAND	16.60	5.797	6.56	2.179	5.68	2.321	4.37	2.709
ENVAPP	15.53	5.700	4.37	2.647	6.55	2.057	4.62	2.644
EINK	15.11	5.686	4.96	2.545	5.69	2.307	4.46	2.533
MOBCHARLOCK	14.46	5.903	4.46	2.642	6.13	2.308	3.87	2.687
SOCIALAPP	14.42	5.209	3.55	2.424	6.20	2.197	4.68	2.506
UMBRBRAND	14.37	5.795	5.31	2.555	5.70	2.554	3.36	2.425
PTFUND	12.79	6.422	5.05	2.759	3.90	2.502	3.85	2.567

there was consensus among the participants for these concepts. These results are quite similar but not absolutely the same with those derived from the AHP analysis, which was conducted for ranking quantitatively the concepts [9].

As Table 1 indicates, the means are in all three cases (for each one criterion) over 4.5. This may mean that the outcome of the collective intelligence's processes is appreciated as 'acceptable' against all three criteria. In addition, the ideas received in general higher scores by the participants against the criterion of "Utility", while the scores against the criterion of "Feasibility" and "Innovativeness" follow, respectively. This finding shows that attendants in the collective intelligence's processes were inclined to think and generate pragmatic ideas that would be primarily 'useful' for PT users and for the PTAs and PTOs as well, and secondary, 'feasible' in terms of various aspects (e.g. technical, financial, legal, etc.) in order to be easily implemented.

Based on the distribution per criterion of the 20 Mean scores for each concept/idea, the three Std. Dev. of the 20 observations were calculated. In more details, Std. Dev. is 0.715 for the case of feasibility, 0.832 for the case of innovativeness, and 1.025 for the case of utility (due to space restrictions the respective diagrams are not provided). This measure indicates that there is a higher level of consensus on the rating placed for the examined concepts against feasibility, and lower level of consensus in the case of the two other criteria. This finding seems to be reasonable, in the sense that feasibility by its nature lies on more stable and objective parameters. On the other hand, innovativeness sounds as a more subjective and conceptual criterion. At last, both innovativeness and utility are highly depended on the person that judges and on his/her priorities, needs, experiences, as well as the view-point that chooses to look the world. To paraphrase a well-known quote, the innovativeness and utility lie more in the 'eye of the beholder'.

4 Discussion

Three scatter plots (Figs. 1, 2 and 3) have been designed for three possible combinations of criteria, depicting the position of each concept based on its Mean value in terms of each one of the three criteria. This approach allows graphically the quick visual identification of those concepts that score high values for two criteria at the same time. By attempting to identify groups of innovative concepts/ideas that are placed closed to each other, sharing a common aspect or characteristic, someone could come up with some interesting conclusions and remarks (Tables 2 and 3).

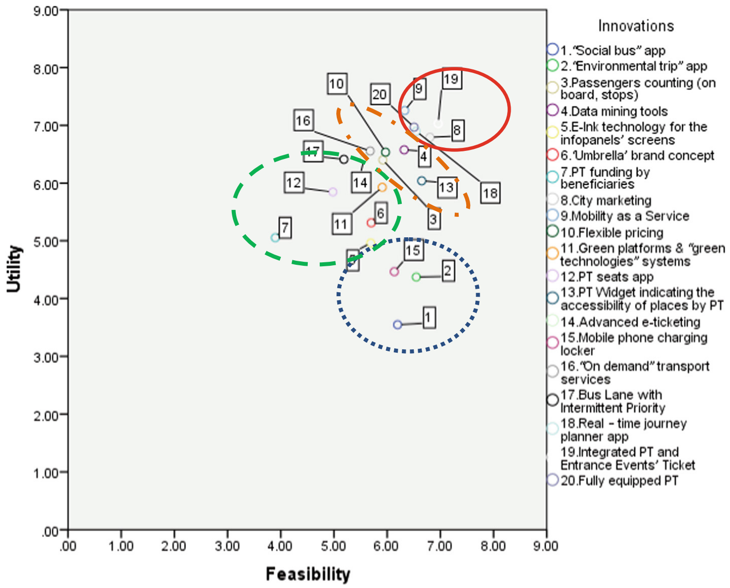

Fig. 1. Plot of the Mean scores for each concept for Utility and Feasibility.

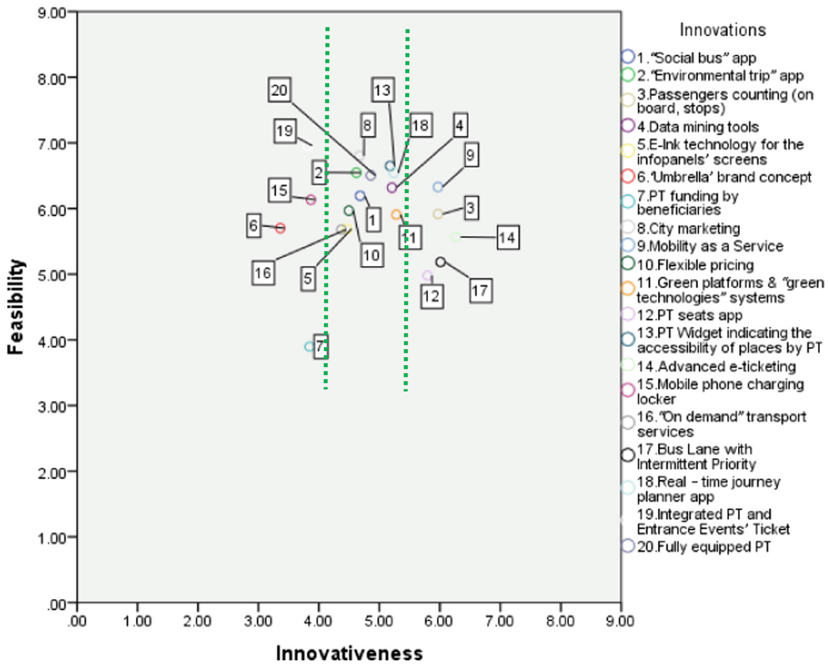

Fig. 2. Plot of the Mean scores for each concept for Feasibility and Innovativeness.

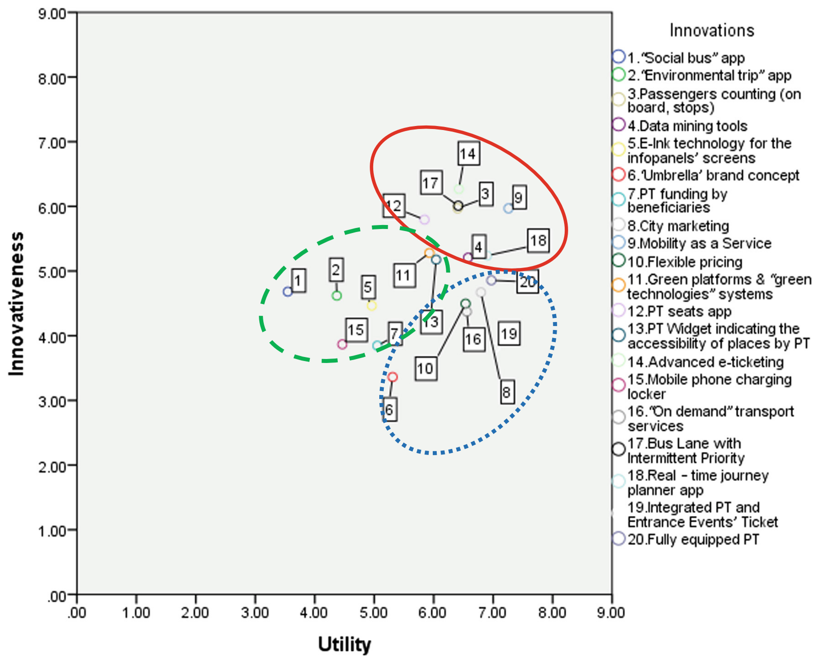

Fig. 3. Plot of the Mean score for each concept for Innovativeness and Utility.

Table 2. Groups of innovative concepts/ideas, sharing a common characteristic.

Figure 1	
Red ———	Integration of the PT system
Orange – · –	Personalisation of the services provided to the passengers
Blue ·······	Supporting passengers by supplementary services
Green – –	Improvement of 'efficiency', supporting the PT system

Table 3. Groups of innovative concepts/ideas, sharing a common characteristic.

Figure 3	
Red ———	Concepts associated with the 'new technologies having a direct impact on the Level of Service (LoS)' for the majority of the passengers
Green – –	Ideas that are dependent on technology, have an indirect impact on the LoS
Blue ·······	Ideas enabled by new technologies, have an indirect impact on the LoS
Figure 2	None distinct group can be visually identified as in the previous cases. Innovation front-running, moderate and followers ideas can be distinguished

5 Conclusions

There is a vast variety of structured methodological ways of evaluating different objects in any field of interest. In this paper, our aim was to evaluate the concepts/ideas derived from collective intelligence's processes, whose implementation could positively influence the demand for PT services, by using 3 distinct criteria. Since ideas were suggested by the citizens themselves it is sensible that their proposals would focus on increasing their utility, paying less attention on the feasibility and innovation aspects, lacking the motives and background to create something new from the scratch. The results enabled us to comment on the criteria nature itself, pointing out that there was a higher consensus in the case of the scores against feasibility, compared to the case of the innovativeness and utility, indicating that feasibility may be interpreted in a less subjective way.

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A Concept for Smart Transportation User-Feedback Utilizing Volunteered Geoinformation Approaches

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Abstract. Public transport systems – especially demand responsive transport – lack a direct feedback possibility for customers. Contemporary approaches allow post-mortem feedback, where the consumer has to input detailed data of past travel experiences. Hence, it is hard to detect the location and time when and where the feedback was submitted, and in particular it is hard to trace the location of the incident that leads to the feedback (e.g. on which line/route, on which exact train the incident happened). Therefore we propose an approach for submitting feedback, that utilizes the current position of the customer. The approach draws on Volunteered Geographic Information (VGI), which is a special case of user–generated content coupled with participatory approaches in Geoinformation. Thus, the approach followed in this paper presents a concept that allows instant feedback, including the current position and timestamp. This approach allows the instant detection "where" an incident happened leading to costumer feedback (e.g. on which train, on which bus). A pilot implementation is tested and critically evaluated in a test region located in the municipality of Gratwein–Straßengel (Province of Styria, Austria). The experiment is conducted in a demand responsive transport system, where we monitor the feedback behavior of the customers using a smart-phone feedback application. The results show, that the concept utilizing VGI–methodologies was successfully applied to a demand responsive transport system. In addition, the results show that the approach provides instant feedback on problems and incidents for decision makers and transport managers, including the crucial information "where" and "when" something happened. In the first two weeks of operation, we received 55 customer feedbacks – of 175 ordered trips – of which the majority was positive and requested the transport service to be expanded in future.

Keywords: Volunteered Geographic Information · Citizen Science Public transport

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1 Introduction

Volunteered Geographic Information (VGI) are present in a wide variety of feedback or information applications, whether it is for cleanliness in cities, damages or defects of public property, dangerous spots in bicycle traffic or maybe a cycle route which is experienced as positive [21]. And yet, during a journey with public transport systems, there exist several difficulties to give direct feedback to the service provider - especially "where" and "when" an incident happened. Often, the issues the customer would like to put forward, are forgotten by the end of the trip or shortly afterwards. In this paper we make an approach for a real-time feedback system, which is based on VGI approaches, to detect "where" and "when" the feedback was provided. Therefore we developed an application tailored for customers of a demand responsive transport system in the municipality of Gratwein–Straßengel.
A demand responsive transport system is a special type of public transport, which is offering sustainable and independent mobility solutions for rural population [17]. It is not limited by the classical modus operandi of public transport systems, like given predefined routes and a fixed schedule.
Since the Word Wide Web was invented, it developed from static document-based information to dynamic high–performance and user–friendly services and finally evolved into a machine-readable web of data. Today the Internet is called "Web 3.0" or Semantic Web [3,4]. The term VGI was first described by Michael Goodchild in his publication "Citizens as sensors: the world of volunteered geography". Through the evolution of the Internet to Web 3.0, users can contribute to data collections that are open to the public as well. As a result user–generated–content projects are on the rise since then [7]. Popular examples of such projects are Wikipedia or OpenStreetMap (OSM) [10]. VGI therefore is a special type of user–generated–content in particular user–generated–geographic–content, where people voluntarily apply there position. The three most frequently used methods of VGI are

- Base Mapping Coverage
- Emergency Reporting
- Citizen Science [5].

Due to length restrictions, Base Mapping Coverage and Emergency Reporting cannot be described here, we focus on Citizen Science (CS). The term CS describes the involvement of communities for scientific purposes [12]. Hakley named different types of CS, where he listed crowdsourcing as most common one is. In this case people act as sensor and provide data for companies or scientific purposes [11]. An example for CS is the e Audubon Society's Christmas Bird Count, conducted by non-professional ornithologists.

Hence, we decided to utilize CS - in particular crowdsourcing - in public transport systems - and in particular in demand responsive transport systems. In our case the customers will provide the data in form of real–time feedback. This is approach is utilized to determine whether VGI is helpful for getting feedback for planning and decision making purposes in demand responsive public transport. The paper is organized as follows. Section 2 gives an overview of related work, which uses VGI in public transport or traffic management. Section 3 elaborates on the research design and methods used to provide and prepared the data. Section 4 presents the field test and the prototype framework. Finally the results, evaluation and interpretation are presented in Sect. 5. In Sect. 6 we give a conclusion and some future research directions on how VGI can be utilized in public transport.

2 Related Work

Verkehrplus [20], Nunes [14] and Teymurian [19] used approaches for getting real-time feedback which are very similar to the one in this paper. Especially the works of Verkehrplus and Nunes present examples for applications enabling real–time feedback, including position and timestamp of the feedback. The prototypes were tested under real-world conditions in the Province of Styria, Austria and in the City of London. By contrast, [19] developed a conceptual framework, based on a cooperation of VGI for quality measurement and an automatic data collection for performance measurement in public transport. Both data sets - quality and performance data should help to identify the weaknesses of existing public transport systems and help to find solutions for it.

Attard [1] and Steinfeld [16] described the potential of using VGI for collecting data in public transport. Filippi et al. [6] pointed out how crowdsourcing can be part of public transport planning. In this study the population are integrated into process of planning from the beginning until the full implementation of public transport solution strategies.

Apart from public transport other studies show how VGI can improve bicycle traffic in cities. Therefore, Griffin and Jiao [9] as well as Nelson et al. [13] demonstrated how the applications “Strava” and “BikeMaps.org” can help in planning and safety issues.

3 Research Design

The research design of the study is divided into four distinct phases: questionnaire design, smartphone application prototype, field test, data evaluation. The research design should help to answer the question if crowdsourced information is helpful for demand driven public transport.

First we developed a simple questionnaire that is tailored towards the usage in a mobile application. In addition, the questionnaire should be rather short, so that customers can finish it while driving with the public transport system. Also, we designed the questions in a way that they are easily understandable and do not require lengthly responses from the customers. Hence, we came up with 14 questions of which thirteen cover the following topics: personal data, mobility behaviour and whether the demand responsive system is going to be accepted by the rural population or not. The last question referred to the position and a timestamp - if it is accepted by customer that we track the position and the time of their response.

Secondly, we developed a smartphone application prototype that is presents the questionnaire to the customers and stores the feedback from them on a database server. The application prototype shall be tested in real-world conditions, in order to see if the crowdsourcing approach works in a demand responsive transport system. In addition, the test shall reveal, if the transport system is accepted by the rural population of the municipality Gratwein-Straßengel.

The analysis step involves a spatial-temporal analysis of the feedback obtained by the smartphone app. The evaluation and analysis requires analysis methods from Geographic Science and Technology (GIS&T) and a Geographical Information System (GIS).

4 Field Test and Framework

The field test was conducted in October 2017, the test subjects were the customers of the demand responsive transport system in a municipality in the north of Graz in Styria. The municipality of Gratwein-Straßengel has 13.000 inhabitants and covers an area of 86,69 km^2. The community is composed of the districts Gratwein, Judendorf–Straßengel, Eisbach and Gschnaidt, which are crossed by two railway lines and five bus lines. In order to provide a better connection for inhabitants who are not within reach of bus stops, train stations and district cores, the commune established a demand responsive transport system. The service time of the demand responsive transport is from Monday to Friday from 08:00 am to 07:00 pm.

The smartphone application to collect crowdsourced data, consists of a front- and a backend. The frontend utilized the jQuery framework for the layout and for the responsive design of the application. Java script functions were used for the positioning via GPS and for gathering the timestamp. Regarding to the positioning we use the "geolocation API" - an application programming interface, which determines the current position via GPS. If no GPS–signal is available the API utilizes cell towers, a wireless network or the IP–address to determine the position. The Backend of the application is based on PHP for the server connection and transmission of the data. A PostgreSQL/PostGIS database is used to store the data accordingly.

5 Results

The results of the study reveal the following results. First we elaborate on the where the feedback was sent, and the overall response rate. Secondly, we have a look at the customers and their usage of the demand responsive transport system. This is followed by an evaluation of the alternative mobility choices of the customers - if no demand responsive transport would have been realized.

The results show that 55 of 175 customers provided a feedback - which equals to a response rate of 31%. The position of each provided feedback is depicted

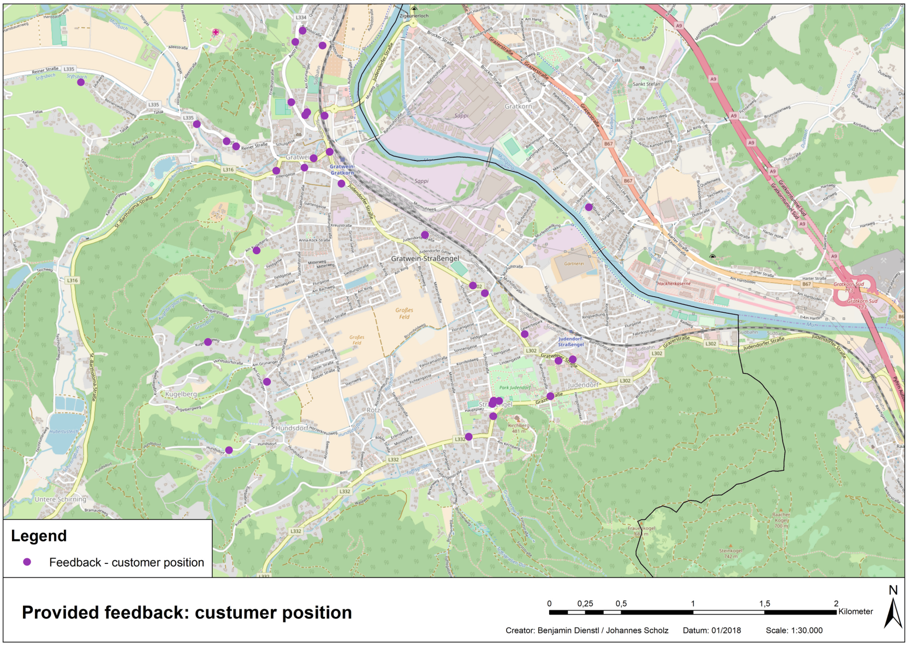

Fig. 1. Provided Feedback – customer position on a OpenStreetMap basemap.

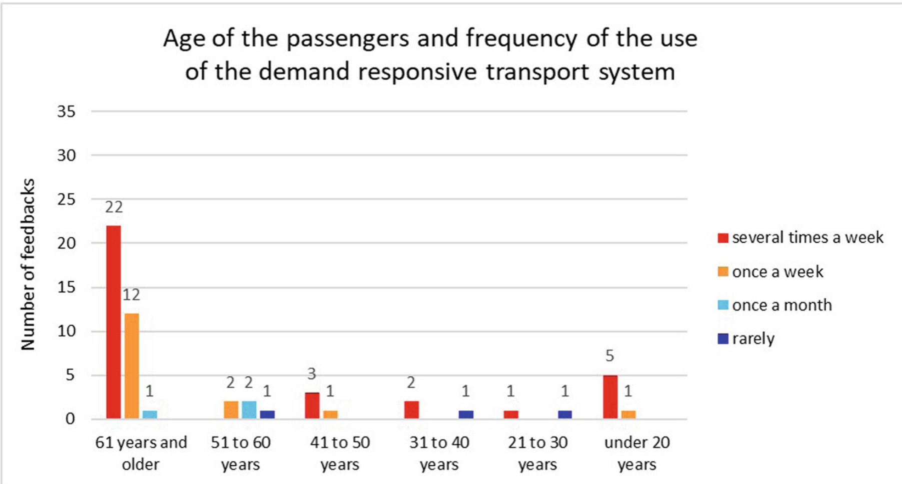

Fig. 2. Age of the passengers and their usage frequency of the demand responsive transport system.

in Fig. 1. The customers that provided feedback are predominantly over 60 year of age. 35 of 55 persons that used the feedback application were over 60 years of age, which equals to approximately 64% of persons over 60 years (see Fig. 2).

More than 58% of the customers use the demand responsive transport system several times a week.

The questionnaire also revealed the alternative mobility choices of the customers - in case the demand responsive system would not be in place (see Fig. 3). Most of the responses show that there is no other public transport as alternative available. Eight persons responded that they would use their own car, 12 persons would use a car as passenger, and nine responders would have to use a taxi instead. Thus, 29 of 55 customers would use a car - i.e. private car, car as passenger, taxi - as alternative way of mobility. Interesting is the fact, that six persons are stuck at home without demand responsive public transport, only 4 could switch to public transport. Nine and seven persons could use their bicycle or walk on foot respectively.

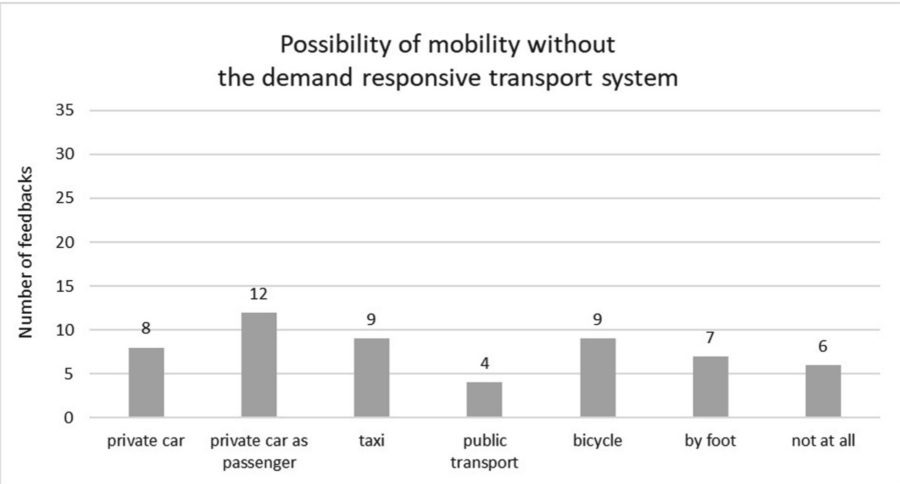

Fig. 3. Alternative mobility choices without the demand responsive transport system.

6 Discussion and Conclusion

This section is intended to discuss the results obtained - which are presented in Sect. 5. In addition, we try answer the research question and draw conclusions from the findings of this paper.

The test of the feedback prototype in a period of two weeks shows that we received 55 customer feedbacks – of approximately 175 ordered trips within ten days which equals to 31% response rate. The feedback positions (see Fig. 1) show that most of the feedbacks were provided in the districts of Gratwein and Judendorf–Straßengel. This is due to the higher population density in those areas, and the fact that shops and public authorities are located in this town centers. The results of the questionnaire indicate that most of the customers, who use the demand responsive transport several times a week are 61 years and older. The second largest user group are customers under 20 year of age. They are using the transport system to get home from school.

Worthwhile emphasizing is the fact that only four customers have the possibility to use any of the existing public transport systems. This means that from the provided feedback, 93% (in total 51) of the trips were newly generated trips (see Fig. 3). Hence, we argue that an increased offer of public transport systems will generate new customers - here under the following conditions:

– The transport system is flexible enough to fulfill the travel demands of the customers (i.e. a demand responsive transport system).
– The customers do not have alternative means of public transport, which is especially true for rural areas (such as our test area).

With respect to planing and decision making with the help of a demand responsive system, we would like to highlight the fact that responses from customers can be directly used to improve the transports system. An example is the installation of additional benches and access aids, as customers are 61 and older. Furthermore the establishment of new stops in the district centers of Gratwein and Judendorf–Straßengel would be beneficial for older customers.

From the results obtained and the relevant literature, we can conclude that collecting feedback in public transport systems - especially demand responsive ones - with VGI–approaches seem to be a promising methodology. In comparison to conventional methods of collecting feedback, where customers have to visit the homepage and complete a short survey about their experience [8], the possibility to provide instant feedback, including "where" and "when" an incident happened, may reduce the reaction time of transport managers. With the removal of entry barriers, the user requires a shorter period of time for the input and therefore providing feedback becomes way more user-friendly. This can be justified by a response rate of 31% in contrast to conventional methods of collecting feedback without any recruiting phase which are significantly lower (e.g. [2,15,18]). Hopefully this may motivate customers to provide feedback more often - even if only minor nuisances are detected, which might get forgotten in a post-mortem feedback system.

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Operating Resilience of Severely Disrupted Urban Transport Systems

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Abstract. A disruption to Athens metro service due to simultaneous malevolent attacks in metro lines 2 and 3 is examined in this paper. The directly impacted area is part of the metro network outside the central metro ring defined by interchange stations Syntagma, Monastiraki, Omonia and Attiki, where detours are not possible. The area covers metro sections in the western part of Athens where the population is more transit dependent. The Strategic Transport Model of Attiko Metro (AM) has been used to assess the consequences in case no alternative transport is provided and in case of bus bridging provision.

Keywords: Resilience · Bus bridging · Metro disruption · Multi-modality

1 Introduction

Metros have been targets of attacks i.a. in Tokyo (1995), London (2005) or Brussels (2016). The study conceptualizes the resilience management of Urban Transport Systems (UTS) considering bus-metro substitution effects. The paper is the first to our knowledge that does not assume the metro as a closed system in case of an attack and considers a resilient response within the frame of a multi-modal network. A system-level modeling of supply and demand impacts is applied in this respect.

2 Connection with RESOLUTE Guidelines

Within the scope of RESOLUTE project [1], guidance is provided to UTS and in particular Public Transport (PT) stakeholders, on how to integrate their resilience-related procedures into a common shared framework, to improve coordination of operations and reduce UTS vulnerability. RESOLUTE focuses on knowing and improving all system functions instead of addressing solely risk management needs. The functions are generic enough to address varying UTS in Europe.

A main output of RESOLUTE is the development of European Resilience Management Guidelines (ERMG). The produced ERMG have been applied and tested in real-life scenarios in project test sites, i.e. in the city of Florence and in the Athens Metro. In the case of Athens Metro, the function ‘Restore System Operations’ is being tested through the evaluation of alternative scenarios with a varying level of service provided by bus bridging substitution during a severe metro disruption. The goal of this

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function is to restore routine UTS activities that were disrupted to their prior level of service. The function encompasses activities planned before a disruption (such as Disruption Recovery Plans) and those implemented after the serious incident. The function must have sufficient resources available at an acceptable level at least for a short-term recovery. The restoration of modal services exploits in case cross-modal network synergies of the UTS.

3 Case Study: Athens Metro Network

3.1 General Characteristics of Athens Metro Network

Athens PT network consists of 3 metro, 3 tram, 4 suburban rail, 15 interurban bus & 303 bus lines. The 3 metro lines (L1, L2 & L3) have 65 stations, 4 of which are interchange stations connecting respective line pairs. ‘Attiki’ and ‘Omonia’ stations connect L1&2, ‘Syntagma’ station L2&3 and ‘Monastiraki’ station L1&3 (Fig. 1).

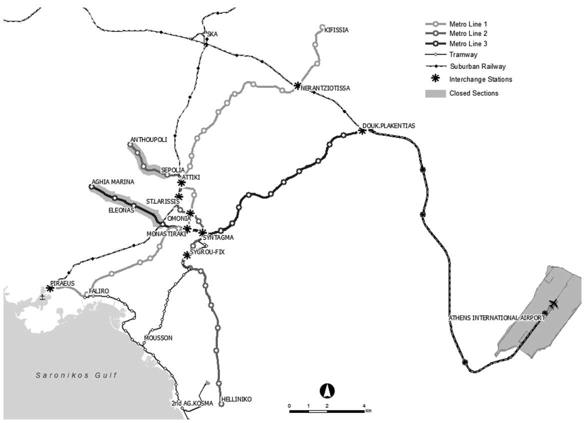

Fig. 1. Athens metro network.

3.2 Base Year Analysis

The recession in Greece during the years 2008 to 2015 affected both the demand and the supply of the UTS. The supply of the PT system has varied with differing rates among transit modes. Operated metro vehicle-kms (L2&3) increased by 24%, mainly due to the introduction of 10 new metro stations (Table 1). However, the counteracting decrease by 29% of the operated metro vehicle-kms in L1 let the total metro vehicle-kms almost unchanged (decrease by 0.4%). Operated bus vehicle-kms decreased by 27% during the same period. The latter decrease is due to: (a) the restructuring of bus lines to adjust to the extensions of L2&3 and (b) a frequency decrease for numerous bus lines due to the recession (2013, 2017 data). In addition, the fare index increased by almost 32%. The fare level increase was even larger for captive bus riders due to the abolishment of the low-priced monthly bus pass since 2014. The Consumer Price Index which demonstrates the trends in prices and inflation in Greece was used to deflate the fare prices (base year 2008). In parallel, bus ridership decreased more than 30%, while the respective decrease of metro boardings was almost 23% [2].

Table 1. Variation of factors impacting transport demand (2008–2015).

Impacting factors	Value 2008	Value 2015	% change
Public transport fare index	0.63	0.83	+32%
Metro vehicle-kms (Line 1)	23,136	16,488	−29% [2]
Metro vehicle-kms (Lines 2&3)	26,906	33,349	+24% [2]
Bus vehicle-kms	122,752	89,200	−27% [2]
Car fuel price index	1.08	1.48	+37% [3]

3.3 Athens Metro Case Study Scenarios

A major disruption to Athens metro service is examined, due to simultaneous malevolent attacks in L2&3 in the western part of Athens, where metro detours are not possible and people are more transit dependent. The Transportation Model of AM has been used in order to assess the consequences in the case that no alternative transport service is provided as well as in case of bus bridging. Three scenarios are being examined:

- Scenario 0 (S0) in which the PT network presents the current state
- Scenario 1 (S1), ‘Do Nothing’, in which L2&3 are partially closed while the residual PT network remains the same with S0
- Scenario 21 (S21), ‘Do Something’, in which on top of the closed metro stations of S1, bus bridging adjustments occur.

4 Methodology

4.1 Model Structure

In the context of the Metro Development Study [4], AM developed a Strategic Transportation Model for the UTS of Attica region, which has subsequently been updated (2006) using data from the following studies: (a) OASA Travel Survey (2006), comprising Origin-Destination Surveys, Trip Survey and Traffic Counts in Mass Transit Modes, and (b) AM study entitled “Passenger Travel Surveys in the Transport Means of Attica Region” (2008–2010), comprising a Road Side Survey and Ridership On-Off Counts in the metro and suburban rail system.

AM Transportation Model is a typical 4-stage multi-modal model and has been used in the present study to examine alternative scenarios in case of the said attack in the Athens Metro System. EMME/4 software has been used for the development of the model. The analysis concerns the morning peak (m.p.) hour in the typical period. The data used for the calibration of the model describe the supply and demand of the UTS for 2016 (study base year). The following data were collected and analyzed: (a) Headways of bus and urban rail modes (2016); transport model update (b) Annual ridership data per PT submode (2008–2015) (c) Annual operated vehicle-kms per PT submode (2008–2015) (d) PT compound fare index (2008–2015) (e) Transport demand impacting factors (disposable income, GDP/capita, fuel price).

4.2 Bus Demand Elasticities

Within the trip generation stage of the model application, trip rates over all travel modes in Attica have been reduced by 15% -i.e. applied to the total journeys generated- to take into account the recession impact on travel demand. Following the application of all modeling stages, validation results were satisfactory for both private and PT submodes, with the exception of the bus ridership. For that reason, bus ridership has been post-processed through the application of supply and fare elasticities and has been adjusted accordingly. Factors identified as the most influential for bus demand including fare and quality of service as well as elasticities chosen, are presented in Table 2. The elasticity applied concerning the influence of the fare level on bus ridership (−0.15) is a revised value of a coefficient estimated in 2004 [5] considering metro extensions since then. The cross-elasticity of car fuel price has not been considered, as bus passengers are essentially captive riders. Bus ridership reduction is estimated to 15% using function (1); the percentage (%) change in ridership V_i of a mode i is the weighted average of percentage (%) changes in each demand-influential factor F_j, where the respective demand elasticities E_{Fj} are the weights [6, 7]. This elasticity-based bus demand change remained fixed through all scenarios investigated.

$$\frac{\Delta V_i}{V_\imath}(\%) = \mathrm{E}_{F1} * \frac{\Delta F_1}{F_1}(\%) + \mathrm{E}_{F2} * \frac{\Delta F_2}{F_2}(\%) + \ldots + \mathrm{E}_{Fj} * \frac{\Delta F_j}{F_j}(\%) \quad (1)$$

Table 2. Combined elasticity-based bus demand change (2008–2015).

Impacting factors		% change	Elasticities	% demand change
Fare level	PT fare index	31.75%	−0.15[a]	−5%
Service level	Bus vehicle-kms	−27.33%	0.38 [8]	−10%
Sum				−15%

[a][5], revised due to PT system expansion since 2004

4.3 Scenarios Description

Scenario 0 (S0) represents the current state of both PT and road network.

S1 simulates the case where simultaneous malevolent attacks take place in L2 (Sepolia station) and in L3 (Eleonas station, including severe damage in Eleonas depot), while the residual PT network remains the same with S0. A disruption of metro service in ‘Sepolia – Ag. Antonios’ and ‘Eleonas – Egaleo’ sections will lead to the closure of 3 L2 stations (Anthoupoli, Peristeri, Ag. Antonios) and 3 L3 stations (Ag. Marina, Egaleo, Eleonas) (Fig. 1). Pertaining to bus lines and road network, there is no change compared to S0.

S21 is the result of alternative scenarios examined with a differentiation in bus service. At the initial scenario examined (Scenario 2, S2) the PT network had been adjusted with a completely new shuttle bus service between the closed metro stations, while some feeder bus lines to the closed metro stations are extended to other metro stations in service. S2 showed that shuttle bus lines passing through the closed metro stations and bridging them with the first metro station in service were not attractive for passengers mainly because of the extra transfer needed. The low ridership of the new shuttle bus lines in combination with the lack of sufficient number of bus vehicles led to the use of bus vehicles retracted from nearby lines either to extended feeder bus lines or to bus lines leading directly to the city center (S21: without shuttle buses).

In the case of L2, 2 bus lines passing through all 3 closed metro stations have been extended up to Metaxourghio station and 2 feeder bus lines to Ag. Antonios extended to Sepolia station. In addition, headways of other 2 bus lines (012, A13) passing through all 3 closed metro stations and leading to the city center have been decreased compared to S0. In the case of L3, 2 feeder bus lines to metro station Ag. Marina and 4 feeder bus lines to metro station Egaleo have been extended to Keramikos station. Moreover, headways of 2 of the aforementioned extended bus lines (820, 852) have been decreased. The 29 extra bus vehicles required for the above modification of the bus lines, have been retracted from other nearby bus lines with the following constraints: (a) the average load factor of the nearby bus lines was lower than 0.5, (b) the number of vehicles that serve each bus line was greater than 2 and (c) the said bus lines either had no direct impact on the area nearby the closed metro stations or the closure of metro stations resulted in very low passenger volumes.

Pertaining to the Private Means network, the existing road network under its current configuration state has been left unchanged.

5 Results

5.1 Modal Split and Traffic Assignment on PT Network

Modal split remains unchanged among different scenarios: 46% of the journeys are made by private modes, 42% by PT and 12% are walk trips. Total demand is considered inelastic, thus the demand remains fixed in all examined scenarios.

The partial closures of L2&3 cause a decrease in metro demand by 10.7% in case that no alternative transport service is provided (S1), whereas the total travel time decreases by 8.6%. On the other hand, in case that alternative transport service is provided (S21), metro demand decreases by 8.5% compared with S0, while the total travel time decreases by 4.5%. It should be noted that metro demand includes all the journeys with at least one metro boarding and that travel time refers to in-vehicle travel time in all PT modes used for the latter journeys.

Scenario 0. In S0, almost 93,000 trips (boardings) are made by metro during m.p. hour. L1&2 are those that attracted more trips, with 32,420 and 32,300 trips respectively, followed by L3 with 28,160 trips. The max. ridership comes up on L2, in a city-center segment with almost 12,000 trips. The critical segments affected by the attacks serve the densely populated areas in the western part of the city: on L2 5,600 and on L3 4,100 *non-satisfied* trips are observed.

Scenario 1. The closure of metro segments 'Anthoupoli – Sepolia' (L2) and 'Ag. Marina – Keramikos' (L3) without any further adjustment of the PT network decreases by 18.5% the boardings on L2 and by 19.7% the boardings on L3. Boardings on metro decrease in total by 11,450 (about 6,000 less boardings on L2 and 5,500 less boardings on L3). Boardings on buses operating nearby the closed metro segments vary according to the configuration of the bus lines. There is a decrease in the ridership of the feeder bus lines to the closed metro stations by 37% and an increase in the ridership of the trunk bus lines leading to the city center by 98%.

Scenario 21. The extension of existing feeder bus lines to an operating metro station increases by 2,200 boardings on metro L2&3 compared to the 'Do Nothing' S1. In comparison with S0, metro ridership decreases by 17.9% on L2 and by 12.6% on L3. In the 'Do Something' scenario, boardings on feeder bus lines to closed metro stations (L2&3) that were extended to stations 'Sepolia' and 'Metaxourghio' are slightly increased compared with S0 (300 more boardings), while boardings on the feeder bus lines that were extended to station 'Metaxourghio' (L3) increased by 72% (2,650 more boardings). On the other hand, boardings on trunk bus lines related to L2 increased by 200% compared with S0 (3,300 more boardings), while boardings on trunk bus lines relevant to L3 increased by 30% (1,500 additional boardings).

In case of a major disruption of metro service in sections 'Anthoupoli – Sepolia' (L2) and 'Ag. Marina – Keramikos' (L3), whereas the PT network is configured as described in Sect. 4.3, most passengers previously served by metro stations Anthoupoli, Peristeri & Ag. Antonios of L2 would travel directly to the city center by bus. On the other hand, most passengers previously served by metro stations Ag. Marina, Egaleo & Eleonas of L3 would travel by bus to Keramikos station and continue their journey by metro. This difference in submode choice between the metro riders of L2&3 shows that metro ridership recovery depends on the topology of the feeder metro stations as well as the structure of the bus network. Keramikos station operates satisfactorily as feeder station, while Sepolia station does not attract the expected ridership mainly due to the station location (Keramikos station is on the way to the city center) along with a sufficient substitution of L2 by bus lines (Table 3).

Table 3. Passenger volumes at metro segments of Lines 2 and 3.

Scenario	Sepolia-Attiki	Attiki-Sepolia	Sum L2	Keramikos-Monastiraki	Monastiraki-Keramikos	Sum L3
S0	6,838	2,537	9,375	4,801	4,144	8,945
S1	1,365	671	2,036	1,913	1,717	3,630
S21	1,650	759	2,409	3,748	2,253	6,001

5.2 Traffic Assignment on Private Means Network

The closure of L2 'Anthoupoli – Sepolia' and L3 'Ag. Marina – Keramikos' segments without any further change to the PT network (S1) induced an increase of road traffic in the western part of Athens. Even in the current state (S0) the 4 main overpasses of Kifissos Ave. (P. Ralli, Iera odos, Athinon Ave., E. Makariou), which connect central Athens and western parts of Athens, are overloaded. In that case, even modest increases in road traffic -because of the closure of metro line segments- can cause significant delay increases. For instance, in Iera Odos a $\Delta V/C = 0.02$ induces a $\Delta delay = 39$ s/veh or 3,300 lost (peak) PCU-hours in a 6-months closure period [9].

5.3 Key Performance Indicators (KPI)

KPI metric for demand recovery is a resilience indicator measuring the transport demand covered by residual metro and alternate carriage capacity as percentage of the transport demand reduction due to the attack [10].

$$\mathrm{KPI} = 100 \times \frac{\text{demand covered due to modal substitution}}{\text{modal demand reduction due to attack}} \quad (2)$$

In case of partial closure of L2&3 ('no alternative service' S1), 10.7% of the total metro demand remains unsatisfied (Table 4). A 82.8%-share of metro demand reduction is covered by bus and walk modes, while in the case of bus bridging provision (S21), bus and walk modes cover 85.1% of *non-satisfied* metro demand. Apparently, the metro demand decrease of 10.7% in S1 is partially recovered in S21, with a recovery rate of 20.3%. The PT network supply is proved quite resilient even in the case of S1, with a considerable resilience level gained in S21 (KPI increase over 85%).

Table 4. Resilience KPI for metro demand recovery (m.p.hour).

Scenario	Metro demand (journeys)	Metro demand reduction	Bus demand (journeys)	Bus demand increase	KPI
Scenario 0	81,251		114,737		
Scenario 1	72,589	−8,662	121,913	+7,176	82.8%
Scenario 21	74,349	−6,902	120,609	+5,873	85.1%

6 Conclusions

The scope of this paper is to investigate the consequences of partial metro line closures outside the central area of Athens where metro detours are not possible and in particular in the western part of Athens where people are more transit dependent and less affluent. AM Transportation Model has been used to assess the consequences in the case that no alternative transport service is provided as well as in the case that bus bridging is provided with buses retracted from nearby lines. It is noted that the resilience of the metro system has been studied as part of a wider multi-modal network, while in all known previous studies (e.g. [11]) the metro system has been studied as a closed one. This is an advance beyond the state-of-art.

In conclusion, in case of a major disruption of metro services both in L2&3 without any further change to the PT network (S1), PT demand decreases by 16,600 journeys. The non-satisfied PT demand is distributed by 80% to private modes and by 20% to walk trips. The bus bridging applied to the PT network (S21) mitigated the reduction of the PT demand due to the metro closure. In case of S21, PT demand decreased by 11,800 journeys compared to S0. Moreover, ridership recovery in L3 is larger than in L2. 'Keramikos' station serves satisfactorily as feeder station while 'Sepolia' station does not attract the expected ridership. This difference in submode choice between metro riders of L2&3 shows that metro ridership recovery depends on the topology of the feeder metro stations along with the structure of the related bus network. Finally, the PT network proved to be quite resilient even in the case of the "no alternative" S1 (82.8% demand recovery) with a considerable resilience level gained in S21 (demand recovery greater than 85%).

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Public Transport in Transnational Peripheral Areas: Challenges and Opportunities

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Abstract. In transport planning, the connection between peripheral and urban areas is a complex issue to be dealt with. Difficulties are even exacerbated when the trans-regional and transnational scales are considered. However, transnational commuting is an increasing phenomenon and regional policy makers should be able to face it adequately. This paper describes the main issues related to this topic and highlights some possible solutions. Then, it presents the condition of the Italian autonomous province of South Tyrol. This territory, at the border with Austria and Switzerland, is known for its well-developed public transport system, supported by an adequate infomobility and integrated tariff scheme. This grants a use of public transport per person that is among the highest at the national level. Despite this, some difficulties are still visible when the trans-regional and transnational scales are considered. A specific SWOT analysis illustrates the main aspects that still need to be addressed. The European Grouping of Territorial Cooperation can be the institutional body able to promote a better integration of the mobility among peripheral and urban areas in transboundary contexts.

Keywords: Transnational mobility · Public transport · South Tyrol

1 Introduction

The connections between urban and peripheral areas present peculiar challenges in terms of everyday mobility (typically, for working and studying reasons). This is due to several factors, such as low density, dispersed settlements and low travel demand, which make public transport (PT) service expensive and in most cases not effective [1]. Such difficulties are even exacerbated when the transnational dimension is considered. In this case, different legislative frameworks, policies and measures introduced at the regional and local levels make it difficult the connection between areas belonging to different countries. The lack of integration between administrations and PT operators may cause further difficulties, such as the limited cross-border PT connections or the unavailability of integrated tickets. As a result, in these areas the private vehicle is the most used transport mean, with all the related negative externalities in terms of air and noise pollution, accidents, congestion, etc. These consequences are even worse in mountain areas, where some externalities can be up to five times higher than in plain [2].

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In terms of travel demand, transnational commuting has been an increasing phenomenon since the beginning of the century, despite the restrictions on labour market regulations (e.g. working permits, transition periods), the insufficient acceptance of qualifications and the different tax and social security systems [3]. This poses relevant and rather new transport implications that have to be addressed.

This paper describes the first results deriving from an analysis of the transnational mobility between urban and peripheral areas performed in the EU-funded project "Connect2CE - Improved rail connections and smart mobility in Central Europe". Three intertwined areas have been found as essential elements that contribute to the enhancement of PT services of peripheral cross-border regions:

1. Connectivity, which includes public service operations and contracts, the harmonisation of multimodal timetables, as well as the improvement of regional and cross-border PT services;
2. Integrated and harmonized ticketing and tariff schemes;
3. Efficient and innovative ICT tools on info-mobility and payment systems.

The analysis is focused on the Italian autonomous province of South Tyrol (ST), which is known for its high quality of PT service. Despite this, the difficulties in providing a reliable transnational PT service with neighboring regions are highlighted, confirming the necessity of a specific focus on this topic.

The paper is structured as follows: after this general introduction, Sect. 2 describes the main issues related to transnational transport in peripheral areas and the approach adopted in Connect2CE to overcome them. In Sect. 3, the condition of ST is presented, distinguishing the good coverage in terms of local PT and the main difficulties in the connections with neighboring areas. Finally, some conclusions about future perspectives and activities within Connect2CE end the contribution.

2 Mobility Issues in Transnational Peripheral Areas

This section indicates the main critical aspects related to a harmonized and integrated transport system in rural and transnational areas, including the main features that can contribute to make PT more efficient.

2.1 Transnational and Trans-Regional Contexts

The transnational and trans-regional PT service is becoming in several territories a fundamental element that determine the development of a region, mostly related to economic and working opportunities. In literature, it is considered as one of the main elements that contribute to define the accessibility of a region. The political cross-border collaboration between public authorities is an essential, but often critical, aspect. To grant the continuity of the service, a cooperation among the authorities that manage or regulate PT operations in bordering areas is fundamental. An important contribute can be given by institutionalized transnational and trans-regional bodies. In this field, the European Groupings of Territorial Cooperation (EGTCs) can play an important role, facilitating and encouraging the establishment of a transnational cooperation, and giving the possibility to integrate different institutional levels into a single structure.

The collaboration between bordering transport providers is a second challenging aspect. In trans-regional contexts, the typical condition is the coexistence of different PT providers that manage the service on part of the network (which can partially include the transnational or trans-regional level). In these cases, finding an agreement for the coordination of services, the harmonization of timetables, the establishment of integrated tariff schemes, information and payment systems, is a demanding but necessary operation, which can be handled either by transport operators themselves through spontaneous agreements or (more easily) by a relevant public authority that is responsible for this integration.

The establishment of a transnational cooperation is based also on the adoption of common or interoperable standards for data, technologies and technical aspects. Particularly, interoperability allows the modeler working with datasets from different topic areas and sources. In the past years, each PT provider developed its own information system, which could difficultly share information with others. To avoid this condition, which is uncomfortable for PT users, the EU is trying to define common protocols that grant the interoperability from a technical perspective. For example, the Service Interface for Real Time Information (SIRI) allow devices that adopt this protocol to exchange real time information about PT services and vehicles. However, in transnational or trans-regional areas this development is more complicated, due to the presence of different systems that may not be interoperable, since national requirements may be different.

An example of this fragmented technical and political condition is given by the five Italian regions that are part of the UNESCO World Heritage Site of the Dolomites (i.e., the Autonomous provinces of Bolzano and Trento and the Provinces of Belluno, Udine and Pordenone), where an attempt of merging the different information systems under the same protocol (based on the planning system DIVA and the EFA journey planner) is still ongoing. Initial hypotheses about this merging were discussed for the first time more than five years ago, but concrete results are not visible yet.

2.2 Peripheral Areas

A second difficulty belonging to the areas object of the evaluation concerns the rural/urban connection. At the European level, the steady trend of depopulation of rural areas in favor of the most urbanized ones determines a progressive isolation of the former. This has relevant consequences in terms of travel demand, which is typically scattered and highly dispersed in areas of low density; furthermore, it suffers from a high temporal fluctuation, with a peak in the student-transport period, a medium scale peak during commuter traffic and low demand during the rest of the day. This vicious circle contributes to increase the lack of PT connections both between rural and urban areas, and also among different rural areas, thus further increasing the ongoing negative demographic trend of rural areas. Alternatively, those who continue to live in these zones consider their own car as the only alternative to move within the territory, because it can cover the door-to-door necessities.

Ultimately, the challenge in these contexts is to provide an effective multimodal and integrated service, in order to shift part of the demand toward more sustainable transport modes. These types of services are crucial especially in the rural areas, where the usual lower PT supply needs to be combined with integrative forms as cycling, bike sharing, car sharing, carpooling, etc. A valid alternative for these areas is represented by the Demand Responsive Transport Systems (DRTSs), which can be provided, according to the morphological context, following four different schemes: one to one, few to one, many to one and many to many [4].

2.3 Connect2CE: Territorial Needs Assessments and Transnational Tool

Peripheral and transboundary areas are object of a specific analysis in Connect2CE. Indeed, the project presents the characteristics of different territorial contexts in Central European Countries, as well as concrete solutions to improve the accessibility of peripheral transnational areas located in Austria, Croatia, Czech Republic, Hungary, Italy, Germany, Poland and Slovenia. The analysis aims at finding the most appropriate themes and it is based on a three-step approach. First, a survey with relevant political and technical stakeholders at regional and transnational levels is provided. The aim is to gather information about connectivity, tariff schemes and info-mobility. This survey is then used to prepare the territorial needs assessments (TNAs) of each region. Thanks to a specific SWOT analysis, TNAs highlight the main elements of each region that concur in defining the current status of PT and alternative transport modes. As final step of this project phase, a specific tool is elaborated, which should be able to help policy makers in defining the priorities to improve the PT and alternative services also in other areas.

3 Transnational Connectivity in South Tyrol

This section points out the main aspects related to the use of PT in ST, which is a border area, mostly mountainous, characterized by several dispersed settlements. For these reasons, it fits well to the features of peripheral and transnational mobility presented in Sect. 2.

3.1 South Tyrol

ST is part of the Italian region Trentino-Alto Adige/Südtirol. It is located in Northern Italy, bordering the Italian Regions of Lombardy (West), Veneto and the Autonomous Province of Trento (South), Austria (North) and Switzerland (North-West). At transnational level, it is part of the Euroregion Tyrol-South Tyrol-Trentino. ST covers an area of about 7,400 km^2 (80% of which is classified as mountainous and only 6% lies at altitudes and in terrain suitable for human habitation). ST (about 524,256 inhabitants in 2016) has an autonomous status with wide-ranging powers devolved to the Provincial Government; it has the highest national average GDP per inhabitant (in 2015, €41.141 against a national value of €27.045). The capital is Bolzano, which is also the biggest town with almost 100,000 inhabitants. Other important -but smaller- centers are: Merano, Bressanone, Brunico, Chiusa, Vipiteno and Laives. ST is also an appreciated tourist region both for natural (Dolomites) and cultural aspects. Therefore, the tourism component is an important component of the local mobility.

In terms of transnational accessibility, ST is crossed North-South by the multimodal corridor Munich-Verona, central part of the TEN-T corridor n°5 Helsinki-La Valletta. Its main infrastructures are the Brenner railway line and the Brenner highway A22. They will be flanked by the high speed/high capacity railway line, which is currently under construction. Despite the presence of the Brenner railway, the connection of ST by PT with main cities and metropolitan areas is rather weak. This is due to the limited daily number of long-distance trains that connect Bolzano with the main Italian, Austrian and German cities. There are some exceptions: Trenitalia, the Italian railway company, grants five daily connections to Rome (via Bologna and Florence). The Austrian national railway company ÖBB, in collaboration with Trenord and the German national railway company DB, grants five daily connections from Munich to Verona; one of them continues to Venice and one to Bologna (in the previous years, also a direct connection with Milan was guaranteed). However, other main Italian and foreign cities requires at least one change, with significantly higher travel times than by car. Costs are another important aspect: A22 is one of the cheapest transalpine highways. As a result, most of the visitors and tourists (about 90%) come to ST by car, which is the most adopted transport mode to reach the destination.

3.2 Public Transport in South Tyrol

The condition of internal mobility is different. The level of motorisation in ST is high: about 830 vehicles every 1,000 inhabitants (year 2015), one of the highest values registered in Europe. Accordingly, the urban modal split for work and study indicates that the car is the most adopted transport mean (36%), followed by foot (25%), bike (13.9%), urban bus (9.7%), train (6.2%), suburban bus (5.8%) and motorcycle (2.2%) [5]. Daily congestion along specific routes is mainly due to the commuters that gravitate towards the main cities for working purpose, with negative impacts on PT service. In this framework, the development of PT plays a key role for a sustainable territorial development. Absolute figures confirm good results related to PT [6]: supply is significantly higher than in the rest of the country (the ratio is 1.49) and similar results are visible for travel demand per inhabitant (here, the ratio between ST and Italy is 1.44); finally, the unitary cost per passenger/km is lower than national values (ST €0.22 * passenger/km, Italy €0.24 * passenger/km).

These good results can be explained by several factors. PT is characterized by the integration of different transport modes into a single system managed by the Passenger Department of the Province. Regional trains for routes within the jurisdiction of the Province, as well as for those reaching Trento, Lienz and Innsbruck, urban and long-distance buses, city buses and certain cable car lines and funiculars are included. Tariffs are based on the km travelled, following the rule "the more you travel by PT, the less you pay". Integration is not limited to PT, but it includes also tourist opportunities for local trips (e.g. snow train, train and bike options).

From an infrastructural perspective, every transport system has its own specific role: rail transport is the backbone of the medium or long journeys and aims at connecting the main localities, while buses grant a widespread connection to final destinations. At the same time cable cars and funiculars increase the accessibility of more remote mountain areas. Furthermore, ST has the highest number of km of cycle lanes per inhabitant, which is an important integrative aspect referred to the provincial level. Rail transport has shown the highest relative increase in last years, also thanks to the huge investments that the Province has granted. In 2016, 9.8 million validations have been registered at the train stations, with an increase by 58% compared to 2013.

The proportion of total operating costs covered by fares is about 24% (even if for the next years an increase of this percentage has to be reached, also considering EU recommendations). Thus, the supply presented above can also be explained thanks to the high provincial subsidies for PT (€5,500 M), equal to about 64% of Passenger Department's budget and 2.17% of total Provincial budget.

3.3 Transnational Mobility to/from ST

When we refer to the transnational mobility, results are different. Main transnational connections by PT include the Austrian cities of Innsbruck and Lienz (14 connections per direction per day by train), the Swiss localities of Martina (13 connections by bus per day) and Zernez (by bus), plus the intermediate steps. A fourth seasonal connection (in summertime) is with the Austrian locality of Obergurgl (by bus). According to the National statistics [7], the number of transboundary provincial commuters in 2011 (last available year) was not negligible: they were 649 with Switzerland, 216 with Austria and 6 with Germany. Almost 75% of them used car to reach the destination (66% as driver, 8% as passenger), while PT was limited to 25% of total journeys (15% by train, 10% by bus). The purpose of the trip was primarily related to work (83%) and secondarily to study (17%). How can this difference with the provincial values of Sect. 3.2 be explained? The three elements recalled in the introduction (connectivity, tariff systems and infomobility) can contribute to this aim.

Regarding CH-IT connections, timetables are harmonized, but the integrated payment is not possible and separate tickets have to be purchased (the service to/from Swiss localities is performed by the company AutoPostale). The multi-modal station of Malles is the main hub. Regarding AT-IT connections, the train connections to/from Lienz (Val Pusteria railway line) and Innsbruck (Brenner railway line) are performed hourly in both directions. At Brenner, in most cases, a change is required. Timetables between IT-AT railways are harmonized (it is possible to pay with the South Tyrol Pass), but not the tariffs: the Austrian ones are more expensive.

In terms of infomobility, some pros and cons may be identified. The journey planner "Südtirol Mobil/Mobilità Alto Adige" [8] provides information and travel alternatives regarding about 5,900 stop points located in ST, in the neighboring Autonomous Province of Trento, in the Province of Belluno, plus the railway stations of Tirol and east Tirol and the bus stops in the Grisons. Information are in four languages. However, a real door-to-door journey planner is not provided, since only main stops outside ST are considered. Furthermore, on-trip information is a critical aspect, since real-time information is provided only for limited transport system and mostly at the local/urban level. Finally, one threat is due to use of different technological solutions between ST and neighboring regions (e.g. different ticketing system with reference to type of operator).

The performances of PT in ST are the result of an approach that joins the renewal of infrastructures with the integration of all transport modes into a unitary system that is based on a unique tariff scheme and ticketing system. This gives good results in terms of local mobility, but, at the same time, it still suffers from some weaknesses, which are mostly related to the transnational connections. Related to this aspect, the most important aspects highlighted in this section are included in the SWOT analysis presented in Table 1.

Table 1. SWOT analysis about transnational and trans-regional mobility in ST.

Strengths	Weaknesses
• Central part of the TEN-T multimodal corridor n°5 Helsinki-La Valletta • Integration of all PT modes into a unique system, managed by the Province and accessible with a single pass • Regional trains from/to Trento, Lienz and Innsbruck included into the provincial supply • Connections by suburban busses with some relevant tourist and working destinations of the neighboring regions	• Weak accessibility for tourists and visitors: only few long-distance trains connect Bolzano with selected Italian, Austrian and German cities • High motorization rate and use of private vehicles by transboundary commuters • Real-time information available only in few cases, mostly at the local level
Opportunities	**Threats**
• Potential growth of accessibility thanks to the realization of the new high speed/high capacity Brenner railway line • Integration with other forms of alternative transport (ST has the highest km per capita of bike lanes and international cycle routes) • Coherency with the vision of EGCT "European Region Tyrol-South Tyrol-Trentino" towards a more integrated mobility	• Territorial context, mostly mountainous and with dispersed settlements • Higher costs of transport than in other (flat) regions to cover the entire territory • Differences of infomobility and payment systems between ST and neighboring Italian Provinces • Economic prosperity of ST, which may contribute to incentivize the use of private vehicles

4 Conclusions

This paper has discussed the numerous difficulties in providing a reliable public transport service between urban and rural transboundary contexts, indicating at least three main aspects to be evaluated: connectivity, tariff schemes and infomobility/payment systems. The case of South Tyrol has been presented, illustrating the differences between the mobility within the Province and its transboundary connections with Austria and Switzerland, where still some difficulties are encountered. The attempts made by other transboundary regions (such as the new integrated service between Canton of Ticino and Lombardy) confirms that this aspect is perceived as relevant also in other contexts and it requires a further analysis.

The consequences of these choices are not limited to the field of transport, but have also strong implications on the territorial development as well as on the social and demographic trend of these areas. For this reason, common choices have to be discussed and agreed at the international level. In this sense, EGTCs, whose main aim is to address the common priorities of transboundary regions, can play a primary role and become the reference institution to improve the connectivity of these areas.

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City Logistics Systems

Development of a Smart Picking System in the Warehouse

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Abstract. In an effort to streamline warehouse logistics processes, the development of a smart picking system is becoming a mainstay for efficient work of a warehouse. A smart picking system is a set of numerous elements of an order picking process which raises the velocity and quality of picking through using the warehouse management system. It comprises the following chain of warehouse operating processes: the way of organizing goods flow, order dividing principle, several location variants for the storing area and picking area, routing methods of picking, replenishment methods, two approaches of goods layout: one picking location for each item, or various picking locations for each single item. The sequence of building a certain model of the smart picking system depends on a variety of conditions of the warehouse. Introduction of such a system in a warehouse would ultimately result in a number of benefits, though the main purpose of a smart picking system is to prevent warehouse problems that may arise daily or due to seasonal changes.

Keywords: System · An order picking system · Replenishment
Smart picking · Picking conditions · Picking methods

1 Introduction

Creating proper logistical conditions is a key driver for the development of any kind of business, and also for an efficient development of warehouse processes, in particular, for the customer order picking process. Therefore, a clear understanding what a picking system means and how it works in a warehouse is an issue of prime importance. On the one hand, a system means a set of things working together as parts of a mechanism [1]. On other hand, a system is a set of principles or procedures according to which something is done; an organized scheme or method [1]. An order picking system is a warehouse management system (WMS) that is designed especially for warehouses to deal with customer orders [2]. The authors regard an order picking system as a set of different elements of a picking process which interoperate with each other. A smart picking system is a set of different elements of a picking process which facilitate the order picking process through using the WMS. Putting in place a smart picking system ultimately results in the following benefits [2]: more organised orders and items; less stressed workers; more productive workers; fast order completion; fewer errors; more satisfied customers; more potential customers, etc.

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A smart order picking system comprises: the way of organizing goods flow, order dividing principle, several allocations variants for the storing area and picking area, routing methods of picking, replenishment methods, approaches of goods layout: one picking location for each item or various picking locations for each single item, etc.

Therefore, the development of different picking methods of logistics in a warehousing area plays a major role for the optimization of picking cost, picking time elements and achieving required service levels. The key indicator for choosing a picking technology in a warehouse appears to be the velocity of order lines picked per paid man hour [3]. If the number of order lines picked per paid man hour is relatively small, it means in most cases that primitive picking technologies are used. Such picking technologies support the physical picking system: walk and pick [4]. The applied picking technologies therefore are: paper picking, Radio-Frequency Identification picking or more developed picking technologies such as: visual picking, picking by voice [5]. This concerns the picking area (PA) that is located in the storing area (SA), which means that the system of one row rack storing is used in the warehouse and the picking process is implemented by picking handling units (HU) and customer units (CU), using the ground level and the first level of pallet racks as PA. A picking location of each item consists of 2 pallets: the first pallet on ground level and the second on the first level of the rack. The replenishment is appropriated to moving the items from SA to PA to avoid stock – outs in the picking time interval. If any single item in a picking location reaches the critical level, replenishment starts at a signal in the warehouse management system (WMS). This is the Red Card Principle (RCP) [6].

The main purpose of the article is to figure out the elements for the development of a smart picking system in a warehouse. The scientific problem of the paper is based on the development of a model of the smart picking system. The object of the research addresses the interconnection of a replenishment process with the picking process. The subject of the research concerns the elements of a smart picking system.

2 Universal Picking of Orders

For a warehouse, to develop a smart picking system interconnecting the three warehousing processes: incoming customer orders, replenishment of picking locations in PA and picking customer orders, is of crucial importance. The order dividing principle (ODP) envisages the division of ordered quantities of each stock keeping unit (SKU) into 2 parts [3]: one - for picking full pallets (FPLL) from SA – for a single order, usually expressed in customer units from SA; the other - for picking HU and CU from PA – for a single order, usually expressed in customer units from PA.

Usually, customer orders are picked by using scanners or printed picking lists. Such kind of picking is called the universal picking of orders. The sequence of the picking process may differ from company to company. However, it generally consists of the following parts [6, 7]:

- Step 1: The picker activates the scanner by entering his password; he presses the button "Begin task" to start picking.
- Step 2: The picker receives the picking list in his scanner according to the fixed list of priorities.
- Step 3: The picker begins picking in accordance with the given picking route.
- Step 4: When the picking starts, the picker goes to the designated picking location, scans the required barcode of products and collects the necessary quantity of products.
- Step 5: the picker goes to the next picking locations and performs Step 4 until the picking list is fulfilled, then he presses "Finished".
- Step 6: If after the picking of an order there is a necessity to combine several items in transport package, the warehouse needs to ensure additional packing process.
- Step 7: The picker moves the complete (picked) order to the departure zone designated by warehouse clerk or scanner.

3 Development of a Model of the Smart Picking System

The sequence of building a certain model of the smart picking system depends on a number of conditions that may vary in various warehouses: number of stock keeping units (SKU); warehouse areas for realizing different warehouse processes; structure of orders by order lines and quantities to be collected; turnover of SKU; availability of stock level; picking technologies; picking methods; routing methods in PA; storing systems (racks, bays, forklifts, reach trucks, elevator types, conveyer types, etc.).

The development of a smart picking system model involves the following elements:

- Step1: Considering the choice of products flow: goods to man (G2M) or man to goods (M2G). This paper deals with the M2G approach.
- Step 2: Choosing the variants of layout of SA and PA. This issue was analysed and the methodology of evaluation of its impact on the total costs of a warehouse was developed by authors in the previous research [7].
- Step 3: Creating replenishment conditions in order to replace stock from SA to PA. The Red Card Principle (RCP) has to be considered. It stands for determining a critical stock level in a single picking address when replenishment automatically starts. The authors offer to use the Min/Max method for solving this problem [8].
- Step 4: Routing shapes and methods of picking. There are several picking methods for the "pick and walk" approach [9, 10].
- Step 5: Determining the proper sequence of SKU locations. It is very important to obtain a general parameter or a group of parameters for the right allocation of SKU in a picking area. This issue was also earlier developed by the authors [11].

- Step 6: Launching the picking process. Clever algorithms and counting formulas have to be verified by logistics data analysts, using data structure, developing counting models, conducting experiments or making simulations, and then results have to consolidated.
- Step 7: Make a data structure analysis for enhancing the work of the smart picking system.

The replenishment conditions (Step 3) refer to the choice of layout of picking locations for each SKU in accordance with the picking route [11]. The methodology for evaluation of total picking costs consists of 5 main steps: choosing variant of layout of SA and PA; giving the description of total picking costs considering the layout of items in PA; determining the factors to the total picking costs for the layout variants of items in PA; calculation of total handling costs for the layout variants of SKU in PA; adopting the decision for an optimal layout variant of SA and PA, and optimal layout variants of SKU's in PA.

There are two approaches to the layout of SKU in PA: one picking location for each single SKU – the replenishment is carried out during the picking process or various picking locations for each single SKU - the replenishment is carried out before the picking process or after it. The first approach defines that the replenishment of a definite address is provided once the stock is below the critical level [6], and a specific inventory stock control method for the procurement of goods is used in order to calculate the critical level. For this purpose, the re-order point (ROP) has been planned. It depends on safety stock calculation, considering the elimination of stock-out [12]. To this effect, for example, the Min/Max stock controlling method can be adjusted. It means that replenishment is carried out in an uninterrupted picking process. The average replenishment costs might be high compared to the next approach.

In the case of various picking locations for each single item, general limitations of the proposed system are following: one single or various locations are foreseen for each SKU [6], no stock-out situations during picking process, uninterrupted picking process, capacity of picking technique is sufficient for picking route. Fast moving of SKU often requires multiple pick face locations to ensure that sufficient picking stock is available to meet the projected demand, while slower moving of SKU may have only one pick face location [13]. The second approach does not allow replenishment at the time of picking. If it is not allowed, then quantities (stock) of each item in an uninterrupted picking process have to be sufficient from the beginning of the picking process till its end. Consequently, it requires different picking addresses for each item, especially, if quantities to be picked exceed two full pallets. Therefore, the replenishment takes place outside the picking process: the replenishment of picking addresses has to be done before the picking process has started. It is necessary to note, that the issue of picking batch [14] of orders is not revised in this article.

4 Example of a Smart Picking System for Foodstuffs

To assume that a picking system consists of mathematical formulas, which describe the correct picking process to be carried out by pickers or automatically to fulfil customers' orders. If we have such kind of algorithms and they are fully incorporated in the WMS, then the picking system becomes a smart picking system. It means that the warehouse of logistics centre needs no more manual calculations, e.g., exporting data from WMS, then data processing in Microsoft Excel and afterwards exporting back to WMS. For seasonal changes, a smart picking system, which is part of WMS, could easily find the optimal way of picking sequence, including the correct number and right locations of SKU.

For example, a large number of SKU of foodstuff is stored in a warehouse of a logistics centre. These SKU are usually characterized by high-speed turnover. If the decision is taken to replenish these SKU, for example, once a day, then an additional need appears to calculate an adequate number of picking locations for each item in the conditions of uninterrupted picking process. Afterwards, it is necessary to develop a plan of picking face - located SKU of picking locations. A smart picking system will ensure correct results of calculations and allocations. However, it is possible only by using correct mathematical formulas. These formulas must incorporate: number of items (SKU); principles of picking route planning and items locations; mass of HU or CU; number of orders; quantity of pallets for each SKU; reasonable interval between replenishment (in our example, - once a day); picking – storing system from the technical point of view; picking quantities and ABC classification of SKU; period of validity of SKU, etc. We have the data basis of picking results obtained for more than 1000 SKU's from PA over the quarter. In order to simplify our example, 17 SKU have been analysed (see Table 1). The time period in the quarter is 65 working days.

As the ground level and first level of pallet racks are used as PA, the single picking location of each item consists of 2 pallets: the first pallet on the ground level and the second on the first level of the rack. The replenishment is used to moving the items from SA to PA to avoid any stock – outs in the picking time interval. The replenishment of stock from SA to PA is R_x - could be estimated once or several times during a day: once a day (R_x = 1); twice a day (R_x = 2); three times a day (Rx = 3); once in two days (Rx = 0,5). The number of picking locations for each SKU (N_{SKUi}) can be calculated by formula:

$$N_{SKUi} = \frac{Q_{PLLi} \bullet K_{Fi}}{N_{li} \bullet R_{xi}}, \qquad (1)$$

Where: Q_{PLLi} is the estimated average quantity of each SKU in pallets to be picked from a picking location (locations); K_{Fi} is the coefficient of picking flow fluctuation for each SKU, which means that the average quantity is 100% plus the coefficient of variation or accordingly service level to avoid stock-out; N_{li} is number of shelf levels defined as picking location for each SKU; R_{xi} is the number of replenishment during the day for each SKU (attention – replenishment carried out separately from the picking process, not during the picking process).

Table 1. Start database for calculation of number of picking locations for each SKU.

Stock keeping unit	Name of stock	Package, litres	Number of orders	Picked quantity from PA, CU	Pallets' quantity, CU/pall	Coefficient of forecast	Coefficient of picking flow fluctuation
SKU_1	Apple juice	1.0	12261	46159	720	1.09	1.1
SKU_2	Carrot juice	1.0	10732	42616	720	1.18	1.6
SKU_3	Pomegranates drink	2.0	14764	63393	336	1.25	1.5
SKU_4	Cherries drink	2.0	10397	62365	336	1.22	1.4
SKU_5	Black currant juice	1.0	11833	83495	720	1.16	1.7
SKU_6	Lemon lemonade	1.5	8262	33327	504	1.21	1.6
SKU_7	Pear lemonade	1.5	8751	102925	504	1.04	1.3
SKU_8	Mineral water "Belindo"	1.5	10050	99415	504	1.18	1.3
SKU_9	Mineral water "Sarema"	1.5	6528	65839	504	1.05	1.2
SKU_10	Table water "Lendi"	0.5	7719	42652	1080	1.17	1.2
SKU_11	Kids lemonade	1.5	8689	42386	720	1.07	1.3
SKU_12	Kvass "The old one"	1.5	9931	58855	720	1.28	1.4
SKU_13	Kvass "Mini"	0.5	8991	66554	1080	1.01	1.3
SKU_14	Pear drink	1.0	11386	72505	720	0.95	1.5
SKU_15	Maple lemonade	1.0	5655	46623	720	0.99	1.4
SKU_16	Cranberry fruit drink	0.5	6444	95532	1080	1.11	1.4
SKU_17	Aloe tee	1.5	7211	41517	540	1.31	1.3

The number of picking locations for each existing SKU (N_{SKUi}) in the warehouse is calculated as follows:

$$N_{SKUi} = \frac{Q_{p.s.i} \bullet K_{FORECATSTi} \bullet K_{Fi}}{n_d \bullet A_{pll.i} \bullet N_{li} \bullet N_{di} \bullet R_{ABCxi}}, \tag{2}$$

Where: $Q_{p.s.i.}$ is the picking quantity from PA for each SKU in the previous season or previous corresponding season (CU/quarter); $K_{FORECASTi}$ is the coefficient of estimates for each SKU in the next season; n_d is the number of working days in the quarter (days/quarter) - if some SKU in picking locations are planned after the season start point, this parameter has to undergo corrections, in other words, number of actual working days a quarter needs to be changed; $A_{pll.i.}$ is the quantity of pallet for each SKU (CU/pll); N_{di} - means the number of pallets in depth of the rack (depends on the type of racks) for each SKU; R_{ABCxi} is the number of replenishments a day for each SKU depending on the inventory turns in the picking process: A is a quick turn inventory; B – medium turn inventory; C – slow turn inventory.

The number of picking locations for each new SKU (N_{SKUi}) in the warehouse is calculated by a similar formula:

$$N_{SKUnewi} = \frac{Q_{Pi} \bullet K_{PAi} \bullet K_{FORECATSTi} \bullet K_{Fi}}{n_d \bullet A_{pll.i} \bullet N_{li} \bullet N_{di} \bullet R_{ABCxi}}, \quad (3)$$

Where: Q_{Pi} is the planned collecting quantity from SA and PA for each new SKU next season (CU/quarter); K_{PAi} is a part of picking from PA for each new SKU.

The principle of allocation of SKU in the picking route planning has been done by applying XYZ/ABC – combined principle when the picker in the picking route first collects the heaviest item with largest number of orders. In the beginning estimated the right sequence of allocation of each SKU in the picking route (see Table 2). In Table 2, the mass of each SKU is unknown. Therefore, the XYZ principle has been applied by using the parameter: package in litres, assuming that 1 litre equals 1 kg of water. The heaviest SKU should be definitely placed on the pallet at first. The ABC principle sorts the number of orders from the largest to the smallest within the condition of package in litres. After that, the average forecasted number of picked pallets is computed for each SKU. Finally, the authors calculated the total number of picking locations for each SKU (see Table 2). The total number of engaged picking locations reached 31 picking locations. After the calculation of the total number of picking locations, each SKU has been allocated into the warehouse plan from above (see Fig. 1) according to the accepted number of picking locations.

Table 2. Total number of picking locations for each SKU after calculation.

Stock keeping unit	Name of stock	Package, litres	Number of orders	Picked pallets in a day	Rxi	Nskui calculated	Nskui accepted
SKU_3	Pomegranates drink	2.0	14764	3.63	1	2.72	3
SKU_4	Cherries drink	2.0	10397	3.48	1	2.44	3
SKU_8	Mineral water “Belindo”	1.5	10050	3.58	1	2.33	3
SKU_12	Kvass “The old one”	1.5	9931	1.61	1	1.13	2
SKU_7	Pear lemonade	1.5	8751	3.27	1	2.12	3
SKU_11	Kids lemonade	1.5	8689	0.97	1	0.63	1
SKU_6	Lemon lemonade	1.5	8262	1.23	1	0.98	1

(*continued*)

Table 2. (*continued*)

Stock keeping unit	Name of stock	Package, litres	Number of orders	Picked pallets in a day	Rxi	Nskui calculated	Nskui accepted
SKU_17	Aloe tee	1.5	7211	1.55	1	1.01	2
SKU_9	Mineral water "Sarema"	1.5	6528	2.11	1	1.27	2
SKU_1	Apple juice	1.0	12261	1.08	1	0.59	1
SKU_5	Black currant juice	1.0	11833	2.07	1	1.76	2
SKU_14	Pear drink	1.0	11386	1.47	1	1.10	2
SKU_2	Carrot juice	1.0	10732	1.07	1	0.86	1
SKU_15	Maple lemonade	1.0	5655	0.99	1	0.69	1
SKU_13	Kvass "Mini"	0.5	8991	0.96	1	0.62	1
SKU_10	Table water "Lendi"	0.5	7719	0.71	1	0.43	1
SKU_16	Cranberry fruit drink	0.5	6444	1.51	1	1.06	2
		XYZ	ABC			Total	**31**

SKU_16	Cranberry fruit drink	A_16	B_16		
SKU_10	Table water "Lendi"	A_15	B_15	SKU_16	Cranberry fruit drink
SKU_15	Maple lemonade	A_14	B_14	SKU_13	Kvass "Mini"
SKU_14	Pear drink	A_13	B_13	SKU_2	Curettes juice
SKU_5	Black currant juice	A_12	B_12	SKU_14	Pear drink
SKU_1	Apple juice	A_11	B_11	SKU_5	Black currant juice
SKU_9	Mineral water "Sarema"	A_10	B_10	SKU_9	Mineral water "Sarema"
SKU_17	Aloe tee	A_09	B_09	SKU_17	Aloe tee
SKU_11	Kids lemonade	A_08	B_08	SKU_6	Lemon lemonade
SKU_7	Pear lemonade	A_07	B_07	SKU_7	Pear lemonade
SKU_12	Kvass "The old one"	A_06	B_06	SKU_7	Pear lemonade
SKU_8	Mineral water "Belindo"	A_05	B_05	SKU_12	Kvass "The old one"
SKU_8	Mineral water "Belindo"	A_04	B_04	SKU_8	Mineral water "Belindo"
SKU_4	Cherries drink	A_03	B_03	SKU_4	Cherries drink
SKU_3	Pomegranates drink	A_02	B_02	SKU_4	Cherries drink
SKU_3	Pomegranates drink	A_01	B_01	SKU_3	Pomegranates drink

Rack A **Rack B**

Fig. 1. Plan of picking locations in the warehouse (upward, first 2 levels of 1 row racks).

5 Conclusions

By implementing proper algorithms, a smart picking system becomes a critical part of WMS. In order to avoid a range of warehouse problems, especially those that occur in the stock picking process, a model of the smart picking system has to be elaborated and thereafter introduced. It is important to be aware that the calculations of picking locations for uninterrupted picking process come as the last part of the smart picking model. Opposite choice would mean to reject all previous calculations and to return to the variant where each SKU has a single location.

Referring to the use of the offered variant of various picking locations of each SKU, it is crucial to avoid any stock – out situations in a picking process and not to interrupt the picking process for replenishment of picking locations in PA.

The total number of engaged picking locations has reached 31 picking locations. It is valid in case when the replenishment of picking locations for each SKU runs once a day. If the replenishment is performed twice a day, the result equals 21 picking locations. For three replenishments a day, the result equals 17 picking locations – one picking location for each SKU. If the decision is to perform replenishment once in two days, then the result equals 53 engaged picking locations. The main problem of such replenishment choice is the long picking distance and mileage done by each picker in total. To highlight once again, a suitable number of replenishments can be obtained by minimising the total picking costs or total picking time.

If we wish to enhance the usable number of rack levels and the usable number of pallets in depth in the rack, the number of calculated and accepted picking locations will decrease.

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A Conceptual Framework for Planning Transhipment Facilities for Cargo Bikes in Last Mile Logistics

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Abstract. Global urbanization processes expedite a growing demand for more sustainability and higher liveability in cities. New logistic concepts like cargo bike schemes can be a vital means towards this goal. In this respect, both logistics planning and urban planning need to address several aspects of the urban fabric, but show a lack of holistic planning tools. We develop a conceptual framework that combines planning objects and planning scales of logistics planning with urban planning. We demonstrate the application of the framework for the theoretical deployment of an urban transhipment facility (UTF). Drawing upon interdisciplinary expertise from urban logistics, urbanism, sociology and psychology, several interdependencies of an UTF implementation with the urban fabric become apparent. Regarding this, several practical recommendations for the use case can be derived. In general, we recommend the application of the framework as a guideline for urban and urban logistics planning purposes to practitioners and encourage scientists to further develop and enrich the framework.

Keywords: Urban logistics · Cargo bikes · Urban planning · Sustainability

1 Introduction

Cities are moving away from a car-centric urban planning paradigm [1] towards more liveability. The urban fabric, the material reality created by certain urban lifestyles and functions [1], shall be transformed towards walkable inner city areas. These are characterized by a high density of people, social and economic activities, a variety of functions, short distances, high accessibility [1, 2], a special urban quality [3] and principles of human dimension [2].

Logistic systems are predominantly adapted to a more technical, car-centric infrastructure. It is a highly competitive market with increasing e-commerce, parcel numbers and amounts of deliveries. Cargo bikes as zero-emission vehicles can be a vital means of transport for logistics in a dense, walkable urban fabric [4] with upcoming smaller and more frequent deliveries. Although cargo bikes are eligible for

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last mile logistics in combination with urban transhipment facilities (UTFs) [5, 6], the planning of new concepts encompassing urban planning has not been described in urban logistics literature yet. As purely technical coordination of city construction does not lead to the special urban quality of a city [3], UTF planning needs to consider the complexity of a city on social, economic, ecological and physical-spatial dimensions and the intervention's respective effects. We therefore aim to develop a holistic planning framework. It shall provide a structure for strategic considerations of municipalities and logistic planners when planning UTFs.

2 The Missing Part in Urban Logistics Planning Research

Deploying UTFs for last mile logistics is a strategic planning task in both domains of logistics and urban planning. The wide body of literature brings up several research avenues related to logistic planning methodologies.

Research on *layout planning* deals with static, quantitative models. They determine locations through the optimization of logistic layout, flow and mode of transport. Some consider prices or flow-disruptions through congestion but remain simplistic by nature. An overview is given in [7, 8]. Another string of research investigates *multi-criteria decision analysis* methodologies, which are increasingly used for complex transport projects [9]; examples in [10, 11]. Although they take the variety of criteria and complexity into account, they apply just in the decision phase of a planning process and are mostly based on experience and valuation of single actors. *Transferability frameworks* [12] and *evaluation frameworks* [13, 14] assess the viability and effect of single innovations with a multitude of criteria. They focus on single implementations and do not give strategic insights. UTFs can be part of *strategic urban development concepts* like mobility plans (SUMP) or even logistic plans (SULP) [15, 16]. However, descriptions of the planning process are at a very early stage [15] and, until now, give little advice on spatial planning, deployment and benefiting integration in the urban surrounding. The application of *living labs* in urban logistics aims to increase the knowledge and common understanding of different actors involved in the planning process [17]. The focus is more on a practical learning process of single stakeholders than on building a theoretical foundation of the planning process.

Urban planning literature is scares in respect to logistics planning, which is in contrast to urban planning goals of creating a long-term orientated order of a city following human needs [18]. In sum, literature on planning UTFs leaves the following gaps:

- The methodologies are predominantly static in relation to urban dynamics and technically superimpose the network on the urban fabric. The literature regarding holistic planning of UTFs in dense urban areas is weak. They do not consider the aspects of urban quality, liveability and effects on urban fabric.
- The literature gives close to zero guidance for municipalities and logistic planners on how to strategically include UTFs and cargo bikes in urban planning.

3 Planning Principles and Layers in Logistics and Urban Planning

The framework will be developed by (a) identifying and describing a common element giving structure to both planning disciplines and (b) assigning planning objects, processes and instruments to its attributes based on standard literature. Hierarchical orders as a common element of urban planning and logistics planning will be used for building the framework.

3.1 Urban Logistic Planning

Logistics can be defined as the planning, designing, steering, realising and controlling processes of material flows to, from and within a company or a network of companies [19, 20]. Urban logistics can further be defined, following [7], as logistic systems consisting out of the four elements flow, facilities, layout and transport of a company in an urban area. Hence, planning is the process of determining a suitable configuration for the specific urban fabric of a delivery area.

Logistic research knows three levels of planning as means to clarify the planning object. The *micro-scale* describes a single facility with its flows inside, in- and outgoing [21, 22]. It is the domain of the planning's realisation. The planning of a facility is a sub-problem of a factory planning task. Methodologies on this scale follow the rational: The object defines the process and, as such, defines the system within the boundary of the building/ site [19]. The rational here is to optimise the processes inside and the necessary in- and outputs (energy, goods), leaving the impact aside.

The *meso-scale* describes a network of nodes and facilities as well as the layout, flows and means of transport facilitating them [21, 22]. On this scale, the planning purpose is the layout of an urban logistic system as the transport realizing the flows. This means planning networks and strategically selecting locations for facilities, determining modes of transport, designing services and directing flows. The planning methodologies on this scale are well established (see 1.2). A city is often split in delivery areas via zip-codes, as in the CEP-sector [23], which are served by subcontractors. However, this does not consider the urban fabric itself.

The *macro-scale* is not seen as a field of analysis of logistic research. It describes the transportation system from the viewpoint of public authorities [21, 22].

3.2 Urban Planning

Urban planning attempts to create coexistence of citizens within the spatial structure of an urban environment in line with human needs [18]. Adjusting the spatial scale is a vital means to handle the complexity of cities [24] and to focus on the distinct planning object and corresponding instruments. The spatial scales are based on the principle of spatial emergence [3]. Netsch names six scales: single building, block, quarter, district, city and region [24]. Following [3], the four spatial scales can be defined as follows:

The *region* is a cluster of different types of settlement entities around the most central place, a city. Planning follows a spatial perspective focusing on long-term arrangements of settlements, technical and social infrastructure and landscapes.

The *city* consists of different types of quarters and districts. The primary task is land-use planning to arrange and connect quarters of different functions and mixtures as well as to distribute and secure space for facilities of public interest.

A *district* consists of at least two quarters. Quarters differ highly in planning challenges, density, accessibility, network configuration and functions. Everyday actions and synthesis processes give form to space and, in turn, the resulting spaces influence the peoples' actions and thus create a place of local identity [25]. The planning task here is the allocation of land, distribution of functions/uses and (public) facilities, street networks and public spaces as the design of the built environment.

Building/ block is the most detailed planning level. It describes a single building or a group, the space between them, the street and the surrounding configuration. The overarching goal on this planning level is spatial synergy [3] and human scale [2].

3.3 A Combined Conceptual Framework for Planning Urban Logistics

So far, we described the spatial scale of planning domains. In this section, we present a three-scale planning framework (Fig. 1) to integrate objects and methodologies.

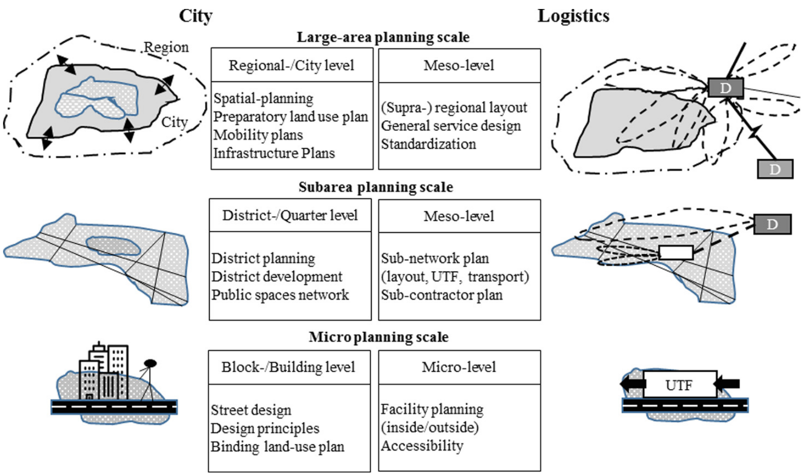

Fig. 1. A conceptual framework for combining urban and logistics planning.

The large-area *planning scale* allows structuring the region's and the city's land use, analysing the urban fabric and analysing interactions between different types of settlement entities, encompassing the flows between the city and (suburban) logistic facilities (see [26]). The latter is placed in supra-regional network-planning. It is the scale to strategically plan locations for facilities. Combining regional and city scale is reasonable because (a) both scales predominantly focus on land-use and infrastructure corridors and (b) logistics does not consider administrative boundaries.

The *subarea scale* is a specific district or quarter with a distinct urban fabric. It is the level for planning a sustainable city transformation and, therefore, the space for jointly planning urban logistic concepts fitting to the specific fabric of a quarter (e.g. on this level, it can be examined in detail whether a cargo bike scheme is viable or not). It is the level to analyse and plan functions and interactions, determine locations for UTFs, plan accessibility, restrictions and infrastructure, choose means of transport and logistics services.

The *micro scale* is the level of a street and its building blocks alongside. It describes the place of the realisation of UTFs. It is dominated by the interrelation between the integration into the direct urban surrounding the composition of a certain UTF according to logistical needs. Hence, detailed planning and analysis of suitable configuration of infrastructure, buildings, functions and public spaces as well as their design take place here.

4 Application of the Framework

In this section, we apply the framework to a theoretical case of an UTF implementation to investigate the possible effects on and interrelations with the urban fabric. A classification of UTFs is given by [5], naming the classes of storage UTFs, consolidation UTFs and transhipment UTFs. We will focus on the latter two in this section since those are facilities with the core-function of transhipment. Storage UTFs are more complex in functions and operations and should be treated separately.

When urban development is discussed, the perspective of citizens is not considered enough [27]. This is despite a long string of research on peoples' needs regarding their urban surroundings [28]. In the following, two aspects of the citizens' perspective will be spotlighted that should be kept in mind when UTF planners aim to consider and positively contribute to the urban fabric. In our scenario, the UTF will extend an existing logistics system and will be set in a long-established inner district. We will therefore just focus on the subarea and micro-scale and leave the very long-term planning perspective of the large-area scale aside.

4.1 Communication-Friendly Design

From a phenomenological perspective, moving through a district can be understood as a dialogue between people and their surrounding [29]. In this sense, movements reflect the architectural and infrastructural intentions of the district, getting inter alia expressed by speed, pace, length of stay, choice of routes and choice of transport mode. Inter alia the raise of e-commerce structures contributed to the decrease of spontaneous social interactions in public space. Following the demand of walkable districts, planners looking at the subarea scale of planning should think about measures to reverse this trend. A communication-friendly design of an UTF could be realised with an open design of the building, e.g., a forecourt as a stopover for the UTF's cargo bikes. This or other creations of so-called semi-public spaces [2] would be more accessible to peoples' perception and, thus, would increasingly be considered in their synthesis processes of social space.

On the operational or micro scale level, the attractiveness of the location for employees and citizens can be assured by involving later users already in the designing process [30]. This has at least two important functions [31]: The first function is *informational*. Employees like, e.g., cargo cyclists, are experts in their own field and, therefore, able to communicate their needs to develop an optimal working environment in cooperation with designers. Citizens living nearby can communicate their needs as later customers but also provide information about the history of the place and aspects of the building that should be preserved to honour that history. The second function is related to *acceptance*: When later users are involved in the process, key issues can be addressed through dialogue. Mutually developed solutions will increase the acceptance of the purpose and the belonging to the quarter.

4.2 Enhanced Functionalities

Referring to the theory of constituting space through actions and structures [32], UTF planners striving for creating a part of social space must offer possibilities for public social actions. One the micro scale, this could be realised, e.g., by enlarging the functions of an UTF by new services, such as parcel counter services, a garage for cargo bikes, a café or a station for renting cargo bikes for private use.

Increased visibility and possibilities to rent cargo bikes should have a positive influence on the diffusion of cargo bikes as an innovation. Several barriers that prevent people from considering cargo bikes as a real alternative would be reduced [33]. Their growing presence would extend the scope of action of the district's residents (subarea scale). A well-designed rental system could lower access constraints and increase the perceived ease of use in the direct surrounding of the UTF (micro scale).

5 Conclusion and Outlook

In this paper, we developed a unique framework for planning UTFs, which covers multiple planning perspectives from long-term planning on a large-area scale to short-term planning on a micro-scale. We were able to show that both disciplines can be merged by means of spatial scales. Further work needs to be done in defining planning objects and instruments on each scale, identifying interrelations between scales and instruments and in specifying missing instruments for achieving the goal of sustainable urban logistics and cities.

We showed that advanced planning of UTFs with regard to the citizens' perspective opens up the possibility of integrating UTFs into social life and thus has the potential of accelerating the diffusion of cargo bikes. A functionally enhanced UTF that considers the urban fabric of the district (subarea scale) and the street (micro scale) could help shifting peoples' mind set both in planning and on the private level away towards walkable cities.

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SWOT Analysis for the Introduction of Night Deliveries Policy in the Municipality of Thessaloniki

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Abstract. At the beginning of the 21st century, the European Commission has decided to set a primary objective, among other things, concerning transportation systems, and that is for them to become sustainable. In this aspect, City Logistics should be transformed from a link of the Supply Chain to an integrated and sustainable transport system by implementing innovative policies.

The Municipality of Thessaloniki, Greece, is ready to make an important step towards the achievement of the abovementioned objective, by implementing the policy of Night Deliveries. The proposed policy is based on a mixed - hybrid approach which includes the imposition of a ban on commercial vehicles exceeding 1,5 tons (and up to 8 tons) in weight inside the area of the Municipality of Thessaloniki during daytime. During this period, commercial vehicles under 1,5 tons weight will be allowed to deliver goods using only the dedicated, for this reason, parking lots. The commercial vehicles exceeding the abovementioned weight will be allowed to deliver goods only during the night. Thus, the local authorities aim to reduce the externalities created by the City Logistics system and upgrading it to a sustainable one.

Within the framework of this paper, a SWOT analysis is carried out concerning the implementation of the specific policy. The existing infrastructure of dedicated parking lots for commercial vehicles is taken into account in the considerations of the Night Deliveries policy in the under study area. The paper makes use of the results of the respective research activities which are carried out in the Department of Transportation & Hydraulic Engineering, School of Rural & Surveying Engineering, Aristotle University of Thessaloniki, during the last six (6) years.

Keywords: City logistics · Night deliveries · Urban distribution Sustainable transport · SWOT analysis

1 Introduction

It is well known that the research promoting sustainable city logistics refers to specific policies and measures, which could be either innovative or "traditional". There are many policies and measures implemented worldwide in order to incorporate

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sustainability aspects to city logistics. The necessity for this process is not always produced by the city logistics system itself but is quite often imposed by the needs of the society.

The climate change, the giant development of urban areas, the overpopulation of urban areas and other environmental, economic and social problems, put a lot of pressure to the city logistics system in order to become sustainable. The Sustainable Urban Mobility Plans (SUMPs) is the new trend in Europe and therefore an increasingly number of cities are either at the stage of developing SUMPs or implementing SUMPs.

In this framework, the Municipality of Thessaloniki has decided to implement the policy of Night Deliveries. This paper attempts to identify the strengths, weaknesses, opportunities and threats arising from this policy. Emphasis is given to the existing infrastructure of dedicated parking lots for commercial vehicles in the under study area, something which is an important requirement in such cases.

2 The Policy of Night Deliveries

The concept of Night Deliveries is based on a simple, yet important, principle: to reduce freight transport during peak hours on a daily basis [1], by applying traffic restrictions for commercial vehicles in a specific area. The goods' deliveries are carried out during nighttime and most commonly from 10:00 p.m. to 07:00 a.m. The specific policy could be considered as a controversial one, since it is implemented during nighttime and at the same time, it concerns the delivery of goods, which can be considered as a rather disturbing activity (e.g., noise).

This happens because most of the people believe that loading and unloading activities during the night are performed in the same way as during the day. This is a common misunderstanding, not only among the citizens in urban areas but also (to some extent) among the carriers, forwarders and even policy decision makers.

Night Deliveries aim to segregate commercial vehicles' traffic from the rest of the traffic and to utilize the spare capacity of the urban road network during nighttime. As a result, less traffic congestion and better logistic services are expected to take place. Although the idea of Night Deliveries is not a new one (there are references that it was first applied by Julius Caesar in Rome, although ultimately the system was collapsed due to the reactions of the Roman citizens [2]) it has become popular during the last couple of decades.

In 1998, the Dutch Government set out standards for noise emission during loading and unloading in retail trade and craft businesses [3]. As a result, a project was developed under the name PIEK which led to the "*PIEK certification scheme for vehicles and equipment operating under 60 dB (A), suitable for use in night time deliveries without causing noise disturbance*" [3]. Pilot projects concerning Night Deliveries have been carried out in several European cities, such as Paris, Barcelona, Dublin [4], Sao Paulo [5] and Rome [6] and the results were promising.

The transition of the logistic services and activities from daytime to nighttime requires an equilibrium concerning the cost between the logistic services providers and the consignees. The providers aim to reduce their total delivery cost and at the same time the consignees aim not to increase their operating cost.

This equilibrium is often hard to be achieved and thus two main types of Night Deliveries have been developed (focus mainly on how the goods are delivered to the retailers): the SOHD (Staffed Off-Hours Delivery), which requires additional staff to receive the goods and perform unloading and loading processes, and the UOHD (Unassisted Off-Hours Delivery), which does not require additional staff. Staffed OHD and two stage systems are characterized by high operational cost and low risk while unstaffed OHD (electronic doorman, double doors and key deliveries) are characterized by relatively low cost and high risk [7] and have shown to help urban economies to reach their most efficient outcomes, providing greater supply chain efficiencies, environmental and quality life benefits [8].

In order for the Night Deliveries to be successfully implemented, the minimization of activities concerning goods delivery during daytime is a requirement (off-hours delivery) [9]. This minimization varies depending on the characteristics of the local Urban Road Freight Transport (URFT) system as well as the characteristics of the urban area.

The specific policy has not been implemented so far as the main policy towards sustainable city logistics. It is still been under examination and evaluation because a large-scale implementation requires significant financial resources for the necessary investments in "silent technologies" for the vehicles, the loading/unloading infrastructure, etc., but most of all requires the willingness of all stakeholders to undertake the additional cost (economic or social).

3 Parking Facilities, Delivery Patterns and the Introduction of Night Deliveries in the Municipality of Thessaloniki

The URFT system in the Municipality of Thessaloniki has not been examined and analyzed thoroughly and systematically at the desired level so far, at least in quantitative terms. The Department of Transportation & Hydraulic Engineering, School of Rural & Surveying Engineering, Aristotle University of Thessaloniki, has conducted several surveys [10–16] during the last decade concerning the URFT system in the Municipality of Thessaloniki.

These surveys concerned the collection of the necessary data in situ regarding the parking infrastructure for commercial vehicles in an area covering the commercial center of the Municipality (an area covering almost 2 km^2). They also concerned questionnaires which were addressed to the drivers of the commercial vehicles in order to understand their delivering patterns.

However, it must be mentioned at this point that quantitative data in terms of origin – destination of goods, traffic volumes, delivering volumes etc. have not been collected and therefore such data are not taken into account in the considerations made within the framework of this paper.

A comparison of the collected data concerning the available parking infrastructure for the commercial vehicles (parking lots dedicated for usage only by the commercial vehicles along the road network) to perform loading/unloading processes has revealed that during the period 2014–2016 the number of the available parking lots has been increased overall by 43%, from 251 lots in 2014 to 358 lots in 2016. Moreover, the locations of these parking lots have also been changed in many cases over the years.

For the purposes of the analysis, the under study area has been divided into two sectors, the northern and the southern sector. The northern sector was surrounded by the Egnatia str. to the south, the Olympiados str. to the north, part of Ethnikis Amynis Street to the east and Dodekanisou str. to the west. The southern sector was surrounded by the Egnatia str. to the north, the Nikis Ave. to the south, the Aggelaki str. to the east and the Dodekanisou str. to the west. The southern sector covers the major part of the historical and commercial area of the center of Thessaloniki.

For the northern sector, 62% of the parking lots remained in their original location (year 2014) whiles the rest 38% was either eliminated or moved to another location. For the southern sector, the respective percentages are 77% and 23%. The most recent survey (year 2017) was conducted in the eastern part of the Municipality of Thessaloniki (area surrounded by Al. Papanastasiou str., 25th Martiou str., K. Karamanli str., Voulgari str., Mitropolitou Kydonion Str., G. Papandreou str. and 28th Oktovriou str.).

It included the identification of the available parking lots for commercial vehicles as well as a questionnaire-based survey, which was addressed to the drivers of these vehicles. The analysis of the collected data revealed small differences of the delivering patterns between central and the eastern areas of the Municipality of Thessaloniki. Specifically, in the central area the number of stops per trip of the vehicles in order to distribute goods is more than 50 while the respective number in the eastern sector is 20–30 stops. In both areas, the vehicles were mostly loaded at a percentage of more than 50% of their capacity.

The most significant problem the drivers of the commercial vehicles face is the lack of available parking lots. They require the construction of new parking lots, although the total number of the available parking lots was increased in the central area.

However, 20% of the drivers have stated that the framework, under which the URFT system in the Municipality of Thessaloniki performs, needs to be reevaluated (during the previous survey the respective percentage was 6%). Furthermore, the drivers have stated that the vehicles must be fully loaded and more stops should be made in order to avoid unnecessary trips and to optimize their work.

The Municipality of Thessaloniki has decided in September 29, 2016 (Decision Number 125) [17] that a new framework will be established concerning distribution activities.

Specifically, the respective decision include the following: "*Along the road network of the Municipality of Thessaloniki, the commercial vehicles up to 8 tons payload are permitted to perform loading/unloading activities using the dedicated for this purpose parking lot from Monday to Friday from 08.30p.m. to 08.30a.m. (next morning), Saturday and Sunday during the time period from 05.00p.m. on Saturday until 08.30a.m. on Monday and during holidays without restrictions*". Furthermore, the commercial vehicles up to 1,5 tons payload can perform loading/unloading activities using the dedicated for this purpose parking lots without any restrictions.

This decision aims at the promotion of the Night Deliveries policy in the Municipality of Thessaloniki. It must be mentioned at this point that a new parking policy is introduced for the residents and visitors in the under study area with time restrictions depending on the type of the users (residents, visitors). The new parking policy foresees specific parking lots for the residents which are free of charge and specific parking lots for the visitors who can park their vehicles up to 4 h with an hourly cost of 1.70€.

The implementation of the new parking policy has started on November 13, 2017 in 2 sectors of the Municipality and soon will be expanded to cover the entire area of the Municipality of Thessaloniki. This integrated system combines the night deliveries policy with the parking policy for residents and visitors.

4 SWOT Analysis

SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis is a very useful tool for analyzing and evaluating decision-making processes and strategic planning processes. The SWOT analysis performed by the authors for the purpose of this paper is made before the implementation of the Night Deliveries policy (ex-ante evaluation of the specific policy). Furthermore, the absence of the necessary quantitative data (as previously mentioned) led to the evaluation of the proposed system using qualitative data only. The results of the SWOT analysis are presented in Table 1.

Table 1. SWOT analysis concerning the Night Deliveries policy in the Municipality of Thessaloniki.

Strengths	**Weaknesses**
• The proposed system introduces a framework for congestion relief, reduction of emissions and energy consumption and finally, improvement of the road safety level • Policies for the optimization of the URFT system in the Municipality of Thessaloniki are implemented by taking into account the international experience • The proposed system is supported by a new parking policy for the passenger cars in the central area of the Municipality of Thessaloniki • The network of the parking lots dedicated to the commercial vehicles is identified and their performance has been monitored and analyzed • Increased reliability level for the receivers of goods • Increased productivity level for the carriers of goods	• Absence (to a great extent) of quantitative data concerning the URFT system in the Municipality of Thessaloniki • There is a rather limited experience from such a policy (night deliveries) in the city • Some problems may appear during the transition period • Enforcement is a crucial element for the successful implementation of the policy and it requires a substantial amount of human resources, something that is not an easy task • No implementation of 'low noise' infrastructure and equipment by the carriers and the receivers is enforced • New technologies concerning the monitoring of the proposed system must be implemented • The network of the available parking lots dedicated to the commercial vehicles need to be optimized on a regular basis in order to cover the needs of the proposed system. Changes in the land use system and in the transport system must be taken into account

(*continued*)

Table 1. (*continued*)

	• Detailed information concerning the way receivers of goods during the night will efficiently use the system is needed. Training of drivers and the rest of personnel is needed in order to successfully perform night deliveries
Opportunities • Increased logistics efficiency in terms of the deployment of Heavy Goods Vehicles (HGVs) and the respective manpower • Enhanced quality of life for the residents, employees and visitors of the central area of the city of Thessaloniki • Improved mobility for vulnerable road users (e.g., pedestrians, cyclists) due to less interference with delivery services (HGVs, loading/unloading etc.) • Lower delivery costs	**Threats** • The number of commercial vehicles under 1,5 tons of payload distributing goods could be increased. This may cause traffic associated problems in the road network • The residents could be annoyed by the produced noise levels during the night deliveries processes

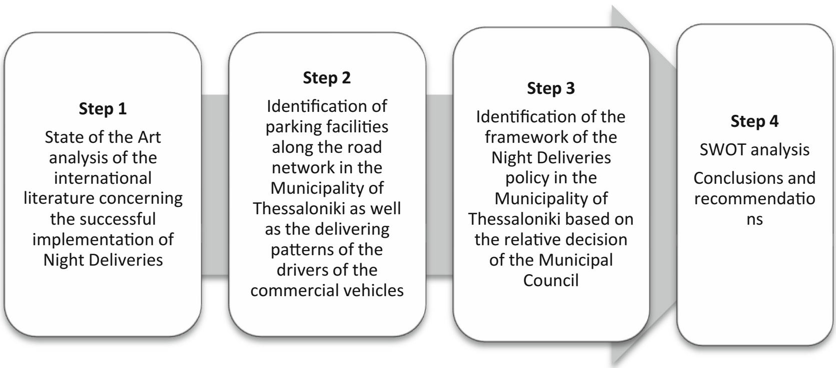

Fig. 1. Steps followed for the implementation of SWOT analysis.

The methodology followed concerning the implementation of the SWOT analysis as an ex-ante evaluation is presented in Fig. 1.

The SWOT analysis presented in the framework of this paper is based on qualitative data only. This analysis could offer some insight for the optimization of the night deliveries policy implementation and evaluation. Dedicated parking lots for delivery purposes, changes in the land use system, parking policy for residents and visitors and technology options are some of the important issues which must be incorporated in such policies. It is estimated that the collection and analysis of quantitative and qualitative data concerning deliveries on a regular basis as well as the monitoring and evaluation of the specific policy (night deliveries) will form the basis for the development of an integrated Urban Road Freight System in the city.

5 Conclusions

The complexity of an Urban Road Freight System cannot and should not be underestimated. Each effort towards the improvement of its operability and functionality must be thoroughly designed and organized and at the same time, it must be socially accepted [18]. The success of such an effort depends on proper policy design and implementation, public consultations and continuous evaluation.

For the case of the Municipality of Thessaloniki, the Night Deliveries policy framework, which according to the time plans should have been already implemented, is based on a well-established approach taking into account the international experience. The success of such an effort depends on a number of tasks that must be done. These task include the following: major surveys should had been performed concerning the collection of data regarding traffic flows (especially those of the commercial vehicles), Origin – Destination of the trips of the commercial vehicles, routes, number of stops, average time per stop, types of delivered goods, weight of delivered goods, types of vehicles used, payload per vehicle, usage of dedicated parking lots for commercial vehicles, etc. The next step should had been the simulation of the existing situation as well as the proposed policy. Afterwards, a pilot phase should follow concerning the implementation of the night deliveries policy in a restricted area in the commercial area. The implementation in full scale should be the final step.

Overall, it is considered as a positive step towards the rationalization of the Urban Road Freight System in the Municipality of Thessaloniki, but there is always room for improvements, especially during the implementation and evaluation process and future extensions of the system.

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Design of a Digital Collaborative Tool to Improve Mobility in the Universities

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Abstract. Mexico City is one of the cities with the highest vehicular traffic in the world. Santa Fe is a commercial and business zone located in the west side of this City. Also, three of the most important Universities in the country are located in this area. Santa Fe stands out as a particularly conflictive place in terms of vehicular traffic due to the high number of floating population, few access roads and non-connection with the massive public transportation of the City.

The main objective is to make more efficient the journeys of the University Community through collaboration, information and synchronization.

The main idea of this paper is the design of a digital tool only available for the University Community. It will be filled with information uploaded by the same Community. Through an APP, they will be able to visualize different options of routes and kinds of transport, also alerts and location. Everything is going to be modified and visualized in real time. This project will be a tool that will empower the University Community.

Keywords: Urban mobility · Collaborative tool · Urban information system

1 Introduction

Road congestion is one of the most common problems suffered by the major cities of the world, this problem has worsened in different parts of the world and has reached extreme levels that seriously affect the quality of life of the citizens. Aspects such as environmental, economic, health or insecurity are affected because of mobility problems in these cities, which involve private cars and the transportation system alike.

Studies such as the published by INRIX Global Traffic Scorecard in 2016 [1] show the complexity of the problem of mobility and traffic in certain cities, for example, it indicates that the inhabitants of the city of Los Angeles, in USA, spend 104.1 h a year stuck in traffic.

Other cities within the count made by INRIX are Moscow, with 94.1 h in traffic, New York (89 h.), San Francisco (82.6 h.) and Bogota (79.8 h.), Mexico City has a calculation of 61.5 annual hours that its citizens pass in traffic.

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On the other hand, TOM TOM TRAFFIC INDEX 2016 [2] places Mexico City first in its ranking where it calculates the "extra time" that is consumed in a route due to road congestion compared to the same route with clear roads, and in Mexico City the time on the road increases by 66% extra due to congestion.

Different actions have been taken to try to solve a problem that has gone out of control since a couple of decades, these initiatives range from imposing taxes on fuels, recovering public space to give priority to pedestrians and alternative ways of transportation or expanding the public transport offer.

While some of these actions have had a positive effect on reducing the mobility problem and the effects it entails, there is still a long way to go to achieve efficient mobility, especially in some cities where government policies and infrastructure are not enough. For this reason, we can see that Universities, Organizations and the private sector are developing new plans to improve mobility.

Gradually people begin to take actions in their hands to solve the problem of mobility and begin to organize with other citizens, therefore, it is necessary to expand the range of platforms and tools that give greater strength to these actions.

This paper presents the process of research, methodology and proposal of a digital tool that finds its main strength in the collaboration between users to solve the problem of mobility in one of the most conflictive points for mobility in Mexico City, Santa Fe.

2 Case of Study: Santa Fe (México)

Santa Fe is the biggest commercial and business zone in Mexico City. It is located in the West side of this city. Also, three of the most important Universities in the country are located in Santa Fe. Due to the high rental costs, the majority of the population that works in the area doesn't live there. A big percentage of people move daily to reach and leave the area after work, school or social hours (floating population).

In 2012, it was estimated that floating population in Santa Fe was of 233,000 people each day. Divided into 78,000 with permanent jobs, 40,000 with temporal jobs, 100,000 visitors and 15,000 students [3]. Also, students, professors and workers of the three Universities have difficulties to reach their destinations.

Santa Fe is isolated from downtown and public transportation that cover the area is slow, insecure, inefficient and have few options. Also, it isn't connected with the main mass transport lines of the city such as the subway, bicycle network and *metrobus* (a bus network that has a special lane, similar to a Tranway but with buses).

When Santa Fe was planned, the automobile was the priority. Therefore, the streets and roads are not made for pedestrians or bicycles. This situation leaves few and complicated options for people who have to reach and leave the area.

From the central area of Mexico City to Santa Fe, there are only three main roads. They are constantly saturated because of the number of cars and public transports.

We found out that the community conformed by the three of Santa Fe universities (Universidad Autónoma Metropolitana, Universidad Iberoamericana and Tecnológico de Monterrey) are really affected by these mobility problems. But we also know there is a big potential in solutions made by this community itself.

3 Related Work

Mobility and transportation are global issues. There are plans around the world that seek to reduce the mobility problems in all sectors of the population. For example, the University of Valladolid in Spain integrated into its institutional development plan a strategy of urban integration and mobility. The idea is to have an "integrated campus" because their buildings are all around the city.

With this plan, they managed to connect the different areas through pedestrian routes, bicycle lanes and open spaces for the community. They connected roads and areas, opened public spaces and made one big University zone [4].

Cambridge is also an example where they tried to give a solution to this problem, but the approach was different. They were looking "to create places where people want to live and work". Their vision is that Cambridgeshire will be a place with strong, growing, prosperous and inclusive communities supported by excellent public services. There, people can fulfill their potential and live healthier lifestyles [5].

On the other hand, Mexico City, also have initiatives in which civil associations have worked together with the government. For example, with the *Ecobici* program [6]. It is a transportation system for shared bicycles. Registered users can use the bicycles and return them in any bike station. Although it is an initiative that helps many people, the system is only in some areas of the city.

Cities like Amsterdam and Copenhagen have shown public bicycles as a sustainable solution to mobility problems with programs like "smart bike" and "City Bike" [7].

Also, there are companies that promote carpool such as *Bla Bla Car* [8], worldwide, and *Aventones* [9], in *Mexico,* they help to reduce costs and the number of cars on the streets.

We also found projects that are based on digital platforms to analyze and/or solve this problem. For example, the "*Twitter Jam*" a University of Porto´s project. They know which areas have more traffic based on the Twitts analysis [10].

Another interesting project is the one of the University of Óbuda in Budapest. They gather information from people attending events in Facebook. Also, download information such as weather and the current state of transit. This way, they have enough information to know the movement of the city and to be able to predict congestions or even to prevent accidents [11].

4 Collaborative Approach

To give a better definition of what we understand by collaboration, we return to the proposal by Crook (1994) who defines it as: "A coordinated and synchronized activity, the result of a sustained attempt to build and maintain a shared conception of a problem" [12].

From this concept we build the core of the digital tool, that is, to coordinate and synchronize collective actions that generate a shared vision of this problem and create a common channel between the users, so they can work on the solution.

We have the hypothesis that through collaboration and collective action, civil society can solve structural problems. That is why the design of the plan we propose is based in collaboration at different levels (between members of the same or different Universities). The strategy has an elaboration, communication and dissemination strategy seen from the communicative perspective and collaborative design.

"People in their daily lives, intent on their daily struggle with problems, opportunities, and ultimately the meaning of life. We observe how, more and more often, these people (re)discover the power of collaboration to increase their capabilities, and how this (re)discovery gives rise to new forms of organization (collaborative organization) and new artifacts on which they base enabling solutions" [13].

On the other hand, we took a more socially-oriented point of view and built the communication strategy based on Paramio's theory of collective action [14].

Based on this theory, we know that to motivate the use of the platform and collaboration, will be offering some kind of rewards.

5 Methodology

For the development of this project, we will rely on the methodology proposed in the "Developing and Implementing a Sustainable Mobility Plan" manual made by the European Union in 2013 [5]. This manual is divided in 4 phases: Research (or preparation), definition of objectives, elaborating the plan and implementation. Each stage includes a series of flexible and adaptable steps.

To complement the phases, we include tools to collect information in qualitative and quantitative forms. We took this tools from the Communication for Development model developed by the Swiss Agency for Development and Cooperation (SDC) [15]. SDC promotes development and actions for social change through community participation. Also, this document has practically the same phases previously indicated in the European Union manual.

5.1 Phase 1: UX Research Studies

In order to learn more about how the problem affected the University Community, we began our research with the community of the Universidad Autónoma Metropolitana, Cuajimalpa. This way we understood how the mobility situation affected the community. The approach was made from a quantitative and a qualitative perspective.

For the research phase, we use different tools such as surveys for students, professors and workers; interviews, statistical data analysis, media monitoring, and focus groups. That way we defined the first steps we needed to follow for the construction of the solution.

According to the surveys we made in the University, 17% of the students travel from 0 to 29 min each way, 25% from 30 to 59 min, 16% from 60 to 89 min, 14% from 90 to 119 min, 16% from 120 to 149 min and 12% 150 min or more.

In the qualitative approach, we made focus groups with some students. This helped us to complete the quantitative information previously collected. Our discovering's were the following (Fig. 1):

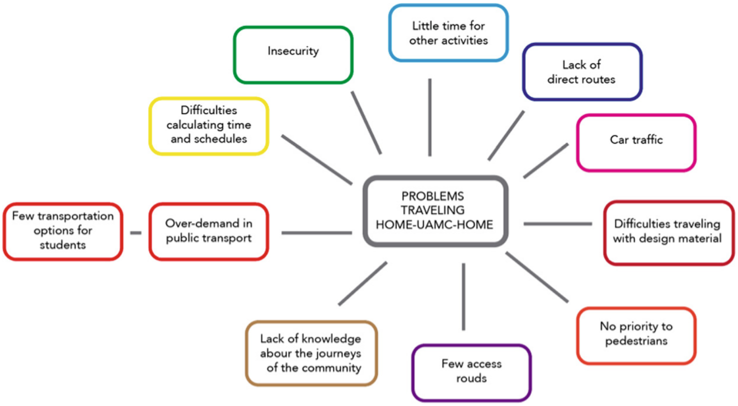

Fig. 1. Foundings.

This first stage helps us reach two important conclusions for the plan's construction. The first one is that the mobility problem has a lot of different factors. This means that it's impossible to think that there is just one solution. We learned that the problem should be approached in different ways, that's why our plan is divided in phases.

In second place, we can conclude that in order to accomplish our objectives and the mobility plan, the solution has to come from the collaboration and collective actions of the community and not depending on the government.

5.2 Phase 2: Objectives Definition

We recognize that it is not viable from our field of study to make structural changes in roads and the transportation system which are controlled by the government and concessionaires.

On the other hand, we are aware that, however limited these structural problems may be, the initiative of the civil society, accompanied by our digital tool, and a communication strategy can generate important changes. Therefore, our main objective is to design a collaborative tool between the community of the three main universities of Santa Fe.

6 Digital Tool Proposal

6.1 Phase 3 & 4: Elaborating the Plan and Implementation

We decided to divide phase in four different stages: 1. Designing the information system's general architecture based on collaboration. This system will have information on routes, schedules and availability in the transport. 2. The creation of the prototype of the system. 3. Design an institutional collaboration strategy for the launch of the system and for monitoring its use. 4. Plan the communication and dissemination strategy focused on the University Community of the three institutions.

Our surveys showed that almost all members of the University Community have a smartphone and mobile internet plans, so it is feasible that the main communication tool for the community is a mobile app. This way they can share their location and know the status of the transport system. Also, the app will be used while the user is in motion, therefore, it must be intuitive and simple.

In this stage we will implement the prototype and start the usability tests. This way we can evaluate the operation and know the opinions of the users. Once we analyze the information we will decide what are the adjustments that will be made.

6.2 System Architecture

The information system will be a mobile application where the University Community can view possible routes from point x to the University and the other way around. This way, users can make the most appropriate decision according to their time and preferences cost. If people collaborate to arrive and leave the University together, they will do it faster by sharing a car or a taxi.

The app will use an Api from Google Maps [16], and it will be powered by:

- Routes, stations and schedules of subway, *metrobus* and bike line. We decided to use only these transportation systems because they have the most established schedules.
- User profile data: academic institution to which they belong, type of transport used, registration and schedules (schedules may change). Also, users will fill if they own a car.
- Routes taken and kind of transport so that the system can define meeting points either by car or without car.
- Alerts regarding eventualities that arise on the road to Santa Fe such as: collisions, strikes, road congestion and transportation saturation.
- Internal chat so that, once you find a match, the users can agree on the meeting point and time.
- Each University will have a specific server with encrypted information. Therefore, access to the databases will be exclusive to each University and the administrators of each University will not be able to access data from the other institutions.
- The application is responsible for displaying data, not storing information.
- To register in the system will require the user to have a University number to guarantee that they belong to one of the educational institutions.

In order to achieve the project objectives and as part of the final delivery of results, we will develop the prototype of the system. However, we will keep the evidence and results of the work to make improvements.

The next Figure (Fig. 2) represents how the system works: first, the information that the system needs from the official public transportation data. Second, recollect the data from the community (University, schedule, routes, Facebook). Finally, the information generated by the interaction between the system and users will create collaborative schedules.

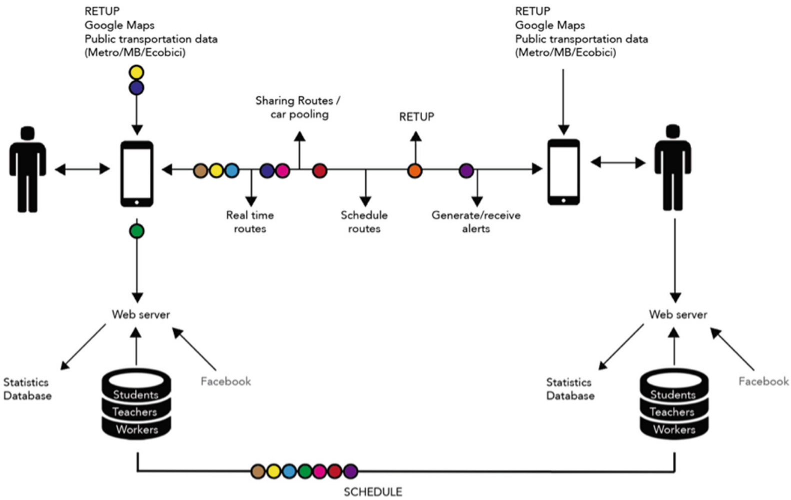

Fig. 2. System architecture.

To deal with the economic aspect, we will expect the institutional support of the three universities in economic resources and infrastructure. Also, the plan considers alliances with the private sector and civil associations.

7 Conclusions

It is important to mention that this digital tool is an element that is part of a larger scale mobility master plan for the three Universities located in Santa Fe, which will include an exclusive transportation system with real time location for the University Community, the diversification of internal and external routes and a more extensive inter-university collaborative work.

With this collaboration tool, we seek to lay the foundations for citizens to have new tools that allow them to face the daily problems that seem to have no solution. We believe that if society begins to collaborate, it will be more feasible to generate an important social change based on small actions taken together.

To the extent that the University Community makes use of this collaboration tool, we see a potential for improvement in the economic aspect of the users; in the environmental aspect, since a contribution is made to reduce the emission of Co_2 with the reduction of the traffic and a more rational use of the car, besides improving the efficiency of the routes and the performance of the members in the daily activities.

The plan is designed for a social sector that has demonstrated its willingness to work together. They look trough different ways to improve mobility in the Santa Fe area and are aware of the potential to do something by themselves, and not only depend on government actions that have not been effective.

We consider that this project has a solid theoretical, methodological and contextual base. This means that it has an important potential to make a noticeable change in the way the University Community relates with the mobility in Santa Fe.

From the academy, it is necessary to continue with the study of the city and sustainable mobility from different areas of knowledge. Mobility problems have very different causes, and this allows for theoretical and practical approaches that contribute to the solution of them, like this project which was made by the interdisciplinary approach of communication, design and information technologies.

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The Implementation of Environmental Friendly City Logistics in South Baltic Region Cities

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Abstract. The European Council has set the target to reduce European greenhouse gas emissions by 20% till 2020. The negative impacts of urban goods distribution are mainly caused by used vehicles (e.g. diesel-powered) and low system efficiency (e.g. low loading factor, low cooperation). The paper is focused on the introduction of the activities realized under new project – Low Carbon Logistic. It's realized under the Interreg South Baltic Programme. The major objective of this project is to implement the low carbon city logistics measures in 5 pilot cities as well as to promote and support this kind of activities in South Baltic Region. The aim of the paper is to introduce the assumptions for the activities realized in pilot cities. The planned results will be mostly focused on development of consolidation systems and implementation of alternative fuelled vehicles (EV and cargo-bikes). Also the major elements of LCL approach have been introduced.

Keywords: City logistics · Emissions · Assessment

1 Introduction

Up to 23% of global CO_2 emissions in 2012 came from the transport sector. About three quarters of CO_2 transport emissions in 2012 came from road transport [1]. Despite that the analysis of emissions from road transport usually takes into account the level of CO_2 [2–5], it should be consider that it is important to pay the attention also on local pollutions, like carbon monoxide CO, aliphatic and aromatic hydrocarbons (including benzo(a)pyrene), sulphur dioxide SO_2, nitric oxide NO_x and particulate matter PM (soot, tar) and heavy metals [6, 7].

Urban areas represent particular challenges for national and international freight transport, both in terms of logistical performance and environmental impacts (emissions, noise, accidents, congestion and land use). Urban freight is indispensable for the city's economy but at the same time freight deliveries significantly affect the attractiveness and quality of urban life [8]. Typically, urban freight transport represents between 20 to 25% of road space contributing to between 10 to 20% of urban road traffic [9]. The goods transport impacts negatively on the city environment not only by the pollutions but also with aspects such as congestion, noise, vibration and safety.

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Increasing the efficiency of transportation and starting to adapt vehicles and routines to be fossil fuel independent is one of the major challenges of our times – and the transport sector one essential segment that must be addressed here.

Due to the specificity of the South Baltic Region, mainly interaction and permeating of maritime economy (merchant and fishing ports) with tourist resorts, the basic problem becomes adequately effective organization of goods deliveries. One method to reduce the environmental impact from freight transport is a concept for consolidation of goods at a distribution centre (DC) or urban consolidation centre (UCC) with focus on last mile transports from the DC to public buildings/units (schools, preschools, nursing homes etc.) [10]. This kind of measure seems to be interesting option for not too big cities, like the ones located at the South Baltic Region. In Germany, Lithuania and Poland, the consideration of such solution is just being started and the opportunities to combine this approach with other green logistic solution must still be investigated, specified and supported with comprehensive and feasible concept. To address this challenge the Low Carbon Logistics project has been established [11]. The cities, towns and municipalities involved into the project plan true related pilot projects and hope to profit from other countries experiences – which is an excellent precondition for the planned project.

2 The Low Carbon Logistics Project

2.1 The General Concept of the Project

The project puts the establishment of green logistic solutions into the focus, and, doing so, will contribute to improving the quality and environmental sustainability of transport services in the South Baltic Region. To achieve this, a consortium of implementation locations and expert partners will join forces on developing improved and more environmentally sustainable freight services in the South Baltic area. The jointly developed solutions of smart transportation concepts aims to decrease the traditional vehicle use. The consortium is built with the 11 South Baltic Region partners from Sweden, Lithuania, Germany and Poland. The leader of the project is the Energy Agency for Southeast Sweden.

The general concept of the LCL project is to address 7 challenges: Challenge 1: Economy, Challenge 2: Demographic change, Challenge 3: Climate change, Challenge 4: Ecological awareness, Challenge 5: Costs/Budgets, Challenge 6: New drives, Challenge 7: Digitalization. In this wide field of issues, the project Low Carbon Logistics has started and wants to find the concrete solutions in the concrete fields of action. Once successful, LCL initiatives will have been developed in most small and medium sized cities. Also, businesses will have realized that LCL solutions for freight transports can enhance competitiveness, while the market for green solutions and products is steadily growing.

2.2 The Activities of the Project

The municipalities in the South Baltic Region will be coordinating their incoming and internal freight transports and the engagement of manpower that are foreseeable. In the effect, less stress and more time for their core business (in most cases cooking) can be achieved. The surrounding environment is also much safer due to fewer trucks around public buildings such as schools etc. Also, a large part of the goods to schools, and to other places dedicated to child care will take place by night using quiet vehicles with renewable fuel or electric vehicles. Fewer trucks and a better fill rate will add to efficiency (fewer deliveries), and the low-carbon solutions combined with renewable fuel will have, in total, resulted in a fossil free transport sector in most municipalities.

With the overall aim of starting the establishment of Low Carbon Logistic project structures in 5 locations within the South Baltic Region, giving them best practice status towards widest possible adaptation, the project will start with:

- analysis of preconditions (flows, type of goods, stakeholders, guidelines etc.);
- joint development of a low carbon logistics concept for towns and rural areas in the South Baltic Region, which will be done jointly by the pilot regions and an international consortium of transport and mobility experts;
- preparation for local/regional working plans and long-term strategies, developed as local adaptations in close cooperation with relevant players;
- active implementation of the determined measures and solutions, one pilot measure per region included.

The aforementioned development of smart transport services and concepts towards a reduction of the carbon food print caused by cargo trucks, will be achieved by the project by developing one holistic concept for this approach and starting the implementation of the concept in 5 South Baltic Region location, aiming at using smarter and more environmentally friendly transport services. In this context 4 political declarations and long-term cooperation agreements minimum will be signed during the project period and 2 international cooperation networks based on formal agreements will be established: the interdisciplinary project consortium itself and the expert support team. The project activities are collected under three actions: pilot activities, public awareness raising, international expert team (Fig. 1).

A third field of project activities, the most important from the future results sustaining, aims to merge the national expertise of the involved expert partners for optimum international use and to ensure that this expertise plus the additional knowhow gained via the project work will remain available for active use during and after the project: For this, an international consultancy structure will be established and lastingly operated towards supporting specific regions with the green logistics attempts, guidance on green policy instruments relevant for this work included. Within the objective "Connect the region", the project makes a contribution to the EUSBSR strategy field "transport" and follows the EUSBSR principles specified in the action plan.

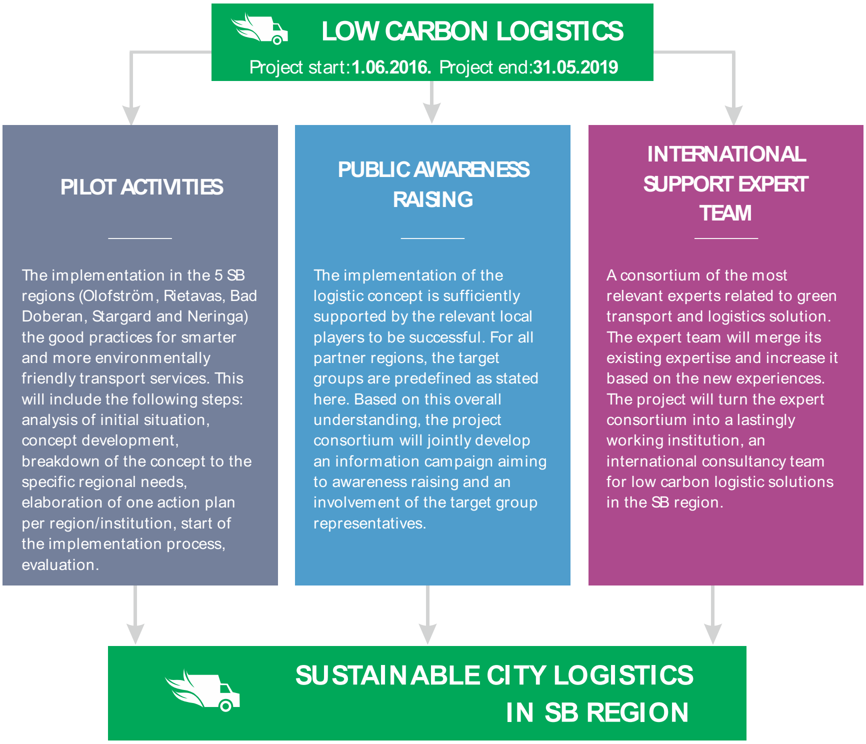

Fig. 1. The LCL major activities.

3 Activities in Pilot Cities

The activities and actions realized under the LCL work packages will be implemented in five pilot cities in each of the involved countries (Fig. 2): Bad Doberan (Germany), Olofström (Sweden), Neringa and Rietavas (Lithuania), Stargard (Poland).

All of the project's regions encounter the pollution and negative emissions in one way or another. As it was mentioned, the pollution of the Baltic Sea Region has a great impact on certain types of activities: tourism, economics and organization of logistics. Additionally, cities and regions do contribute to higher levels of pollution while performing certain economic activities. Therefore, an overview and analysis on regional problems is focused on environmental aspects of freight transport efficiency (Table 1).

Each regional project partner will, based on the concept, physically implement at least one measure improving the environmental sustainability through reduction of carbon emissions from logistics operations in the region. All pilots will be jointly evaluated and the results will be summarized and disseminated to serve third regions with information on different examples of how they can improve their logistical systems. The sum of all pilots shall transfer good practice across borders, inspire South Baltic Regions to improve their logistical system, recommendations and an implementation guide book.

Fig. 2. The LCL pilot cities map.

The basis of the implementation activities is the approach similar to the concept proposed in [12]. The starting point for this process was the questionnaire-based data collection (*ex-ante* analysis). It helped to analyse the present situation and needs in all partner sites. In the next step the measures analysis has been done. It helped to establish the local visions for all regions involved in a project (Table 1). Finally, the assumptions and first drafts of business models (using Business Model Canvas method) have been prepared.

The pilots will assumingly enhance innovation through knowledge/methodology transfer (bringing and gathering a successful methodology and expertise to new user groups in other countries). Options that can be of relevance to the project partners can be new distribution central or adaptation of present buildings, e-vehicles for transportation, coordinating software or route optimizations. The critical important step, which is realized now is to establish the proper business models for all planned initiatives, based on the concept of business model canvas. The ambition of the project consortium is to utilize the experiences achieved in the related projects and activities, like C-LIEGE [13], TURBOLOG [9], GRASS [14], STRAIGHTSOL [15], NOVELOG [16].

The whole process is designed to be continued after the project towards a holistic low carbon logistic area in accordance with the international concept. To achieve this, this work will be accompanied by extensive public acceptance measures from the very beginning, which includes campaign work, but also the development and recommendation of business models related to low carbon logistics, the creation of an international label for low carbon logistics institutions and learning from best practices by different means.

Table 1. The LCL local challenges and visions.

Partner city	Regional challenges	The local vision
Bad Doberan	Because of the importance of tourism, the inner city of Bad Doberan has developed into a compact city centre with many shops, whose supply with goods by trucks and transporters causes air pollution, noise and congestion. While analysing the most important challenges in the city, the problems of environmental impact and the need to optimize transport efficiency were indicated. The challenges that are central in Bad Doberan are new drivers as well as legislations and regulations. To enforce this, cities will employ regulations. In order to this, CEP services need new drivers and have to react with new concepts for the last mile	Because there are various CEP services operating in Bad Doberan and they are not interested in working together, different concepts are to be tested. Among the CEP services there are partnerships in Low Carbon Logistics with UPS and DPD. And for bundling parcels at the work place, the IT service Pakadoo will be installed in administration buildings and companies
Neringa	City is located in the Curonian Spit. The entire territory of Neringa municipality has the status of nature reserve Park. To reduce noise and pollution in the Curonian Spit area, it is recommended to encourage the use of electric/hybrid vehicles	The special plan foresees the development of the necessary infrastructure for EV – automatic loading stations. Moreover, the solution of acquisition of the electric/hybrid vehicle and the project of consolidation of the activities of municipal institutions will be further established
Olofström	As a consequence of the business structure in the municipality there are a lot of heavy fright transportation in the municipality and its surroundings, both train and trucks. The challenges that are prioritized in this region are economy and ecological awareness because the most important stakeholders in this region is the inhabitants/municipality suffering from “social” problems and the strong industrial culture and business structure	The measure that is chosen to further investigate is the dedicated truck-parking-area TPA. Distribution centre (DC) will be coordinating and consolidating deliveries outside the city center. TPA giving all trucks somewhere to wait for new assignments after delivering. The TPA is a first step. From this area the DC, the digital solutions (CODiMu) will be developed
Rietavas	The most important challenges are linked with safety and security and need of transport effectiveness	The measures to solve the problems are focused on traffic control, speed restrictions, authorization/prohibition

(*continued*)

Table 1. (*continued*)

Partner city	Regional challenges	The local vision
	(transport optimization). Air pollution and noise level are the most actual environmental problems in the Rietavas at this moment. Transit flow that crosses city territory is an essential problem that creates conditions to form a number of issues to be solved by the measures of green logistics	of traffic depending on time of the day, day of the week or season. Additionally, the establishment of centralized systems of goods and inventory distribution is planned. At least every institution operating under municipalities' order (kindergartens, schools, hospitals, etc.) may organize goods delivery in co-operation with other institutions. Additionally, development of environmentally-friendly transport fleet
Stargard	The most important challenges in Stargard are linked with environmental impact and the need to improve road infrastructure, as these problems result in air pollution. The city is included in "Programme of air protection for West Pomerania Voivode-ship" due to large dust concentration. Therefore, Stargard Municipality developed "Plan for low carbon economy for city of Stargard" which describes planned system activities aimed at reducing energy consumption and carbon emissions as well as increasing the production of renewable energy sources. The most challenging issue is to find the best organizational solution and financial model for this measure	The LCL concept is to implement Urban Consolidation Centre (named: Urban Consolidation Centre for Municipal Entities – UCC-ME) idea in Stargard that will serve several public entities located in the city. Presently freight deliveries in Stargard are realised directly from suppliers to receivers. They are managed separately and are not coordinated with each other. Because every delivery is realised independently, it generates negative results for the city environment due to increased number of vans or trucks. Developing the concept of UCC-ME allows these problems to be eliminated

4 Summary

It is the general intention of the project to establish low carbon logistics solutions that remain in operation and are further expanded after the end of the project – accordingly, all developed project results will have durable effect: The analysis by preparing the ground for the concept development, the concept being not only the basis for the local/regional implementations in the partner locations, but also serving as a lasting guidance for other regions interested in low carbon logistics. The communication measures will support the ongoing dissemination of these information, which is why the operation of the project website is continued after the end of the project under the guidance of the international expert consortium. This consortium as well as its practical consultancy offers to interested regions and locations are established in the project to remain lastingly active which is determined in a related cooperation agreement. And, last but not least, the established low carbon logistic solutions, like central distribution units, involvements of green vehicles etc. will be lastingly operated with pilot character and accompanied by ongoing public involvement work to enable a continuation of the started low carbon logistics work in all involved places. Generally speaking, the project will take an important step toward widely establishing green logistic solutions in the South Baltic Region area which go along with positive impacts on road safety, air quality, noise level, congestion, but also on the awareness of the involved players, procurement processes and supply chain set-ups which will take green arguments much more into account if integrated in such a concept.

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Environmental Aspects of Urban Freight Movement in Private Sector

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Abstract. As concern for the environment rises, green logistics is becoming essential and necessary to expand profit margins for companies and improve customer services. As such, companies take into account the external costs of logistics associated mainly with environmental pollution and a possible area of improvement is determined in the context of vehicle utilization. The aforementioned considerations form the background of this paper, which aims to investigate different operational scenarios of a company for urban logistics in an effort to reduce routing and environmental costs. Assuming a homogeneous fleet of capacitated vehicles, the goal is to design minimum cost vehicle routes for the service of a set of geographically scattered customers. The objective is to minimize the number of vehicles required to service all customers and the total mileage in order to indirectly streamline the urban delivery operations related to products. Besides routing costs, the environmental perspective behind this study is captured minimizing the total fuel consumption and thus, the possible pollutant emissions generated. An efficient routing algorithm is proposed utilizing several types of data specifying operational constraints such as vehicle's capacity, fleet size, location information and customer's data (i.e. time windows, demand, service time). For the evaluation of the different operational scenarios, an empirical study based on real data is conducted assessing the performance of the proposed algorithm and the reported results demonstrate both operational and environmental impacts.

Keywords: Energy efficient distribution · Urban logistics · Private sector

1 Introduction

In the urban environment, typically arriving from the producers' location to major facilities in the urban/suburban areas, produce are distributed to local consumers either in single shipments by privately owned vehicles or through intermediaries that consolidate shipments, usually not in an optimal way [1]. The high frequency and delivery time requirements as well as the large number of single shipments characterizing these deliveries in addition to freight vehicles operating well below their capacity, often lead to substantial negative externalities such as increased congestion, energy consumption and other environmental impacts such as noise and air pollution.

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As concern for the environment rises, green logistics is becoming essential and necessary to expand profit margins for companies and improve customer services. As such, companies take into account the external costs of logistics associated mainly with environmental pollution and a possible area of improvement is determined in the context of vehicle utilization. The effective planning and management of delivery schemes may impose a significant impact on current distribution operations optimizing the logistics of the produce supply chain thus minimizing several of the relevant externalities.

The aforementioned considerations form the background of this paper, which aims to investigate different operational scenarios for urban logistics in an effort to reduce routing and environmental costs. Assuming a homogeneous fleet of capacitated vehicles, the goal is to design minimum cost vehicle routes for the service of a set of geographically scattered customers. The objective is to minimize the number of vehicles required to service all customers and the total mileage in order to indirectly streamline the urban delivery operations related to products.

Besides routing costs, the environmental perspective behind this study is captured minimizing the total fuel consumption and thus, the possible pollutant emissions generated. An efficient routing algorithm is proposed utilizing several types of data specifying operational constraints such as vehicle's capacity, fleet size, location information and customer's data (i.e. time windows, demand, service time). For the evaluation of the different urban operational scenarios, an empirical study based on real data is conducted assessing the performance of the proposed algorithm and the reported results demonstrate both operational and environmental impacts.

The remainder of the paper is organized as follows: Sect. 2 provides a description of the most recent literature review on the environmental aspects of city logistics from the perspective of private sector and Sect. 3 describes the model formulation. The solution framework used for generating delivery routes is presented in Sect. 4. In Sect. 5, an empirical case study is conducted and the corresponding impact of the examined operational scenarios is provided. Finally, Sect. 6 concludes the paper by presenting the main findings and future research recommendations.

2 Literature Review

In the context of environmental sustainability, most studies are implemented from the public sector as they are mainly focused on the environmental objectives. However, this study aims to capture the trend of corporate social responsibility (CSR), which is defined by the European Commission as *"the responsibility of enterprises for their impact on society"* [6], and in which environmental cost is a significant initiative of many enterprises. The most recent approaches are the following which aim to involve both companies and public policy makers. McKinnon et al. [8] present a detailed study of the environmental effects of all the activities involved in the transport and the issues discussed in the book are topical, important and currently engaging the attention of company managers and public authorities. In terms of green logistics, the paper of the Cezarino et al. [2] investigates and studies the concept of green logistics approaching theory and practices specialists with urban transportation categories. Similarly, Mancini

[7] aims to point out relevant issues arising in real-life freight-distribution problems and to describe still-open issues and gaps between models and real-life applications.

3 Model Formulation

Efficient and effective urban freight transport contributes to a wide range of objectives for which the public authorities have an established competence and reinforce the growth level of the area. Moreover, the trend of CSR contributes to social welfare [3] and is a significant initiative of many companies aiming at long term progress beyond profit maximization. Companies are increasingly using CSR reports in order to have a common understanding on sustainability and monitoring both economic and environmental objectives.

In the context of direct deliveries as the most urban deliveries are, operational restrictions affect significantly both economic and environmental aspects. Strict time windows of customers dictate to a large extend the vehicle routing plan, and relatively few customers are served per vehicle route. These result in low flexibility cases with increased waiting times where the vehicle remains idle consuming extra fuel, increasing operational costs and generating increased GHG emissions to the wider urban area.

Fuel consumption constitutes a critical pollution factor with harmful consequences for human health (cardiovascular diseases, respiratory problems, chronic obstructive pulmonary disease etc.) and the environment (carbon dioxide, methane and other greenhouse gas emissions). The factors that have the greatest impact on fuel consumption and considered in the corresponding measure *KpL* (Kilometers per Litre) could be synopsized to the following: distance travelled d_{ij}, vehicle speed v_{ij}, vehicle load factor L, waiting time at customers w_i and road gradient γ_{ij}.

Given a $G = (V, E)$ is a complete graph with a set of nodes $V = \{0,1, \ldots, n\}$ (0 is the depot) and a set of arcs $E = \{(i,j) \mid i,j \in V,\ i \neq j\}$, the travel distance between a pair of customers is d_{ij} and the travel time is t_{ij}. Let $K = \{1, 2, \ldots t\}$ be the homogeneous set of vehicles with capacity Q and each customer has a demand d_i, arrival time a_i, waiting time w_i, service time s_i and a predefined time window $[e_i, l_i]$. Based on Suzuki [4] and on the well-known model of the Vehicle Routing Problem with Time Windows [5], the model formulation of the studied problem is described as follows:

$$min \sum\nolimits_{k \in K} \left(\sum\nolimits_{ijk} \frac{dij}{(a0 + a1vij)\gamma ij\pi ij} + \sum\nolimits_{i} wi\rho \right) \tag{1}$$

Subject to

$$\sum\nolimits_{ik} xijk = 1, \forall j \in V \backslash \{0\} \tag{2}$$

$$\sum\nolimits_{jk} xijk = 1, \forall j \in V \backslash \{0\} \tag{3}$$

$$\sum\nolimits_{i \in V\backslash\{0\}} xi0k = \sum\nolimits_{j \in V\backslash\{0\}} x0jk = 1, \forall k \in K \tag{4}$$

$$\sum\nolimits_{\mathrm{k} \in \mathrm{K}} \sum\nolimits_{i \in V\backslash\{0\}} xi0k = \sum\nolimits_{\mathrm{k} \in \mathrm{K}} \sum\nolimits_{i \in V\backslash\{0\}} xijk = t \tag{5}$$

$$\sum\nolimits_{\mathrm{k} \in \mathrm{K}} \sum\nolimits_{i \in \mathrm{S}} \sum\nolimits_{j \in \mathrm{S}} xijk \geq 1, \ \forall S \underline{\subset} \mathrm{V}\{0\}, \ \mathrm{S} \geq 2 \tag{6}$$

$$\sum\nolimits_{\mathrm{i} \in \mathrm{V}} xi\mathrm{j}k = \sum\nolimits_{\mathrm{j} \in \mathrm{V}\backslash\{0\}} xijk, \forall k \in K, \forall i \in V\backslash\{0\} \tag{7}$$

$$\sum\nolimits_{i \in V\backslash\{0\}} di \sum\nolimits_{j \in V\backslash\{0\}} xi\mathrm{j}k \leq \mathrm{Q}, \quad \forall k \in K \tag{8}$$

$$(ai + wi + si + tij - aj)xijk \leq 0, \forall i, j \in V, i \neq j, \forall k \in K \tag{9}$$

$$ai \leq li, \forall i \in V \tag{10}$$

$$ei \leq ai + wi \leq li, \forall i \in V \tag{11}$$

$$xij \in \{0, 1\}, \forall i, j \in V, \forall k \in K \tag{12}$$

where $x_{ijk} = 1$ if the vehicle k travels from customer i to customer j, π_{ij} is the deviation from the average value *KpL* due to load, $\alpha 0$ is the parameter for the speed intercept, $\alpha 1$ is the parameter for the speed slope and ρ is the parameter for fuel consumption when the vehicle is idle.

On the basis of the above, this paper aims to study how different operational scenarios affect both economic and environmental aspects. As such, useful comparisons are made towards the effect of customers' time windows by studying two scenarios according to the percentage of customers with flexible time windows w.r.t. the total number of customers (i.e. 10% and 30%) that allow a longer scheduling horizon. Towards this direction, the effect of max route duration is also studied by allowing drivers to work overtime either for 60 min or 100 min and two extra scenarios are analyzed.

4 Solution Framework

The proposed framework consists of a greedy randomized construction phase for building initial solutions, a Guided Local Search algorithm (GLS) [9] to enhance intensification and an evolutionary mechanism to explore the solutions' space for high quality solutions. The GLS utilizes a construction heuristic based on Solomon's work [10] and an ordered list called restricted candidate list, composed of a number of most beneficial elements. To this end, one saving-customer is selected at random from the list and inserted to the route.

On return, the evolutionary mechanism explores trajectories of high quality solutions by utilizing a ruin-and-recreate scheme [11]. A new complete solution is generated and a GLS tuned for intensification search. GLS uses a set of selected features to penalize all possible directed arcs that may appear in a vehicle routing plan with feature costs equal to sum of arc distances and vehicles' waiting time.

It is a modification of the original algorithm proposed first by Voudouris and Tsang [9] and uses an augmented objective function penalizing solution features to help the search to escape from local optima. The main idea lies on the fact that a better solution consists of low cost features and as a result, high cost features are considered unfavorable and they must be removed. Hence, penalties are set to costly features increasing more their cost and driven the search in a different place on the solutions space.

5 Empirical Case Study

An empirical case study is conducted to evaluate the performance of different operational scenarios in terms of economic and environmental costs. As such, the first objective is to minimize the total number of vehicles and the secondary to minimize the fuel consumption of the routing plan. A real data set of 137 customers in the urban area of Attica region is utilized and given a set of depot-returning capacitated vehicles, a routing plan is generated for servicing them on a regular basis. The vehicles belong to the same company that has to serve the set of customers. Each customer is visited only once by exactly one vehicle in order to receive products and within predefined time windows that set the earliest and latest acceptable time of deliveries.

The base case scenario is the best obtained solution generated utilizing the proposed solution framework and following the operational constraints of the company. The 1st scenario involves a 10% of randomly selected customers with flexible time windows and the 2nd scenario involves a 30%. Note that the first 10% of customers are also included in the 2nd scenario. Regarding the effect of max route duration, drivers are allowed to work overtime either for 60 min (3rd scenario) or 100 min (4th scenario). A composite indicator for evaluating the different scenarios is adopted based on the form ***"100 × Number of Vehicles + Total Distance Travelled"*** [10] in order for the comparisons to be fair. However, an extra cost of 1 unit per minute is added to this form in case that a driver works overtime.

Table 1 summarizes the results obtained for the base case and the corresponding different scenarios. The columns list the different scenarios as analyzed above and the lines present the relevant objectives. In the studied case, the longer scheduling horizon attempt is more efficient in case that a driver works overtime for 60 min. There is a significant deviation from the base case (10.81%) and the reductions on the fuel consumption and total travelled distance reach 25.84% and 31.08% respectively.

Table 1. Detailed results of the different scenarios.

	Base case	1st Scenario	2nd Scenario	3rd Scenario	4th Scenario
Number of vehicles	9	9	**7**	9	8
Fuel consumption	1046.84 lt	1008.54 lt	1500.52 lt	**776.29 lt**	1163.80 lt
Total distance	722.69 km	640.07 km	831.45 km	**498.09 km**	639.02 km
Composite indicator	1984.84	1908.54	2200.52	**1736.29**	2063.80

However, the “overtime” strategy results to negative results in case that a driver works for 100-min extra. For this case, there is an increase of 6.01% regarding the composite indicator compared to the best solution obtained for the current operational case, even though there is a decrease in the total number of vehicles (11.11%) and in the total distance traveled (11.58%).

Moreover, there is also a slight decrease (1.97%) in the composite indicator in case that there are a 10% of randomly selected customers with flexible time windows (1st scenario). On the other hand, it should be mentioned that the 2nd scenario succeeds the minimum vehicles for servicing the customers of the studied company (i.e. total 7 vehicles). However, there is an increase of 13.03% regarding the composite indicator compared to the base scenario. Overall, Figs. 1 and 2 depict the different objectives and how the studied scenarios affect them presenting also the interrelations among them.

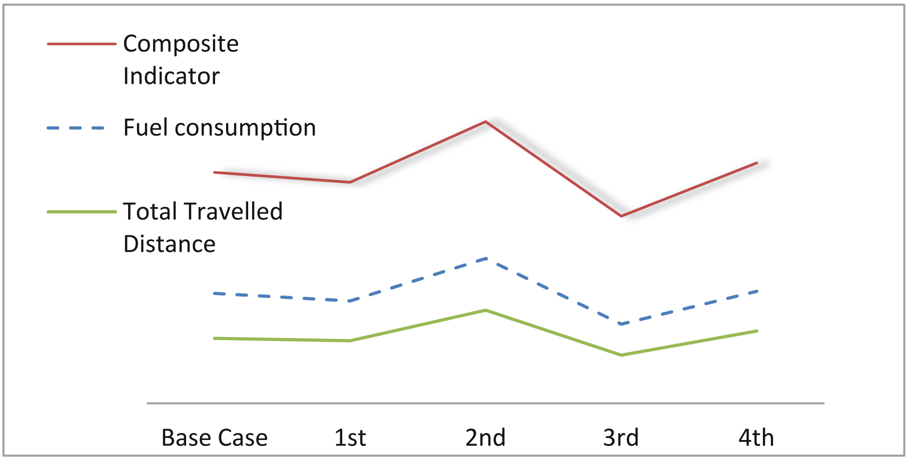

Fig. 1. Performance of different scenarios and objectives.

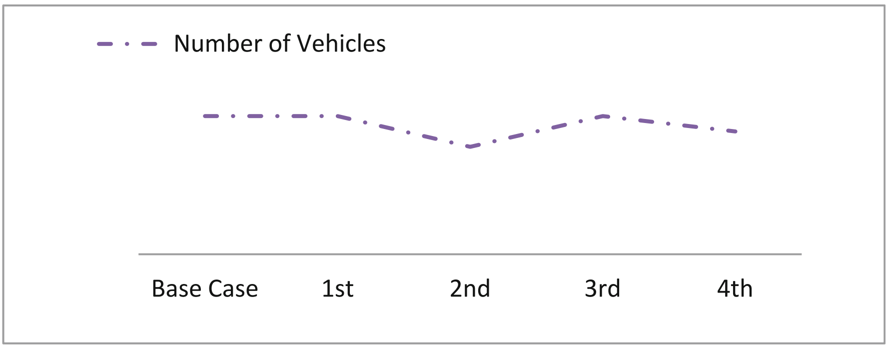

Fig. 2. Performance of different scenarios in terms of total vehicles utilized.

6 Conclusions

The paper presents the impact of different operational scenarios for distributing produce to customers. It is one of the few attempts that studies the environmental aspects of the private sector and tries to presents how both private and public sector could appear common objectives even from different perspectives.

Building upon successful solution approaches, an efficient solution framework is adopted for the evaluation of the different operational scenarios promoting both economic and environmental objectives. An empirical case study is conducted and four scenarios are analyzed to demonstrate the performance of different scenarios in a real case in terms of fuel consumption, total travelled distance and total number of vehicles used. The context of the distribution is described and the scenario within which drivers are allowed to work overtime for 60 min proved to be more competitive promoting also a more environmental friendly urban freight approach of the company.

In terms of future steps, valuable insights are drawn for real-life applications and emphasis should be given by companies even in simple actions at an operational level so that the number of vehicles required is reduced and the vehicle load factor is improved. Hence, they will achieve economic benefits and enhance their CSR profile contributing also to the society.

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Assessing Traffic and Environmental Impacts of Smart Lockers Logistics Measure in a Medium-Sized Municipality of Athens

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Abstract. Home deliveries and e-commerce activities have increased substantially in the recent years. This fact led to the increase of the number of last mile trips in urban areas contributing immensely to the overall impacts on the urban environment. Communities are called to find smart solutions to alleviate these impacts, providing at the same time efficient logistics operation, service quality and user satisfaction. "Smart lockers" is a novel city logistics measure aiming at mitigating issues generated from the last mile of parcel deliveries, thus promoting the principles of sustainable urban mobility.

In the present study a microscopic simulation of freight traffic flows was performed in a medium-sized municipality of Athens, Greece. Actual delivery data were obtained from a well-known logistics provider and used as input in PTV Vissim software in order to firstly assess the current operation of the deliveries in the study area. Further, an alternative scenario was developed, assuming that instead of home addresses, deliveries were made to the existing, though currently of limited use smart lockers network, assuming final collection of the order by the consumers. Consumers' traveling options and preferences, were simulated in more sub-scenarios and results were compared to provide better understanding of the potential benefits arising by implementing the measure. Impacts on traffic (i.e. travel times and delays), as well as on the environment (i.e. emissions) were further assessed in a multicriteria framework which led to the estimation of the Logistics Sustainability Indices of the tested scenarios.

Keywords: City logistics · Urban mobility · Simulation · Evaluation

1 Introduction

As urbanization increases by the years, the needs of the modern societies, in terms of quantity of goods deliveries in the cities, are becoming higher and more demanding. Decision makers and transport operators have to seek into implementing innovative smart logistics solutions towards alleviating traffic congestion, accidents and environmental deterioration, maintaining at the same time a high level of service. "Smart lockers" is a novel city logistics measure aiming at mitigating issues generated from the

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last mile of parcel deliveries, thus promoting the principles of sustainable urban mobility.

Home deliveries constitute a convenient delivery method, especially for online shoppers, but at the same time the most problematic part of the delivery course, in terms of cost and service's organization. Alternative applications, as Automated Parcel Stations (APS), which satisfy both recipients' demand for flexibility and companies' needs for optimization of the delivery process through consolidated shipments, are fast-growing solutions. These solutions involve the final recipient in the delivery process and specifically, into traveling the last mile to receive his/her parcel. In that way, parcels are delivered for deferred collection by their individual recipients within a certain time period, e.g. 48 h, without interacting with the operator. This gives flexibility to final recipients' pickup, lowers the delivery costs as compared with the costs of a home delivery and systematizes the delivery process [1].

The present study uses a traffic simulation software to model the network characteristics, and to assess traffic and environmental impacts, under two scenarios in a case study of a medium-sized municipality of Athens; the prior situation with the home deliveries and the current situation in which deliveries are made to the smart lockers assuming deferred pickup by the final recipients within the same day. Analytically, the study is organized in five chapters. Section 2 notes all the relevant to the measure findings from the literature review. Section 3 explains in detail the methodology that has been followed for the assessment of the measure. Section 4 showcases the example of a medium-sized municipality of Athens along with the results, while Sect. 5 concludes all the findings from the analysis.

2 Literature Review

Applications of smart lockers have been in place since the beginning of the last decade in various European countries. Most of them are carried out by logistics service providers in cooperation with retailers. In Germany, smart lockers for Business-to-Consumer (B2C) and Consumer-to-Consumer (C2C) deliveries, called Packstations, operate since 2002, resulting in the reduction of energy consumption and the improvement of transport efficiency and of the quality of life [2]. In 2004, in Paris, smart lockers were tested for Business-to-Business (B2B) distribution of spare parts to craftsmen, with the latter reporting a reduction in fuel consumption and a simultaneous increase of their productivity [2]. In Berlin, a type of smart lockers called Bentobox was tested as a consolidation hub, as well as a transshipment location for an operator. Reports highlight the de-coupling of the delivery process and the bundling of shipments resulting in fewer delivery trips. Bentobox was also tested as a receiving point for storing retailers' deliveries, with reports highlighting the absence of distributor - receiver interaction requirement and the decrease in handling time for the operator [3]. In Szceczin, Poland, a study of the postal company's smart lockers implementation, reported an impressive increase in the provider's efficiency (10 times more parcels delivered traveling 53% less kilometers, compared to the traditional delivery system) and a huge reduction in CO2 emissions (95%, regarding the fleet of the distribution company) [4].

3 Methodology

Data concerning parcel deliveries in the Attica region of Greece were provided by DHL Express for a period of one month (March 2017). Analysis of this data in Excel spreadsheets (route statistics, load factors, etc.) led to the selection of the study area (Municipality of Halandri, a suburb in the northern part of the Athens agglomeration) and consequently the simulation day. Spatial analysis and mapping of stop points for deliveries were carried out using the QGIS geospatial software.

Freight flows simulation was performed using the PTV VISSIM traffic microsimulation software. Traffic volumes and speed data from detectors placed in distinctive positions of the municipality's road network, were acquired from the Traffic Management Centre of the Attica Region, while traffic signal programs were given from the corresponding department. All the obtained data were used as input in the software for the development of the simulation model. Distinctive road axes in the study area were selected for the configuration of the model's road network and designed in VISSIM using geometry information extracted from Google Earth (e.g. number of lanes on each direction, length measurements of intermediate sections and lane widths) and CAD drawings of intersections (e.g. permissible turning movements and signal heads position) that were provided along with the traffic signal data. Model's parameters (e.g. desired speed limits and relative flows) were estimated from obtained data and/or reasonable assumptions. Traffic data lacked any information on vehicle composition, a fact that led to the selection of only two vehicle types (car and Heavy Good Vehicles). HGV relative flows were assumed fixed lengthwise and for the whole duration of the day. Specifically, mean values from measurements across the study area's road network were given by Attiko Metro S.A. [5].

After completion, the model was calibrated using the calibration criteria by the Wisconsin Department of Transportation for their Milwaukee freeway simulation model [6]. A sufficient number of data collection positions were selected for the calibration. These positions corresponded to actual detectors positions, from which traffic data were available, a fact that rendered them appropriate for comparing real values to simulation ones. A total number of 10 simulation runs with different random seeds was decided in order to guarantee representative normalized results. The warm-up period was set equal to 1800 s in order to load the network realistically before the beginning of the evaluation of the results [7]. Results indicated a deviation between reality and simulation values, beyond the criteria limits. A series of modifications was performed on the model's geometric and traffic parameters (e.g. corrections in link geometry, relative flows in certain turning movements), so that the calibration criteria be met using trial and error method.

The calibrated model was used for the configuration of the two scenarios (base and alternative). Actual delivery stop points spread throughout the study area. The model's road network, though, consists of a limited number of axes. For the purposes of the simulation, stop points that were positioned outside the model's network, were projected on the nearest axis of the model. After a sufficient number of runs (same as before), the results from the simulation of the two scenarios were evaluated. Traffic impacts were estimated using certain indictors in Vissim (travel time, veh-km) individually for the two stakeholders (courier company and final customers). Environmental impacts of the two scenarios (indicators: CO_2, NOx, PM10) were estimated using the EnViVer software. Finally, a sustainability index of the two scenarios was estimated using the Evalog tool for the evaluation of lockers as a logistics measure [8]. For this, the three aforementioned environmental indicators were used, along with a traffic indicator (total delays). The flowchart below is an overview of the methodology followed (Fig. 1).

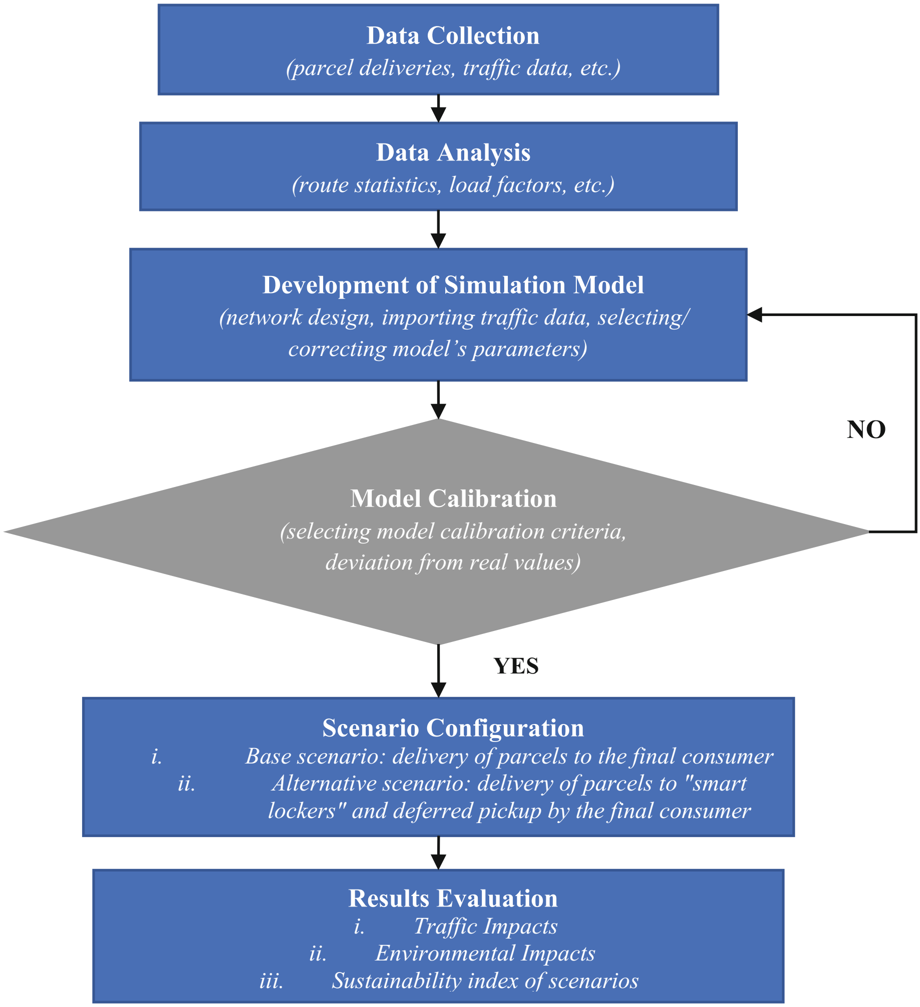

Fig. 1. Flowchart of methodological approach.

4 Case Study of Implementing

In Greece, DHL Express has launched from 2016 the installation of the first smart lockers at selected gas stations. So far, ten stations have been installed and operated in Athens and one in Thessaloniki. The application is at an early stage with small network development and a particularly low utilization rate (10%–15% of its capacity, according to information from DHL Express).

Analysis of the delivery data provided by the company, showed that Halandri featured more deliveries in lockers compared to the rest of the municipalities in the DHL lockers network. Additionally, it is the only area served by more than one smart lockers stations.

4.1 Base Scenario

On the selected simulation day (March 9th, 2017), 70 delivery stops were realized in the study area, between 11:00 and 16:30, by five DHL vehicles, each one of them following a different route which included other neighboring areas too.

During these stops all parcels were delivered to end-user addresses (home deliveries). All five vehicles entered and exited the study area's road network two times during their route for the completion of the delivery process. The consequent freight flows were simulated in the base scenario model in order to firstly assess the current operation of the deliveries in the study area. It should be noted that deliveries of parcels weighing over 20 kg were excluded from the simulation of both scenarios, as this is the locker's weight limit per parcel.

4.2 Alternative Scenario

In this scenario, the same parcels are transported by the company's vehicles to the locations of the two smart lockers stations and are temporarily stored inside the lockers. The final recipients move to the lockers to pick up their parcels, during the day and at a time of their convenience. This scenario simulates, in addition to company's vehicles, the recipients who use their car as a means of transportation to and from the lockers.

On March 9th, the company's vehicles delivered parcels weighing a total of 156.6 kg in the area of Halandri. This load is considered to be small compared to the load capacity values found in the company's vehicles (<15% of the capacity of a typical DHL vehicle). Without taking into account possible volume constraints, as there was no data on the dimensions of the parcels available, this load can be borne by any of the company's used vehicles. For the purposes of this scenario, it was assumed that the company's five vehicles of the base scenario were replaced by one that would deliver the parcels to the two locker stations. Each of the 70 deliveries was assigned to the nearest locker station for temporary storage.

Subsequently, the number of cars which would be involved in receiving the parcels from the lockers, was estimated. From all the possible modes of transport to and from the lockers, only the car option was taken into account for the simulation. Pedestrian movement and cycling have zero environmental impact, while public transport routes are being executed whether the recipients choose to use them or not. Regarding the percentage of the pickups that will be made by car, the results of a study in Szczecin, Poland, were used [9]. According to this study, 51% of customers using lockers for receiving their parcels, uses the car to access the lockers. A set of criteria was created for the selection of the most suitable deliveries to be picked up by car (e.g. delivery weight, distance travelled), using findings from similar studies [10, 11].

The routes of the resulting cars were considered as generated traffic due to the implementation of the measure, the effects of which were investigated. According to the assumptions of this scenario, the company's vehicle delivering all the packages to Halandri area, enters the model's network at 8:30 am and makes its first stop at the locker station located at Pentelis Ave, to continue afterwards, for its next and last stop at the locker station located at Kifisias Ave. The pickup routes start at 10:30 and last until 23:00. The sequence of departure times was selected to follow traffic activity throughout the day.

4.3 Results

After multiple simulation runs on both scenarios, results are shown in the tables below. Travel time and distance and the number of vehicles per stakeholder and scenario, are shown in Table 1 for comparison. Changes in the values of the selected indicators (CO_2, NOx, PM10, Total delays and the sustainability index), due to the implementation of the lockers measure, are highlighted in Table 2.

Table 1. Total simulation results per stakeholder and scenario.

Stakeholder	Courier company		Final customers	
Scenario	Base	Alternative	Base	Alternative
Travel time (sec)	23085	4073	0	26662
Travel distance (m)	58097	5265	0	118742
Number of vehicles	5	1	0	118742

Table 2. Changes in indicators' values due to the implementation of the lockers measure.

Indicators	Environmental			Traffic	Sustainability
	CO_2	NOx	PM10	Delays	LSI
Changes	−0.30%	−0.40%	−0.30%	−2.00%	+1.1%

5 Conclusions and Future Research

This paper proposed a methodology to investigate the impacts of Smart lockers, as a city logistics measure, and then used traffic microsimulation to evaluate the situation before and after their establishment.

5.1 Results' Analysis

Based on the results, great benefits have appeared by the establishment of the Smart lockers, both for the operator and the municipality. Specifically, the average travel time of the freight vehicles reduced by 82.4% with analogous reduction in traffic delays. The total veh-km reduced by 90.9% meaning that almost 80% of the fleet of vehicles is not necessary anymore. Under the view point of supply chain operator, the above findings in conjunction with the reduction of person months indicate a steep downsize of the direct and indirect operating costs and risks. At the same time networks' overall emissions and traffic delays were slightly improved, showing that the benefits from avoiding home delivery trips outweigh the negative impacts induced by the extra pick up trips of final recipients which are realized with motorized vehicles.

Other expected benefits from the establishment of Smart lockers are the following:

- Limitation of the not-at-home deliveries phenomenon, owing to the absence of the recipient, resulting in double and triple deliveries with extra costs.
- Less vehicle kilometers for the operator, which leads to a reduction of the price of the service provided.
- Less freight vehicles on the road network, means less unregulated parking stops, less urban space engagement, less infrastructure usage, more green spaces, the unoccupied parking of other cars and the lack of space for loading/unloading, higher quality standards.
- Flexibility, by combining individuals' pickup/delivery trips with trips for other purposes.
- Smart lockers are mostly located in areas (commercial centers, shopping malls, city centers) served by public transport, so part of the delivery/pick up trips do not burden the road network or/and the environment at all.

5.2 Further Analysis

A questionnaire will be developed and disseminated, as a future step, in order to capture recipients' perceptions on the level of service of the measure as well as the transport mode that they will use to reach the local locker. In order to validate and further analyze the impacts of Smart lockers establishment the applicability of this methodology should be checked in a bigger scale.

Concerning further research on this very model, additional measures should be tested to assess their performance in comparison with the Smart lockers. Finally, the assessment of the measures should be expanded not only to transport and environmental aspects, but also socioeconomically.

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Adaptability/Transferability in the City Logistics Measures Implementation

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Abstract. Urban freight transport is a part of a complex system comprising a considerable number of various participants, numerous limitations, fragmentation of goods flows, which decreases the transport effectiveness, pivotal connections in supply chains, and also the risk of conflicts between expectations of particular stakeholders. The problems require that a well-thought approach to implementation decision making should be applied. A prerequisite for a correctly implemented process of urban freight transport optimisation and rationalisation is an ex ante, in-depth analysis of the current situation and condition of a given urban system, a well performed assessment of obtained results and correct identification of goals for future actions. The paper is focused on the methodological assumptions for the implementation of the city logistics measures based on the adaptability and transferability approach. The major objective is to establish the general framework for this kind of activities.

Keywords: City logistics · Urban freight transport · Adaptability
Transferability · Implementation · Development

1 Introduction

City logistics is a part of a complex system comprising a considerable number of various elements, like transport operations, points of storage and sale, processes connected with goods and types of moves, kinds and equipment connected with serving the physical flows, locating and managing the basic structures indispensable for physical flows (including warehousing processes of incoming and dispatched goods), operations of logistics IT systems [1]. Moreover, this kind of system includes different types of participants (logistic services providers, senders, recipients, municipalities and regional authorities, city inhabitants and visitors, etc.), numerous limitations (e.g. regulations regarding the traffic and customers' needs), fragmentation of goods flows, which decreases the transport effectiveness, pivotal connections in supply chains (reloading, contacts with customers, last kilometre deliveries), and also the risk of conflicts between expectations of particular stakeholders (e.g. inhabitants and shippers) [2]. The complexity of this system requires that a well-thought approach to implementation of measure supported its functioning should be applied. According to the results from many projects realized in the past (like BESTUFS [3]) or in recent years (like C-LIEGE [4], GRASS [5], STRAIGHTSOL [6], SULPiTER [7], LCL [8]), the utilization of good

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practices is very efficient method of implementation of UFT measures [9]. The most important problem is the proper assessment of the adaptation requirements, correct identification of the possible actions and appropriate good practices' choice as well as the efficient on-going analysis which will help to assess the proper Critical Success Factors fulfilling. The present approaches are usually focused only on the analysis of measures and not include the ability of the implementation environment to make the changes and adapt the planned solutions. Whereas, the efficient implementation also should be based on the assessment of the adaptability level of the implementation area, in this case – the city. It is related to the city structure, the infrastructure existing in the city and the goods flows generated within the city [10] as well as a local and regional role, policy, and maturity of the city [11].

The paper is focused on the major assumptions of the adaptability/transferability-based implementation process, which have been developed in the NOVELOG project [12]. One of the objectives of NOVELOG was proposing a methodology that makes it possible to implement good practices in the city logistics systems on the basis of the city and measures adaptability level assessment. The efficient measures implementation in city logistics is strongly related to the analysis of the city as the area of the implementation process, called in this paper the *adaptivity* of the city. The aim of the paper is to underline the importance of this aspect and introduce some general issues, expectations and drivers related to that.

2 The Methodology of Adaptability/Transferability-Based Implementation Process in Urban Freight Transport

The implementation process may be realized on the base of three major approaches [2]: creation (developing completely new solutions from scratch), transfer (direct copying of practically proven solutions), adaptation (transferring practically proven solutions while making changes that mainly depend on the implementation environment). Figure 1 presents the methodology of adaptability/transferability-based implementation process of UFT good practices, which concentrates on examining the effectiveness itself and focuses on taking into account the assessments made by stakeholders.

In the case of a transfer or adaptation, using the models and sample measures is the basis of an implementation procedure and a significant part of activities are focused on searching for appropriate models and in-depth analysis of the proper benchmarking parameters, indicators and effectors. Due to that a prerequisite for a correctly implementation of urban freight transport optimisation and rationalisation measures is an ex ante, in-depth analysis of the current situation and condition of a given urban system, a well performed assessment of obtained results and correct identification of goals for future actions. The adaptability/transferability-based implementation process in city logistics systems should be realized taking to the account two dimensions: the adaptability of the analysed good practice (or practices) and the *adaptativity* of the city as the environment of the implementation.

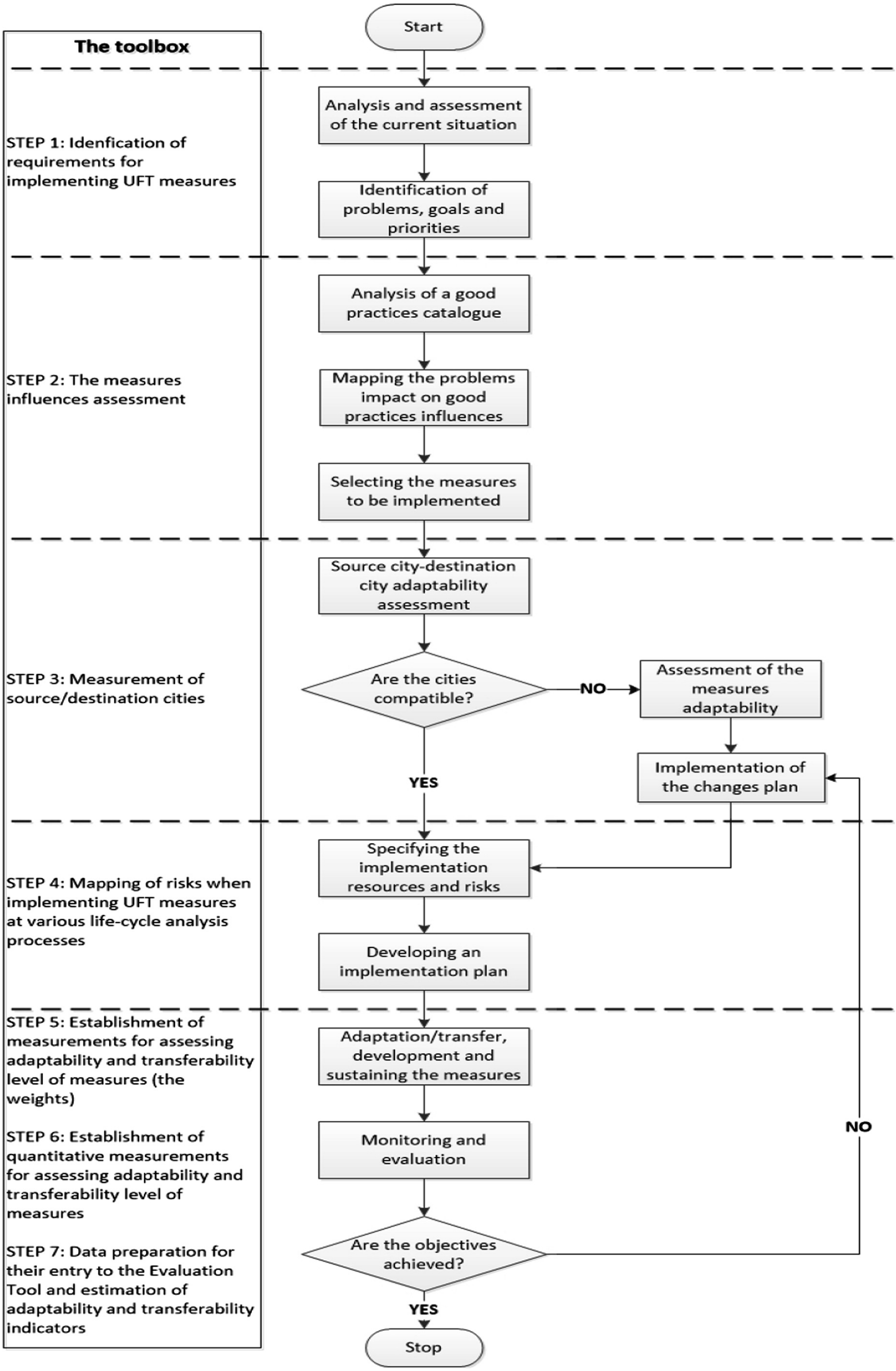

Fig. 1. The adaptability/transferability-based implementation process in city logistics.

3 The City Adaptivity Assessment

The starting point for the identification of the city *adaptivity* level is the analysis of the structure, present situation and freight flows inner the city area. The proper, full assessment of the present situation in the city related to the urban freight transport functioning should include three areas of the analysis [10]: **analysis of the city structure** (general features of the city in terms of urban planning, infrastructural specificity, economic description, regulations referring to administrative measures to regulate the city traffic), **analysis of the infrastructure existing in the city**, **analysis of the goods flows generated within the city** (logistic parameters, technological and organisational parameters, logistic processes optimisation level, specificity of logistic processes management, shippers typology, types of logistic nodes (taking into account senders and recipients of cargoes), secondary flows, additional aspects of contacting customers).

Analysing the city physiognomy, the five basic elements of its appearance and the corresponding landscape characteristic features should be involved: districts (city centre, green areas, housing estates, industrial quarters, single-family housing, dispersed housing), borders and edges (rivers, embankments, railway lines, traffic arteries), roads and paths (traffic arteries, city roads, footpaths, cycling paths), nodes and knots (functional, symbolic), landmarks and dominants (historical monuments, high-rise buildings, public buildings, city symbols, memorial sites, other functional elements) [13]. The most problematic area of the analysis is the assessment of goods flows generated within the city. It mostly resulting from the fact, that urban deliveries involve mainly private companies, which usually do not want to share data on their transactions, supplies and transported goods with their competitors and the public sector (it is, of course, observed not only in the case of transport within cities, but also in interurban, national, or international transport) and, moreover, there are no standardized research methods in the field of urban freight deliveries [14]. Good method to fulfil this gap is the utilization of mobile traffic detectors as well as the survey focused on the delivering needs (more in [15–19]).

The full analysis of the present situation in the city is the basis of the major problems and the implementation goals identification. The major assumption for this analysis is to find a compromise in view of diverse problems and needs voiced by different stakeholders groups. Based on the analysis realized under NOVELOG project, the set of typical problems in urban freight transport systems have been identified (Table 1). Active policy making on the part of the city authorities with regard to goods deliveries in urban areas contributes to activating various stakeholders groups and enables dynamic cooperation towards a consensus. Reaching a high usability level of any adapted measures is determined by complementary synergistic measures underlying the possibly full implementation of the resultant bundle of goals of the stakeholders. More details related to that in [2, 15, 20]. The goal implementation degree (including the key, i.e. significant level of stakeholders satisfaction), which is the prerequisite to achieve a planned level of the implemented measures usefulness, is determined mainly by synergistic complementary actions, based on the possibly full implementation of the resultant bundle of goals of individual stakeholders.

Table 1. The identification of the city problems in relation to the major stakeholders groups.

Problems	Stakeholder group
Poor availability of places for loading and unloading operations and dedicated parking spaces for vehicles	Freight carriers
Insufficient space to park commercial vehicles	Freight carriers, Residents
Conflicts with other road users	Freight carriers, Residents
The large number of trucks on the streets/Transit problems	Freight carriers, Residents
Inappropriate or inadequate regulations	Freight carriers, Shippers, Truck/vehicle manufactures, Administrators (Authorities)
Too much traffic congestion in the city	Freight carriers, Residents
Access restrictions for commercial vehicles to certain urban areas	Freight carriers, Shippers
Too narrow streets	Freight carriers, Shippers, Truck/vehicle manufactures
Different expectations of stakeholders groups	Administrators (Authorities)
Low awareness of citizens	Administrators (Authorities)
Low accessibility of information on existing regulations and legislation in relation to UFT	Administrators (Authorities), Freight carriers, Shippers, Truck/vehicle manufactures
Lack of economic incentives for good practice in the field of urban logistics	Administrators (Authorities), Freight carriers, Shippers, Truck/vehicle manufactures
Low accessibility of information on existing functioning of UFT in the city	Administrators (Authorities), Freight carriers, Shippers
Environmental impact of UFT	Administrators (Authorities), Residents
Not efficient deliveries	Shippers, Residents
Lack of city logistics coordination	Administrators (Authorities), Freight carriers, Shippers

It must be borne in mind that it is the unique features of the city's logistic system that determine its *adaptativity* to implementation of good practices and the level of their usefulness for the whole city organism, especially taking to the account the quality of life of its inhabitants [21]. Mostly the goal analysis is based on a multi-criteria decision making process. Following that and considering the expectations of the different stakeholders groups, the multi-actor, multi-criteria analysis methodology (MAMCA) can be applied at this stage [22–24]. To support the process of consensus finding in the different stakeholders expectations, the bundle of goals should be simplified by using the versatile objectives categories. The basis of the categorization proposed under NOVELOG project is the identification of the corresponding impact areas, covering: **environmental impact** (air pollution, noise level) – EI; **demand for energy** (fuel consumption) – DE; **economic aspects** (mainly the costs of logistic operations for producers, wholesalers, retailers, customers) – EA; **safety and security** – S; **transport**

effectiveness (transport optimisation, improved cost effectiveness) – TE; **land use and impact on the planning processes** – LU.

Thanks to the simplification of the bungle of goals mentioned above, the appropriate measures could be easy identified. The Table 2 presents the chosen city logistics good practices and their impact on the six proposed areas. It is worth noticing that in general the problems connected with freight transport encountered by various cities are

Table 2. The measures influence on major areas of the impact.

Measure	Impact area[a]					
	EI	DE	EA	S	TE	LU
Multimodality for urban freight	+	+	++	+	+	++
Urban consolidation centers	++	+	++	+	++	+++
Trans-shipment facilities	+	+	+	+	+	+
ITS for freight monitoring and planning/routing	++	+	++	++	+++	+
Home deliveries system	++	++	+++	+	++	+
E-commerce system for small shops	+	+	+++	+	++	+
Cargo bikes for B2B and B2C	+++	+++	++	+	++	+
Electric vehicles diffusion in businesses (zero-emission transport)	+++	++	++	+	++	++
Reverse logistics integration into supply chain	++	+	++	+	+++	+
Lockers introduction	++	++	+	+	++	++
Loading/unloading areas and parking	++	+	+	++	++	+++
Access: time windows, emission zones	+	+	++	++	+++	+
Access by load factor	++	+	+	++	++	+
Multi-users lanes	++	+	+	++	+++	++
Enforcement and ITS adoption for control and traffic management	++	+	++	+	+++	+
Businesses recognition scheme	+	+	++	+	++	+
Public transport indirect promotion for shopping	++	++	++	+	++	+
Urban planning measures	+	+	+++	++	+++	+++
Harmonization and simplification of city logistics rules	++	++	++	+	+++	+
Off peak deliveries	+	+	+	++	++	+
Public transport for freight	+++	+++	++	+++	++	++
Freight travel plans	+	+	++	+	+++	+

[a]EI – environmental impact; DE – demand for energy; EA – economic aspects; S – safety and security; TE – transport effectiveness; LU – land use and impact on the planning processes
+ – non-impact or small impact, ++ – medium impact, +++ – strong impact

of similar nature, however, the specificity of the cities themselves hinders making any quick comparisons, whereas it is necessary to apply a highly detailed assessment to enable development of recommended solutions that are implementable in a given city.

Following that, the identification of the chosen good practice, which is planned to implement at the city area should be realized by the analysis of the source city (the city, where good practice already exist) in comparison to the destination city. It is the major step to decide regarding both adaptability and transferability procedures. The level of similarity of the source city and destination city influence on the level of adaptability/transferability processes (Fig. 2).

Fig. 2. Adaptability vs transferability.

The high level of the similarity means that it is possible to copy the measure from the source to the destination (transferability-based implementation). The lower level of the similarity means that the changes are needed – the measure has to be adapt to the destination city specificity as well as the environment of adaptation process has to be adapt to the specificity of the measure (adaptability-based implementation).

4 Conclusions

One of the objectives of NOVELOG was proposing a methodology that makes it possible to implement good practices in the city logistics systems on the basis of the city and measures adaptability level assessment. Important consideration of this process is utilization of the benchmarking method. Based on the analysis of the source city and destination city it is possible to establish the similarity level of them. It help to decide which approach could be more efficient for the implementation process: direct copy of the measure from source city (transfer) or development of the changes (adaptability). The important assumption of the method is that the major effector of a successful implementation of good practices in urban freight transport is involving the stakeholders in each and every stage of this process. The implementation process has to be based on a compromise in view of diverse problems and needs voiced by them, as well as the similarity level of the source city and destination city. Due to the considerable heterogeneity of the urban environment, lack of a wide range of evaluations and no consideration for the multi-faceted nature, the results will be much biased and incompatible with the real expectations of the parties engaged in freight transport functioning and organisation. This paper is focused on the first stage of the process – the problems identification and measures choice. More details related to the adaptability assessment are introduced in [25, 26]. It could be important support for the municipal decisions makers and authorities.

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Does the Implementation of Urban Freight Transport Policies and Measures Affect Stakeholders' Behavior?

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Abstract. The aim of this paper is to investigate potential changes in stakeholders' behavior towards Urban Freight Transport (UFT) policies and measures. In order to capture such behavioral changes, an online questionnaire survey was conducted in 12 European cities, and feedback was received from 292 stakeholders, including supply chain stakeholders, public authorities and other stakeholders. Stakeholders were asked to rate in a scale from 1 to 5, twelve variables, namely: green reputation, diffusion of information, perceived alternative mobility, quality of life, awareness level, green concern, perceived visual and audio nuisance, motivation for eco-driving, compliance with regulations, enforcement, eco-driving practice before the journey and eco-driving practice after the journey. The latter four variables, supplemented by the appropriate statements, were also used for testing the Transtheoretical Model of Change. In this case, supply chain and other stakeholders were asked to choose one of the six stages of the model that mostly represented their attitudes, before and after the implementation of UFT measures in their city. The analysis of results revealed the changes in stakeholders' knowledge, attitudes, intention and consequently behavior towards UFT policies and measures, and useful conclusions were drawn about the proportion of those stakeholders who have repudiated their previous unsustainable behavior and established the new "desired" behavior.

Keywords: City logistics · Urban freight solutions · Stakeholder analysis Behavioral modeling

1 Introduction

Motivations, experience and other behavioral factors influence stakeholders' behavior towards adopting Urban Freight Transport (UFT) measures or complying with new policies and regulations. Behavioral modeling is an efficient approach, which can reveal and assess any impacts that are generated by several stakeholders involved in city logistics, propose actions, and eventually affect behavioral changes. Considering that each category of stakeholders has specific objectives, it is possible to estimate the likelihood that operators adopt sustainable measures, cross compare subjective versus

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objective data, capture what motivated behavioral changes, and assess the level of acceptance of measures through comparison groups or time series analyses [1]. Several theories frequently use attitudes, intentions, behavioral beliefs and norms as constructs to interpret and predict behavior under particular driver, vehicle, network and environmental conditions.

Such an example is the Theory of Planned Behavior – TPB [2], which predicts that intentions affect behavior, meaning that behavioral changes are directly related to users' intention to comply with a measure. The Theory of Interpersonal Behavior [3] incorporates normative and social factors into TPB, addressing in this way perceived consequences of a behavior and habits as predictors of users' intention and consequently behavior. The Transtheoretical Model of Change [4] addresses the process of changing behavior, by analyzing the various stages of the change: pre-contemplation, contemplation, preparation, action, maintenance and termination.

In this study, the Transtheoretical Model of Change was applied in order to investigate the proportion of those stakeholders who have repudiated their previous behavior and have established the new behavior towards sustainable UFT measures. It is clear that progression through the six stages is not irrevocable, since there is a possibility that the individual moves both forward and backward. This means that each stage can have risks, till the stage of termination, where the new desired behavior is established, and it is rather unlike that the individual will return to its previous (undesired) behavior [5].

For its application and in order to determine possible behavioral changes, an online questionnaire survey was conducted in 12 European cities that tested several UFT measures or policies throughout the lifecycle of the European Union project NOVELOG, namely [6]: London Borough of Barking and Dagenham Riverside (*freight travel plans*), Gothenburg (*consolidated deliveries to shopping centre*), Athens (*sharing vehicle capacity*), Graz (*home deliveries for shop visitors*), Mechelen (*locker walls for last mile distribution*), Turin (*multi-users lanes*), Regio Emilia (*urban consolidation center*), Bologna (*home deliveries system*), Venice (*public transport for freight last mile deliveries*), Barcelona (*super-blocks concept*), Rome (*integrated decision support system*) and Pisa (*enforcement and intelligent transport systems adoption for control and management*).

The rest of the paper is structured as follows: the methodology of the paper is given in Sect. 2, followed by the presentation of results in Sect. 3 and conclusions in Sect. 4.

2 Methodology

2.1 Experimental Design and Data Collection

In order to achieve high reliability, the analysis was based on a before-after experimental design, which allows to indicate whether any behavioral changes can be attributed to the UFT policy or measure realization. The measurement variables used are the following: green reputation, diffusion of information, perceived alternative mobility, quality of life, awareness level, green concern, perceived visual and audio nuisance, compliance with regulations, enforcement, eco-driving practice before the journey (i.e. vehicle proper maintenance, trip planning), eco-driving practice after the journey (i.e. smooth acceleration and braking) and motivation for eco-driving.

For the data collection, a questionnaire survey was designed and the software "SurveyMonkey" was used. Three different categories of stakeholders were invited to rate in a scale from 1 to 5 (with 5 indicating the best) the variables mentioned above, and also provide background information. The survey was implemented in two time periods, before and after the implementation of the UFT measure in each city. For the "before" period, data were collected from November 2016 to January 2017, and for the "after" period, in September 2017.

2.2 Data Analysis

According to the availability or completeness of data, the appropriate statistical tests were conducted. Descriptive statistics were applied for the analysis of the sample characteristics per stakeholder category. Also, taking into account stakeholders' rating, the mean and the standard deviation of the variables were also calculated. In the case of inferential statistics, and in order to estimate whether there were any differences in the average rating of respondents before and after the measure implementation, or between different stakeholder categories, hypothesis testing was used. Kruskal-Wallis testing and Mann-Whitney two-sample U-testing were performed to assess differences among and between the samples in responses measured on the 5-point scale, respectively. A confidence level of 95% and confidence interval of 5% were assumed.

3 Results

3.1 Sample Description

The total sample of stakeholders, which is equal to 292, was formulated into three groups, based on the stakeholder category. The majority of stakeholders are men (67%) and the rest 33% women. Regarding age, the 3% of the respondents are between 18–25 years old, the 31% of them between 26–40, the 63% between 41–65, the 1.5% older than 66 years old, and the rest 1.5% preferred not to answer this question. The split of the sample into the three groups and the time period, before and after the implementation of a UFT measure, is presented in Table 1:

Table 1. Sample split.

Stakeholder category	Time period		Total
	Before	After	
Supply chain stakeholders	29	29	58
Public authorities	39	130	169
Other stakeholders	40	25	65
Total	108	184	292

3.2 Before-After Analysis

For each of the three groups, the average rating of the variables was compared between the two-time periods, and the results are presented in Tables 2, 3 and 4, which describe the z-statistic, the calculated effect size ($r = z/\sqrt{N}$, where N is the total number of observations) and the p-value, indicating the strength of the respective evidence.

For the group of the supply chain stakeholders, results showed that there was an improvement in the average rating after the measure implementation, compared to the "before" period in five out of ten relevant to this group indicators, namely: diffusion of information, enforcement, eco-driving practice before the journey, eco-driving practice during the journey, and motivation for eco-driving. Especially regarding "enforcement" and "eco-driving practice before the journey", the differences were statistically significant, meaning that the realization of the measure affected the behavioral changes of the specific group of stakeholders towards the positive direction (p-value < 0.05) (Table 2). On the other hand, stakeholders characterized their reputation better before the measure implementation than after (p-value < 0.05). This can probably be explained by the fact they had greater expectations or that more time is needed for the assimilation of the measure by the general public.

Table 2. Average rating and summary of test results for comparisons before and after the measure implementation – Supply chain stakeholders [6].

Variable0	Supply chain stakeholders						
	Before (B)		After (A)		B vs. A		
	M	SD	M	SD	z-statistic	Effect size (r)	p-value
Green reputation	3.4	1.09	2.8	1.1	–2.153	–0.29	0.03*
Diffusion of information	2.7	1.0	2.8	1.19	–0.016	0	0.99
Perceived alternative mobility	2.8	1.47	3.0	1.45	–0.422	–0.06	0.67
Quality of life	2.8	1.0	2.5	1.0	–1.408	–0.19	0.16
Awareness level	3.5	1.01	3.6	1.1	–0.258	–0.03	0.79
Compliance with regulations	3.9	0.95	3.9	1.0	–0.416	–0.06	0.68
Enforcement	3.1	1.27	3.9	0.97	–2.113	–0.28	0.04*
Eco-driving practice before the journey	3.3	1.45	3.9	0.92	–1.115	–0.15	0.27
Eco-driving practice during the journey	3.1	1.18	3.8	0.76	–2.522	–0.34	0.01*
Motivation for eco-driving	3.7	1.29	4.2	0.54	–1.342	–0.18	0.19

M: Average rating, SD: Standard Deviation, *statistically significant (p-value < 0.05)

In the case of public authorities, where three indicators were selected as relevant for the category, results showed that the realization of the measure affected their green concern, since a slight increase was indicated in the rating of the relevant indicator. However, this difference was not statistically significant (p-value > 0.05) (Table 3). Also, it seems that the measure realization did not improve the awareness level about

Table 3. Average rating and summary of test results for comparisons before and after the measure implementation – Public authorities [6].

Variable	Public authorities						
	Before (B)		After (A)		B vs. A		
	M	SD	M	SD	z-statistic	Effect size (r)	p-value
Green concern	4.1	0.97	4.3	0.9	–1.549	–0.12	0.12
Quality of life	2.7	0.99	2.8	1.0	–0.134	–0.01	0.89
Awareness level	4.0	0.92	3.2	1.2	–4.071	–0.31	0*

M: Average rating, SD: Standard Deviation, *statistically significant (p-value < 0.05)

the goods' delivery systems in their cities, revealing that the advantages of applying UFT measures and policies should be addressed in a long-term horizon.

When testing the group of other stakeholders (Table 4), an increase in the rating of almost all eight relevant indicators was observed after the measure implementation, compared to the "before" period. Statistically significant differences were indicated in the diffusion of information, where stakeholders stated that they were more satisfied with the diffusion of information regarding potential changes in the mobility standards due to goods' deliveries in their cities, after the realization of the UFT measures. On the other hand, stakeholders stated that they feel more annoyed after the measure implementation, due to the visual and audio nuisance that goods' deliveries cause. This outcome clearly shows that a lot of effort and progress is required in the process of goods' deliveries, which has to meet more sustainable criteria.

Table 4. Average rating and summary of test results for comparisons before and after the measure implementation – Other stakeholders [6].

Variable	Other stakeholders						
	Before (B)		After (A)		B vs. A		
	M	SD	M	SD	z-statistic	Effect size (r)	p-value
Green concern	4.2	0.99	4.4	0.62	–0.095	–0.01	0.92
Perceived visual and audio nuisance	3.5	1.1	3.8	0.88	–2.098	–0.26	0.04*
Diffusion of information	2.9	1.05	3.3	1.1	–2.257	–0.28	0.02*
Perceived alternative mobility	2.6	1.08	2.9	1.0	–0.809	–0.1	0.42
Quality of life	2.9	0.9	3.0	0.84	–0.235	–0.03	0.81
Awareness level	3.6	1.0	3.6	1.14	–0.205	–0.03	0.84
Compliance with regulations	4.0	1.07	4.0	1.19	–0.079	0	0.94
Enforcement	3.7	1.0	4.1	0.86	–1.881	–0.23	0.06

M: Average rating, SD: Standard Deviation, *statistically significant (p-value < 0.05)

3.3 Transtheoretical Model of Change Testing

The Transtheoretical Model of Change was applied to the supply chain stakeholders and other stakeholders, as they are relevant to behavioral changes upon application of a measure. The analysis revealed some interesting findings. The relevant proportions of the supply chain stakeholders in different stages of change, when testing “compliance with regulations” and “enforcement” before and after the implementation of UFT measures, are presented in Figs. 1 and 2, respectively. For the first indicator, results showed an increase in the proportions of stakeholders, who stated that they belong to the lower stages of change after the measure implementation, compared to the “before” phase, and a relevant decrease in the higher stages of change. This shows that the supply chain stakeholders, did not reach the “termination” stage in their behavior for the new measure. Similarly, when testing “enforcement”, results revealed that, even if there was an increasing tendency in the intermediate stages of change, i.e. “action” and “maintenance”, once again, the proportion of stakeholders, who reached the “termination” stage was lower after the implementation of UFT measures, as compared to the before.

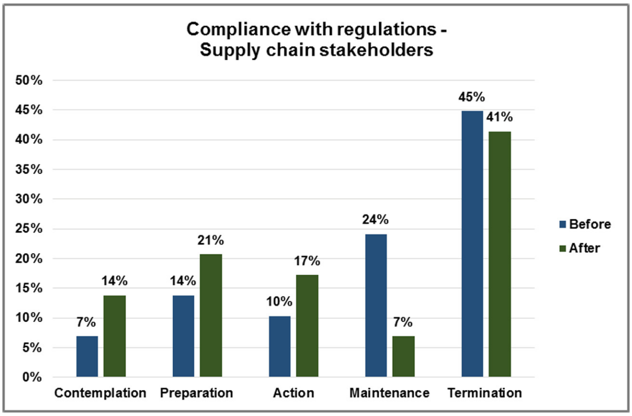

Fig. 1. Proportions of supply chain stakeholders in different stages of change – Compliance with regulations [6].

In the case of other stakeholders, a slight increase was indicated in the proportion of stakeholders who stated that they respect regulations that aim to facilitate goods’ deliveries in the city, and that’s what they tend to do in the future (2% increase of stakeholders belonging to the termination stage) (Fig. 3). Similar results were observed when testing the indicator “enforcement”, where a 4% increase was indicated after the measure implementation, in the proportion of stakeholders, who comply with new UFT measures, rules and regulations, and that’s what they tend to do in the future (termination stage) (Fig. 4).

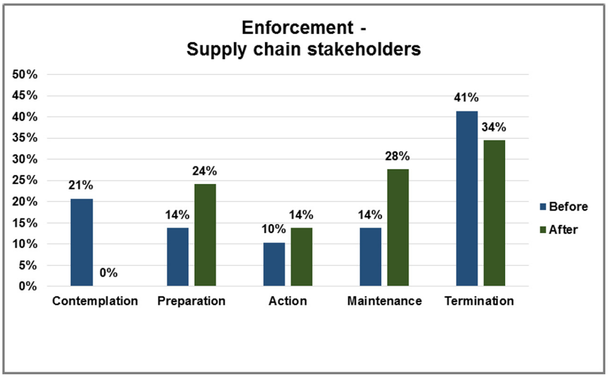

Fig. 2. Proportions of supply chain stakeholders in different stages of change – Enforcement [6].

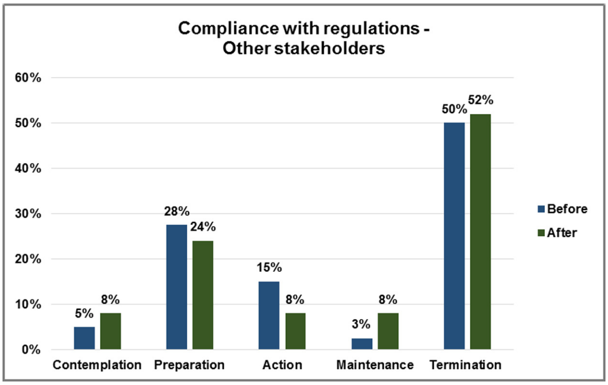

Fig. 3. Proportions of other stakeholders in different stages of change – Compliance with regulations [6].

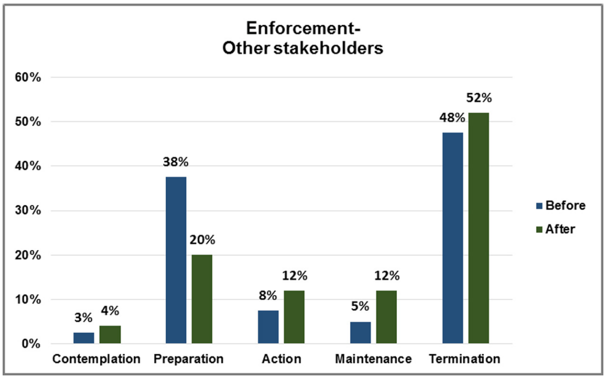

Fig. 4. Proportions of other stakeholders in different stages of change – Enforcement [6].

4 Conclusions

Statistically significant increase after the measures' realization was met in the average rating of "enforcement" and "eco-driving practice during the journey" by the supply chain stakeholders. In the case of public authorities, it was revealed that the implementation of UFT measures, slightly affected their green concerns towards environmental preservation, and their attitudes about the level of quality in their cities. When investigating the group of other stakeholders, statistically significant increase after the implementation of the measures was met in the average rating of the indicators "perceived visual and audio nuisance" and "diffusion of information". In addition, some contradictory findings were revealed, since although the specific stakeholders believe that the quality of life in their cities was slightly improved after the measures' implementation, at the same time they stated that they feel more annoyed due to the visual and audio nuisance that goods' deliveries cause.

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An Agent-Based Simulation of Retailers' Ecological Behavior in Central Urban Areas. The Case Study of Turin

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Abstract. The paper provides an empirical analysis of urban freight transport in the city center of Turin through the use of Agent-based Modelling. The aim is to explore to what extent the policies fostered by Turin's municipality within the European project NOVELOG (New Cooperative Business Models and Guidance for Sustainable City Logistics) could trigger more ecological behaviors in retailers during the provision's process. The model is based on the idea that ecological behavior depends both on economic and social features, such as imitative component and service's quality perceived and individual environmental sensitivity. The agents are informed through real data provided by the City of Turin. A price-based policy simulates the effect of an hypothetical NOVELOG monetary incentive, while a motivation-based policy would exploit the network effect. The results show that the policies improve the timing of the diffusion of virtuous behaviors, reducing the total production of pollutant emissions. The most effective results are given by strong monetary incentives for purchasing an ecological vehicle within the own-account option, or by the combination of price and motivation policies for the shift to a third-party option.

Keywords: City logistics · Agent based model · Retailers behavior

1 Introduction

The paper presents an empirical Agent-Based Model (ABM) of urban goods' provision of retailers located in the Turin central Limited Traffic Zone (LTZ).

Being one of the most polluted cities in Europe [1], the City of Turin is one of the partners of the European funded project NOVELOG (New Cooperative Business Models and Guidance for Sustainable City Logistics – H2020), whose aim is designing a more efficient and less pollutant freight provision system within many European cities.

The model presented in this paper has the aim to provide support to policy design by the City of Turin within the NOVELOG framework [2]. The city addressed so far the rules on logistics service providers' access to LTZ through a permit dedicated to incentivize the replacement of highly polluting vehicles with more ecological ones. If this replacement

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takes place, the logistics service provider receives the permit that grants more flexible entry time into the LTZ, the use of bus lanes and of loading/unloading areas.

Since the measure seems effective in encouraging ecological behavior of logistic operators, the city is evaluating the possibility of extending the permit also to retailers which often use own-account transport. For this reason, the empirically based ABM presented in this paper is focused on retailers of Turin LTZ. The tool utilized is NetLogo. Agents are informed through real data provided by the city of Turin. Different scenarios of the city logistics process both in absence of policies and in presence of alternative policies, are presented. The output variables are, firstly, the time needed to obtain a certain percentage of agents shifting from non-ecological to ecological behavior due to policy implementation and, secondly the change in pollutant emissions due to shift of agents' behavior[1]. The research questions that the simulation model addresses are the following. First, which mechanisms have stronger influence on the retailers' decision-making process about ecological or non-ecological behavior for goods supply? Second, to what extent NOVELOG-based policies implemented by the city of Turin may foster more ecological behaviors of retailers during the process of freight provision?

The paper is structured as follows: next section presents data and methodology, while Sect. 3 describes the model simulation and Sect. 4 discusses the results.

2 Data and Methodology

Agent-Based Modelling has been chosen to reproduce retailers' behaviors because it is particularly appropriate to represent very complex, dynamic and non-linear social systems, such as the urban transport system is [3–6]. In particular, ABM permits to take in consideration stakeholders heterogeneity, monetary and non monetary incentives and social networks dynamics, implementing a generative approach [7] and considering spatial, temporal and behavioural complexity [8].

In the model presented in this paper, called "ABM-TO", high importance is given to the fact that, while prices and economic determinants continue to be very influential variables on the decision-making process, often behavioral change is also triggered by imitation-based behaviors or by choices driven by subjective perception of the received service. In this phase the focus of the paper lies on the behavioural dimension of the agents linked to monetary and social variables. It is planned to include an explicit spatial dimension that influences the decision making process, by integrating the GIS (Geographical Information System) tool into the NetLogo Platform.

ABM-TO reproduces the process of goods' provision conducted by retailers. Using data provided by Turin City, a non-spatial network has been built, which represents retailers professional network within the LTZ of Turin. The decisions of 762 agents (30% of the 2,542 retailers in Turin LTZ) are simulated. Every agent symbolizes a retailer and represents one of the network hubs. The network structure acts a proxy of the relational and social relations within the domain of the working context.

[1] Literature reviews on retailers behaviours and needs are to be found in [10–14].

The structure and the dynamics of the network are based on the approach developed by Bass in 1969 [9]. Each retailer may use either own-account or third-party solutions for freight transport. An "ecological behavior" is defined as the use of own-account with low pollutant vehicle or the use of third-party transport, following the hypothesis, based on economies of scale and density, that the efficiency of transport providers is higher than in the case of the own-account transport. On the other hand, "non-ecological behavior" is defined as the use of own-account high pollutant vehicle.

In the baseline model, without policy implementation, a slow process of behavioral improvement is simulated, producing a shift from non-ecological to ecological behaviors. The simulation of the policies will improve the timing of the diffusion of virtuous behaviors. The incentive for behavioral change of the agents derives from three different kinds of mechanisms:

- A low random probability that the agent will change his/her behaviour for personal reasons, which are out of the influence of both payoff and social pressure of the working context. We assume that this probability is independent from the professional social network, but it is linked to other factors out of the model control, such as personal value change or influence of social networks different than the professional one. This probability is low because we assume that the choice about the freight transportation method is mainly dependent on economic reasoning and on influence of the professional network.
- Agents with non-ecological behaviour compare service quality and the price that they have to pay. If the final satisfaction level (payoff) is lower than the price, the agent has an incentive to change behaviour from non-ecological to ecological.
- In case that the payoff is higher than the price, the agent observes his professional network members and is subject to their influence.

The data which are utilized are contained in two different databases, both provided by the Turin City. The first database contains data on vehicles crossing the entry points of the LTZ of Turin within 10 days in 2013, indicating the type of vehicle and transport (own-account or third-party). The second dataset contains information about commodity sectors, location and size of commercial activities within the LTZ in Turin. According to the scientific literature (among others, [10, 11]), the behavioral trends of the retailers belonging to the different commodity sectors are observed, in terms of choice for either own-account or third-party transport, and in terms of frequency of freight provision. We exploit the information included in both databases to inform the agents' model and assign to each of them an initial behavior regarding frequency of goods provision and choice for own account or third party transport. By knowing on the one hand the percentage distribution of vehicles by feature through the data on entry points of the LTZ, and on the other hand the trend of frequency of freight provision by commercial categories through the scientific literature, we assigned to each agent the correspondent probabilities of restock frequency, of use of own-account or third-party and of vehicle features (Euro class). Table 1 shows the distribution of retailers among the different delivery frequency classes and the tendency of each frequency class to use either own-account or third-party solutions for freight transport.

Regarding environmental pollution, the PM_{10} emissions generated by vehicles of the different Euro classes have been taken into account, as they are considered to be

Table 1. Retailers features [10, 11; city of Turin data].

Frequency of goods delivery	Distribution of retailers	Percentage of use of own-account transport
Many times a day	1.2%	0%
Daily	51.0%	70%
Many times a week	5.1%	65%
Weekly	19.5%	50%
Many times a month	3.4%	28%
Seasonal	19.8%	12.5%

among the most dangerous for human health [15]. Table 2 shows the values for the average PM_{10} emissions of every Euro class and the percentage of vehicles crossing the LTZ entry points belonging to every Euro class. These data have been utilized to statistically infer the distribution of simulated agents' vehicles across the Euro classes.

Table 2. Euro Class of freight vehicles LTZ of Turin.

Euro class	PM10 (g/km)	Percentage of use in the Turin LTZ
Euro 0	0.2	0.65%
Euro 1	0.18	0.6%
Euro 2	0.11	5.4%
Euro 3	0.07	25.45%
Euro 4	0.04	50.4%
Euro 5	0.005	17.5%

From the real data provided by the city of Turin, it emerges a relatively virtuous situation, with the majority of vehicles recorded (50.4%) being of Euro 4 polluting class. From the data of the city of Turin, it is possible to observe that for each frequency class, the probability of using a Euro 5 vehicle, with least emissions, is of 17.5%. In the framework of this work, Euro 5 is considered to be the threshold between ecological and non-ecological vehicle, since this threshold has been utilized by policy makers for designing the NOVELOG permit.

3 The Simulation Scenarios

Different scenarios, which are constructed according to the level of intensity of different policies or their combination and hypothetical different reactions of the stakeholders, are compared. In the simulation, agents tend to improve their behavior according to the three processes presented above. Consequently, simulated policies apply to the starting scenario. Every agent starts choosing either the own-account or third-party option given its restock needs, which are based on the size of the business, the type of operations, the sector where it belongs. The hypothetical application by Turin Municipality of the

NOVELOG policy directly to the retailers is simulated. A so-called price based policy implies the possibility of giving an indirect incentive to retailers for the purchase of a less pollutant vehicle or to shift to third-party transport services, promoting a more environmental behavior. The indirect incentive would not be a direct monetary transfer, but it would consist of a set of requirements that the retailer should comply with, in order to obtain a permit similar to the one that NOVELOG designed for the logistics operators, as explained in Sect. 1. This permit would produce a decrease of the total costs that the retailers should pay for freight supply. While designing the simulated policies, the so-called "pull" approach is followed, which already characterizes the NOVELOG policy, seeking for providing incentives for proactive attitudes by the beneficiaries, instead of concentrating on punishing beneficiaries' behaviors that violate the rules.

Three types of price policies are simulated: (i) *Soft own-account policy*: focus on light decrease of the price of own-account with low pollutant vehicle (Euro 5); (ii) *Strong own-account policy:* focus on strong decrease of the price of own-account with low pollutant vehicle (Euro 5); (iii) *Third-party policy*: focus on strong decrease of the price of use of third party transport option. Moreover, these three policies have been combined with a motivation policy (see last two columns of Table 3). This last policy is represented by a parameter that increases the preference for less polluting means of transportation, i.e. the above called "personal motivation", of 10% independently from their price. In other terms, the policy positively affects the agent intrinsic motivation for ecological behavior and on the desire to increase its reputation within the network [16]. Examples of motivational instruments are educational campaign or eco-labeling. The "no policy" scenario (the starting situation; first row) and the three scenarios of price policies application are summarized in Table 3. The prices of the different transport solutions vary in the range 0–5 (second column). The same range is utilized in the model code in order to quantify the level of subjective satisfaction about the service, and this last variable is randomly evolving over time and heterogeneous among the agents. In absence of particular incentives in place the own-account option with ecological vehicle (OAE) is the most expensive one (5 level), followed by the own-account with a non-ecological vehicle (OANE: 3.5 level). The third-party transportation solution is the cheapest, when compared with the others two (TP: 2.5 level). The third column indicates the initial share of agents having an ecological behavior calculated by the model, after the calibration with the data described in Sect. 2. It indicates the initial shock given by the policy (only by the motivation policy in the scenario 1 and by price policies and their combination with motivation policy in scenario 2, 3 and 4). The model calculates for each scenario the unit of time needed in order to increase of 20% the number of "adopters", i.e. agents that shifted from non-ecological to ecological behavior. One unit of time corresponds to one tick in NetLogo software (the minimum value is 1). The unit of time to reach the threshold in case of price policy application is indicated in column 4, while the corresponding value in the case of combination of price policy with motivation policy can be found in the last column. In the no-price policy scenario (first row) agents tend to become "adopters". In that scenario motivation policy is used alone, obtaining a strong improvement, since the unit time to increase the adapter of 20% decreased from 1.83 to 1.54. The application of price policies improves the timing of adoption. In scenario two (second row), the soft own-account policy is applied, which means that the main focus is placed on the shift from OANE to OAE, with "light" incentives in this direction. The price of OAEmoves from level 5 to level 3 while the price of the third-party (TP) option goes only from level 2.5 to 2.3. This price policy generates a reduction of 7.1% of the time needed to reach the desired threshold of adopters. Moreover, if these price policies are combined also with the motivation one, the time reduction improves (–9%).

Table 3. Results of policies' implementation.

Scenario	Price levels	Initial share of adopters of ecological behavior (PM10 g/km)	Unit of time to reach +20% adopters (price policies)	Time reduction (price policies)	Unit of time needed to reach +20% adopters (motivation policy)	Time reduction (motivation policy)
1. No-price policy	TP: 2.5 OAE: 5 OANE: 3.5	57% (22)	1.83	–	1.54	–
2. Soft own-account policy	TP: 2.3 OAE: 3 OANE: 3.5	55% (23.43)	1.7	–7.1%	1.41	–9%
3. Strong own-account policy	TP: 2.3 OAE: 2 OANE: 3.5	59% (21)	1.56	–14%	1.4	–9%
4.Third-party policy	TP: 1.5 OAE: 4.5 OANE: 3.5	60% (20.18)	1.68	–8.19%	1.32	–14.28%

Note: "Adopters" means agents that shifted from non-ecological to ecological behavior
TP = third-party transport. OAE = own-account with ecological vehicle. OANE = own-account with non-ecological vehicle. Prices of freight transportation are expressed into 0–5 range.

In scenario three (third row) a more intense, but similar kind of policy, called "strong" own-account policy, is applied. The imaginary monetary incentives for retailers would produce a decrease of the OAE from level 5 to level 2, while the price of the TP solution would change again only from 2.5 to 2.3 level. This policy mix generates a decrease of 14% of the time needed to reach the desired threshold. The addition of the motivation policy produces the same results of scenario two (a time reduction of 9%). Finally, in the last scenario (fourth row), the third-party policy application is simulated. The TP price strongly shift in this case from the initial 2.5 to 1.5 level, while the OAE would decrease by a small proportion, changing from 5 to 4.5 level. In this scenario the combination of price policies with motivation policy gives better results (–14.28% of time reduction) than the price policies alone (–8.19%).

4 Results Discussion and Conclusions

The results show that even just the initial shock given by the policies increases the share of adopters, because of the agents' decisional rules supposed in the model. The best scenario is n. 4 that shows an increase of adopters from 57% to 60% and a corresponding decrease of emissions from 22 to 20.18 PM10 g/km.

Looking at the percentage of time reduction, it becomes clear that the most effective policies are the strong own-account policy which significantly reduces the price of low pollutant vehicles (scenario 3) and the third-party transport policy, but only if coupled with an intervention on the motivational level (scenario 4). In both cases, indeed, the time needed to increase of 20% the adopters of an ecological behavior is reduced by 14%.

The addition of the motivation policy to price policies tends to amplify all effects with the exception of scenario 3, while the use of motivation policy alone (first row) shows a strong improvement (time unit decreased from 1.83 to 1.54). Soft incentives for more ecological vehicles in own-account transport (scenario 2) are more effective overtime than as initial shock.

In all the scenarios the environmental emissions always decrease by about 34% when the percentage of adopters increases (from about 20–22 to 14.52 PM10 g/km).

Concluding, results suggest that a policy oriented at providing incentives for a shift from own-account to third party freight transportation seems more effective with respect to an alternative policy giving a low monetary incentive for the purchase of an ecological vehicle in the own-account option, but only if this policy is coupled with an intervention at the motivational level. In case it would not be possible to implement this last kind of intervention, then a strong own-account policy with incentives for purchasing ecological vehicles would be most effective. Results are the product of a balance between the effect produced by the price based policy and the effect produced by the network influence which influences and are influenced by the personal motivation. The strong role played by this last dimension in the simulation confirms the findings of the scientific literature on reputation effects [16, 17].

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Diagnostic of the European Logistics and Road Freight Transportation Sector

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Abstract. Within this paper, an analysis of the road freight transport and logistics market at EU level is presented. Based on the findings of the AEOLIX project, a preliminary analysis of the market size, volume and share of the logistics sector in Europe is presented herein, along with the respective allocation of costs in differentiated categories. Similarly, the road freight transport sector is examined in terms of volume of transported goods and its evolution in time, number of freight transport operations by commercial vehicles, vehicles' age and kilometers travelled, distance class, and volume of cabotage in Europe. The paper concludes with a critical analysis of the presented data, delivering key messages for the future of freight transport in Europe regarding world trends, future drivers for successful business options in the sector and the role of SMEs therein, current needs in terms of services and related environmental concerns.

Keywords: Freight transport · Logistics market · Data analytics

1 Introduction

The logistics market size is the object of several analyses conducted in previous years both in Europe and worldwide. It is the nature of logistics and its undisputable place in today's business world that has attracted interest both from private and public stakeholders, in an effort to better understand its dynamics, spatial and temporal character and potential, and propose policy or other measures and actions towards its enhancement. To this end, the AEOLIX project aims to set the current play in the logistics and freight transport market identifying future needs and considerations that need to be looked at. In its framework, open data is utilized and analyzed towards concluding on the key messages for the logistics and freight transport sector of the future.

1.1 The Logistics Market Size and Volume

One of the most comprehensive market surveys for the European logistics sector is conducted annually since 1995 by the Fraunhofer IIS – Center for Applied Research on Supply Chain Services SCS [1]. As a standard reference work for the logistics industry, the "TOP 100 in European Transport and Logistics Services" provides the latest

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statistics and key figures for the European logistics market, in addition to outlining the market structures and players [2]. Some of their key findings reveal that compared to 2012 (€879.3 billion), the European logistics sector grew by €20 billion in 2014, reflecting a 2.6% increase in two years. These values used for describing logistics market size are not based on turnover but rather on costs for staff, vehicles, warehousing, administration and planning for logistic activities. In terms of market volume per segment, [2] report that more than 40% of the European logistics market volume is attributed to contract logistics, while there is an approx. similar share among other segments, with warehousing and terminal, ocean cargo and general truckload having the next bigger shares, concluding that the logistics sector is highly heterogeneous. It is interesting to correlate the notions of market volume and GDP in Europe. This indicator can be calculated by taking the ratio between freight transport performance (in ton-kilometers) and Gross Domestic Product (GDP) and indexing on a single reference year. In this case, we use the Eurostat database, where freight transport performance is an aggregate of inland transport modes: road, rail and inland waterways, as due to their predominantly international nature, air and rail transport are omitted from this analysis. The indicators are indices with the base period of 2005 and the indicator is presented in Fig. 1.

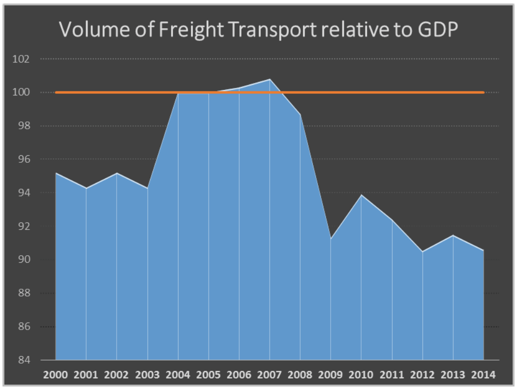

Fig. 1. Volume of freight transport relative to GDP (EU28) [3].

1.2 The Logistics Costs

In [2], a segmentation among the 5 main logistics costs categories in EU30 (incl. Norway and Switzerland) is conducted, revealing the dominance of transportation costs vs. all others (warehousing, inventory/carrying, order processing, administration). Similar findings at company level are found at [4]. The Davis Logistics Cost and Service Database is an ongoing annual survey that manufacturers, distributors and retailers participate in, in order to receive a customized benchmarking report of logistics costs and services. The database is an internationally recognized source of logistics costs and service information. Started in 1974, the Establish Davis Database contains logistics costs in the following categories: transportation; warehousing; customer service (order/entry); administration; inventory carrying.

Data are summarized and reported annually; the May 2016 report includes a series of important findings for the logistics costs in general [4]:

- Logistics costs for the average company are 9.56% of sales and 68€ per CWT of cargo (the hundredweight (abbreviation: cwt), formerly also known as the centum weight or quintal, is an English, imperial, and US customary unit of weight or mass of various values. Hundredweight refers to 100 lb (45.359237 kg)).
- Logistics costs as a percent of sales increased from 2% to 3% between 2014 and 2015.
- Transportation and warehousing costs drove the increase while inventory carrying costs slightly decreased.
- Overall logistics costs are continuing on an upward trend.
- Companies with higher product values continue to have lower logistics costs.
- Smaller companies continue to have higher logistics costs.
- Service performance levels show a reduction in cycle time (from order to average delivery) and a decrease in product availability.

The breakdown of logistics costs per sales and cost per CWT of cargo reveals that transportation is the dominating cost (either as a percent of sales or of CWT). Warehousing costs have a higher importance when calculated based on weight, as there is a correlation between weight and volume, which is the main driver for warehousing costs. Over the course of the last 12 years, transportation costs are the only ones fluctuating (given their dependency on changing fuel prices, container rates, etc.), while marginal increases in shipping and warehousing costs are attributed to the increased value of cargo for the former and the recovery of the economy for the latter.

Economy of scale is observed when comparing logistics costs with the size of a company, as there is a reduction in the long-run average and marginal costs due to the increase in size of operations, i.e. larger companies experience lower logistics costs. Data from 2009 to 2015 reveal the latter in Fig. 2.

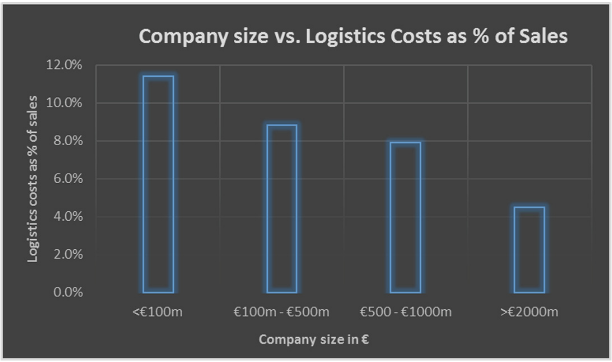

Fig. 2. Company size vs. logistics costs as % of sales (adapted from [4]).

Quite interestingly, logistics costs as a percent of sales keep trending upwards. As observed in Fig. 3, technological advances in the early 1990s have considerably decreased this figure, only for it to be increased both until the 2008–2009 market crash and after its initial recovery in 2013. However, this leaves potential for ICT services, or in this sense soft technological advances similar to the ones of AEOLIX, not directly associated with production, manufacture, warehousing or transportation itself, but with the management, coordination and optimization of those, to decrease this figure to a lesser percentage than today.

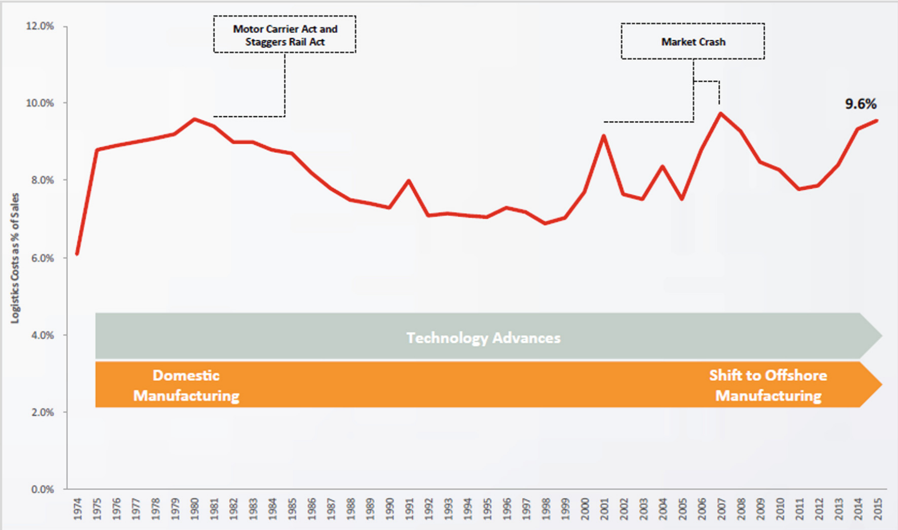

Fig. 3. Logistics costs as a percent of sales (1974–2016) [4].

2 Road Freight Transport

2.1 Volume of Transported Goods and Type of Transport

The role of road in the transportation of goods is slowly increasing in the past years. Although EUROSTAT reports an approx. 20% decline between 2007 and 2013, in the last 3 years there is a continuous upward trend for road transport of goods (+3%), which will bring the sector in the 2009 figures when the economic recession appeared worldwide. In general, road transportation is dominating goods transport in Europe and it is still under investigation whether reported decreased figures throughout the last decade are to be attributed to modal shift to other transport modes; on the contrary, it is mostly down to internal market changes, levels of productions at country-level, shift of the European economies to services and non-tangible products, etc.

Still, negligible as they might be when looking at the overall picture of modal share for goods transport in Europe, changes did affect SMEs that lost a significant share of the market when the latter shrinks (for any reason); this is especially the case for road transportation where, as opposed to railway, pipeline and maritime of transport, business enterprises of lesser magnitude are easier to be formed, developed and operate, as investment costs for initiation are considerably lower. It is therefore crucial to safeguard such enterprises if competitiveness and innovation in Europe are to be reinforced through the logistics sector by making sure that any actions from policy to operational levels are directed their way.

Freight transport operations on the contrary though, are not increasing at a similar rate with the amount of goods transport in Europe [3]. This highlights the fact that after the 2009 recession a lot of transporters have started looking for solutions towards sharing or exchanging loads in order to reduce empty vehicle kilometers traveled, and have managed to create a culture towards this approach which is evident today. Regardless of the cost-reduction oriented motives of transport companies behind this initiative, there are potentially huge societal benefits included there as well. It is therefore central to create the technological tools, models and platforms that will facilitate this freight transport exchange, ideally utilizing latest technological trends and technologies in real-time and big data, etc.

Statistics produced in EU on the basis of Regulation No. 70/2012 concern the following road freight transport operations by heavy goods vehicles registered in the reporting countries:

- Commercial road freight transport, referred to as ‘hire’ road freight transport.
- Road freight transport by private vehicles and by vehicles owned by companies classified in other classes than professional road freight transport. This kind of transport is identified as “Own account” road freight and it covers transport operations by manufacturing industry, construction, trade and other companies.
- Operations by small goods vehicles (the definition of “a small goods vehicle” depends on the country) and extra-EEA vehicles are not covered in these statistics [5].

2.2 Age of Vehicle Fleet

A critical issue to be looked at concerns the vehicles that move these goods, and circulate in European highways, regional and urban roads. The share of ton-kilometers travelled by vehicles registered after 2010 (up to year 5) has significantly decreased in 2015 by 16% as compared to 2011 (from 63% to 47% out of the total), although being stable before. The statistics reporting of 2016 will reveal whether this has been an exception to the otherwise hardly changing share (between 2011 and 2014) or if indeed there is a rising issue of an ageing freight transport fleet. In any case, in 2015 only, approx. 54% of the total vehicle-kilometers reported in Europe have been travelled by vehicles that have been registered before the dawn of the decade (prior to 2010), while a remarkable 20% has been travelled by vehicles beginning their lifetime in the late 90s – begin of 00s. The ageing fleet of freight transport vehicles is strongly attributed with the degree and extent to which the sector contributes to pollutant emissions in Europe. There is a direct need for new vehicles and more importantly, new technologies that will address the environmental aspect of goods transport.

2.3 Ton- and Vehicle-Kilometers Travelled, and Distance of Trips

As data shows, there is no sign of decreasing vehicle-kilometers travelled; on the contrary there is an upward trend since to 2012 that will reach the levels of 2009 in the coming 2 years (Fig. 4). A similar trend is also observed for ton-kilometers; however, the latter are constantly higher than vehicle kilometers, revealing the increased load factor of goods vehicles since 2009. Distance class of freight transport operations is also an important indicator for the logistics market in general and road goods transport in specific.

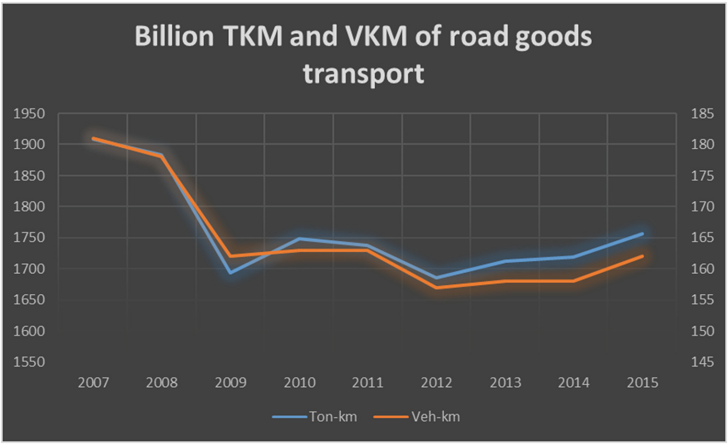

Fig. 4. Billion TKM (ton-km) and VKM (vehicle-km) of road transport of goods in EU28, source: European Commission, 2014.

2.4 Cabotage in Road Freight Transport

In the territoriality concept, 'cabotage' is a form of national transport. It refers to those cases where both loading and unloading take place in the same country but the vehicle used is not registered in that country. For instance, a vehicle registered in Spain loads goods in Barcelona and unloads them in Paris - this is an international journey. If it then loads goods in Paris and unloads these goods in Marseille (France) - this would be a cabotage journey. This same vehicle might then load goods in Lille and unload them in London - another international journey.

3 Findings and Key Messages

Data presented and analyzed in the previous sections are herein translated in key messages for the logistics and road freight transport sector.

World trends: Bidirectional Influence with the Logistics Sector
Globalization, demographic development, sustainability, state intervention, climate change and disruptive technologies are world trends that will influence the way future logistics operations will be conducted. But this is not a one-directional influence; on the contrary, the logistics sector will respectively influence the way and rate of evolvement of these trends as a major.

Drivers for Successful Business Options
There are certain drivers that currently determine the way the European logistics market is shaped and will continue to do so in the next years. These drivers include professionalization and efficiency, focus on core competences and effectiveness, service orientation, innovative technologies and faster ticking clocks, and can be adopted for successful business operations.

Transportation Costs Monopolize Other Logistics Costs as a % of Sales for the Average Company
Logistics costs comprise up to 10% of potential sales of a company, with transportation having a 4.5% share on this. In sheer numbers, for every 45 kg of transported cargo there is a total of 68€ costs for logistics; 31€ of which are transportation costs.

Dominance of Road Transport in Freight Operations – No Sign of Change
Road transport is dominant among all modes of transport when it comes to cargo movement in Europe. Data reveal a modal split share of approx. 75% for road transport, as compared to those of rail (6%), sea (8%) and inland waterway transport (3%). Additionally, there is no reported evidence of change of scenery in the coming years; on the contrary, statistics and trends suggest a minor increase in the coming years for road transportation in the expense of all others (and mainly rail transport).

Safeguard the Little Man – SMEs in Road Transportation
Road transportation of goods is the only business sector in the field that can facilitate the existence and operation of SMEs. In comparison to all other modes, where investment and operational costs make it hardly possible for any other stakeholder (rather than public ones or joint endeavors of big business players) to enter the market, road transportation allows by nature smaller enterprises to join in. This inherently creates a necessity to safeguard such initiatives as drivers of employment, innovation and technology driven productivity, as they are most likely the main players to experience market fluctuations and potential shrinks. In turn, this has several messages at several levels: from policy and decision makers on a higher, strategic level, to AEOLIX itself on an operational level.

Amount of goods transported increasing – amount of transport operations stable. A hint for freight exchange needs?
Although there is a marginal upward trend in the amount of goods transported since 2012 (with all transport modes), transport operations for the actual transportation of these goods has remained stable. This might be a hint for an already cultivated culture among transport operators towards freight transport exchange; technological solutions

and innovation efforts should be therefore directed to this end. Additionally, the multimodality of freight exchange.

An Ageing Road Goods Transport Vehicle Fleet: Apparent Need to Renew After Investigating Potential Collateral Impacts
In 2015, about 20% of the vehicle-kilometers travelled in Europe for goods transports were conducted by Heavy Goods Vehicles (HGVs) that were either registered between 2000 and 2005 (15%) or prior to 2000 (5%). These figures are cause for environmental pollution concern; the older the vehicles, the less clean they are; the more these vehicles travel, the more they pollute. What is alarming, but not yet conclusive due to lack of the 2016 respective figures, is that this share has risen in 2015 by 16%. In other words, vehicles up to 5 years of age, have significantly decreased their vehicle-kilometer share over the total from 63% to 47% from 2011. As apparent the need for renewal of the vehicle fleet might be, there needs to be a closer look at potential collateral impacts of these choices. How can this renewal occur and who will bear the expenses of it? State-aid is prohibited in the EU regarding purchase of freight transport vehicles – therefore there is no direct relieve of purchase costs. Other types of incentives could be looked at, for instance through tolling older, more pollutant vehicles. But then a possible shift to e.g. EURO6 combustion engines for HGVs would mean considerably lower income for infrastructure operators and managers, which in turn creates the question of who will bear these costs? For sure though, fuel consumption reduction for Heavy Goods Vehicle should be prioritized for manufacturers as this is hardly at the crux of their agenda (as opposed to passenger vehicles).

Acknowledgements. This work presented herein is part of the AEOLIX (Architecture for European Logistics Information Exchange). For more information please visit http://www.aeolix.eu.

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Urban Traffic Management Utilizing Soft Measures: A Case Study of Volos City

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Abstract. This paper examines the current and the future performance of the traffic network around the center of the city of Volos in Greece, after the implementation of local traffic management measures and the introduction of innovative Intelligent Transportation System (ITS) services.

The study focuses on the urban road of two main streets Iasonos (up to Fillelinon street) and Dimitriados (section between Fillelinon and Athanasiou Diakou streets) where during the peak hours, congestion results in high delays, bottlenecks and conflicts. System performance is based on specific indicators, which have been set to evaluate the traffic situation in the three main areas of interest: traffic quality, safety and environment.

An investigation on the current and potential problems of the study area has been performed, by modeling the current situation (base scenario) in the microsimulation software VISSIM and using the "Surrogate Safety Assessment Model" (SSAM) to assess the traffic safety. The findings were low quality of signal control, low compliance of drivers to traffic laws (illegal and unregulated parking, trespassing of the bus lane), critical safety hotspots and increased emissions. "Soft" countermeasures are simulated and evaluated in VISSIM. Such "soft" countermeasures are the ban of access to Urban Freight Transport (UFT) vehicles during the peak hours, the adoption of ITS to prevent illegal parking, the adjustment of the coordination time offset.

Apart from evaluating the impact of the countermeasures, the paper constitutes also a roadmap for achieving overall improvement of an urban traffic network without resulting into the construction of new transport infrastructure.

Keywords: Traffic flow · Traffic safety · Assessment · Network performance

1 Introduction

Sustainable urban planning and sustainable transportation within modern cities are two vital notions for city's overall sustainability. Cities' Sustainable Urban Mobility Plans (SUMPs) focus on strategies and actions that improve accessibility and provide high quality mobility, dealing with, at the same time, with phenomena that result in congestion, bottlenecks and increase in delays, accidents, environmental pollution and fuel consumption.

Local traffic management can contribute to the alleviation of local traffic flow issues by making a more efficient use of the available network capacity. The primary objective

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of traffic flow improvement measures is the enhancement of the existing network's efficiency as well as the alleviation of traffic congestion and the reduction of environmental pollution without implementing new hard measures. Moreover, there has been a growing tendency claiming that combinations of several interrelated traffic control strategies can lead to more efficient and substantial reductions in travel time and delay. A combination of such strategies has been selected for the city of Volos, simulated and tested, for drawing useful conclusions on their effectiveness in improving the performance of the urban transportation network.

2 State-of-the-Art

There is a plethora of studies in the literature that refer to implementing soft measures for pursuing sustainable mobility in congested urban networks. Soft measures refer to introducing new transport policies, modifying the operational structure of the network, and/or adopting Intelligent Transport Systems (ITS) for information provision, and traffic monitoring and control. Cairns et al. [1] present a list of ten types of soft measures with focus on the voluntary reduction of car use and shift to less energy intense modes of transport, where they provide an estimated reduction in car usage per measure. Among them are the workplace and school travel plans (8–30% reduction in car usage), personalized travel planning (7–15%), public transport information (1–5%), home shopping, car sharing/carpooling and travel awareness campaigns. Möser and Bamberg [2] in their study analyze five soft measures that are the most implemented and evaluated in the last decade. MIDAS European project [3] shows some of the best practice examples of soft measures that have been implemented in the case studies of Aalborg, Bologna, Clermont-Ferrand, Cork, Liverpool and Suceava. Measures in these case studies include information and marketing campaigns to encourage greater use of public transport, cycling and walking, car clubs and carpooling, and mobility management initiatives. Richter et al. [4] conducted a review research about when and where a list of soft measures can be proved effective for sustainable mobility.

3 Methodology

Traffic microsimulation tools have been extensively used in studies assessing the impact of traffic management measures in small networks, such as traffic lights coordination [5], intersection redesign [6] and other studies. The flowchart below is an overview of the methodology followed (Fig. 1).

For the evaluation of the model traffic, environmental and safety indicators were used. The indicators' name along with a short explanation can be found in Table 1.

Based on the "Intersection Delays" indicator the Level of Service (LOS) was determined for the two critical intersections of Iasonos - K. Kartali and Dimitriados - Venizelou. To measure the number of conflicts the "Surrogate Safety Assessment Model" (SSAM) [7] was used.

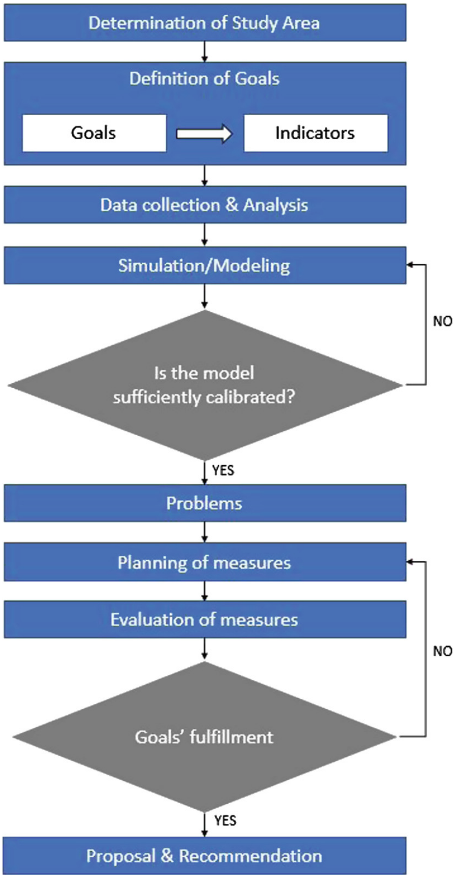

Fig. 1. Flowchart of methodological approach.

Table 1. Evaluation indicators.

Name	Explanation
Delays	Sum of delays
Average speed	Average speed of all vehicles
Intersection delays	Average extra time to cross an intersection per vehicle
CO	total emissions of CO
NOx	total emissions of NOx
Total number of conflicts	Total number of conflicts in a specific area

4 Application in Volos

Volos is a coastal city geographically situated in the center of Greece and is the sixth largest city of the country with 144.449 inhabitants [8]. The city center which is run by the commercial streets of Dimitriados and Iasonos (study area) is arranged based on the Hippodamian or grid plan and serves high traffic volumes especially during the summer season when visitors and tourists cross the city either to visit the magnificent beaches of Pelion, which are European-wide known, or to catch the ferry to Sporades island complex.

According to a survey carried out by the Volos Development Company SA (ANEVO) [9] the central district of Volos has 4583 residents that own 1380 cars, while the parking places are only 395. The problem becomes even worse due to the thousands of employees that are moving from the suburbs to the center with their car, searching for a parking space. The lack of parking areas is one of the main reasons that lead to congested roads as drivers circle around the city center looking to park their vehicles.

In order to solve the problem and reduce the use of private vehicles the municipality of Volos focused on the attractiveness of Public Transport. More specifically, a reserved lane for buses and taxis is created in the two main axes of Iasonos and Dimitriados, while the vehicles can use the two remaining lanes. However, this measure did not bring the expected results, since one of the two remaining lanes is illegally used either by private vehicles for parking or by UFT vehicles for delivering the retail shops. High delays due to long queues that are built along the two axes force a share of private vehicles to use the bus lane, causing delays eventually, to public transportation. The inappropriate use of the existing system mentioned above worsens the problem of congestion making imperative the need for more effective solutions.

4.1 Data

Based on a travel survey conducted in 2011, 2012 and 2013 by the Traffic, Transportation and Logistics laboratory (TTLog) of the University of Thessaly aiming at developing an origin-destination matrix of travel demand in the city of Volos (1.81% of the total population participated), the morning and evening peak hours were determined between 08:00–09:00 and 20:00–21:00, respectively. For the purposes of this study, evening peak-hour traffic data were obtained from on-site measurements realized by TTLog. In parallel, results from observations made at a large number of intersections in the city center, helped to have a more precise understanding of their operational attributes. Traffic conflicts and incidents were recorded and critical intersections were identified for further analysis. In addition, travel times were also measured in order to be used as a reference for the calibration of the model. Traffic lights' programs were given by the Traffic Management Center of the city of Volos. All the rest operational elements required for the microsimulation model (VISSIM) were determined either from google maps or on-site observation. Finally, for the evaluation of emissions, the share of light- and heavy-duty vehicles was considered based on the percentage of local sales of alternative fuel vehicles in Greece in 2016 [10, 11] (Table 2):

Volos public transportation system consists of twelve bus lines that serve the city and the surrounding areas with a fleet of 51 busses and 3 mini busses. According to a

Table 2. Share of vehicles based on their fuel type

Fuel type	Light duty vehicles	Heavy duty vehicles - Buses
Petrol	92.53%	0%
Diesel	6.41%	100%
CNG	1.05%	0%
Electric	0.01%	0%

survey [12], which was conducted by the International East Mediterranean Research Center for Transport in 2005 on behalf of Volos Municipal Bus Service Company, an average occupancy rate of 22.9% was found for all lines. The five public transport lines that run through the study area during the peak hours operate every 20 min and stop at eight public transport stops on Iasonos and Dimitriados streets. Their schedules were retrieved from the Municipal Bus Service Company website. Onsite sampling measurements of public transport within our study area during the peak hour showed the following results:

- The ridership of the buses is close to the estimated average occupancy in the survey.
- The operation of the bus lines has no significant discrepancies from the schedule (delays of max. 3 min were noticed).
- No problematic spots for buses in the study area (except for the lane change of busses serving the lines 2, 3 and 4, on Iasonos street between Venizelou and K. Kartali street, which causes small delays and multiple conflict points).

4.2 Simulation

A total number of ten hourly (3600 s) simulation runs with different random seeds was completed in order to guarantee representative normalized results. The warm-up period was set equal to 1800 s in order to load the network realistically before the starting collecting data to be used in the evaluation. In order to ensure a validated representation of reality, the model was calibrated by checking for coding errors and false insertion of input data while adjusting various parameters iteratively until results fall within certain thresholds [13]. The acceptance tolerances appearing in literature were met [14].

4.3 Measures

Based on the problems identified in the simulation model a series of measures is suggested. The selected measures to be modeled will be evaluated all together in a scenario. Analytically the measures and the scenarios are:

- Ban of access to UFT vehicles during shopping hours (Measure 1)
  - Modeling effort: Set to 0 the probability of vehicles to park in sparse located parking lots along the two main road axes
- ITS adoption (surveillance systems) to prevent illegal parking and short term stops (Measure 2)

  – Modeling effort: Set the attribute "ParkRate" for all Parking Lot vehicle routes equal to 0.1%, from 3%, parking duration distribution remained the same)
- Adjustment of the coordination time offset (Measure 3)
  – Modeling effort: Decrease time offset of signal programmes between intersections (Table 3).

Table 3. Scenarios.

	Base scenario	Scenario with measures
Measure 1	Probability: 12% (arose from the calibration process)	Probability: 0%
Measure 2	ParkRate: 3%	ParkRate: 0.1%
Measure 3	–	Decrease offset time between successive intersections

5 Results

The evaluation indicators' values and a comparison screenshot based on conflict type for the two scenarios can be found in Table 4 and Fig. 2. The analysis of conflicts was performed considering the default values of conflict thresholds (max. time to collision: 1.5, max. post-encroachment time: 5, rear end/crossing angle: 30/80).

Table 4. Transportation network performance indicators for the period between 19:00 and 20:00.

Indicators		Base scenario	Scenario with measures	Change
Traffic quality	Network's total delays (s)	609,396.6	138,464.3	–77.3%
	Network's average speed (km/h)	10.38	25.39	+144.6%
	Average delay (s/veh) and LOS at Iasonos - K. Kartali intersection	22.6 (LOS C)	15.7 (LOS B)	C to B
	Average delay (s/veh) and LOS at Dimitriados - Venizelou intersection	22.5 (LOS C)	15.9 (LOS B)	C to B
Safety	Total number of conflicts	33,550	1,226	–96.4%
Environment	CO_2 (g/km)	715,649	665,253	–7.0%
	NO_X (g/km)	5,141	4,798	–6.7%

From the evaluation results, it can be safely concluded that the proposed bundle of measures improves the traffic conditions and the environmental impacts of the whole network, by reducing travel delays by 77.3%, pollutant emissions by 6.8% (in average)

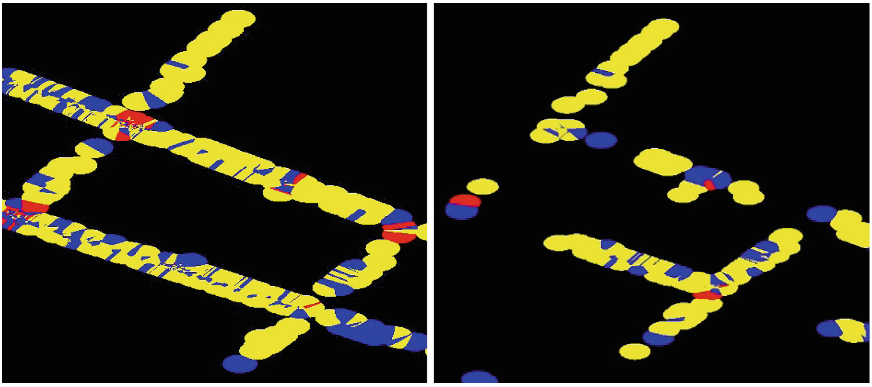

Fig. 2. Mapping conflict types at the two critical intersections, left: base scenario, right: with measures (Note: Crossing conflicts: red, Rear End: yellow, Lane change: blue)

and most importantly the number of conflicts by 96%, without changing or rebuilding the existing transport infrastructure.

6 Conclusions and Discussion

This paper examines the improvement of the performance of the urban transportation network under an analytical approach based on simulation, as achieved through the implementation of traffic management measures, which do not require construction of new infrastructure. The results show that implementing better enforcement in parking activities and signalization coordination can improve traffic conditions without the need of expensive infrastructure and long-lasting development projects.

In addition, even though this study considers exclusively motorized vehicles, it is believed that the implementation of such soft measures above will bring positive impacts also for pedestrians and cyclists. Analytically:

- Pedestrian sidewalks will become wider (due to wider side clearance area) and thus, safer
- General accessibility and visibility will be improved
- Public transportation will become more attractive (fewer accelerations/decelerations for passengers, higher comfort, punctuality, performance and credibility)
- Aesthetically pleasing mobility experience.

Moreover, even though in this particular case study all suggested measures present positive impacts, the modeling of additional measures in the developed test bed model could disclose the correlation and tradeoffs among the three main areas of interest (traffic quality, safety and environment). The future steps are to consider other supporting measures, such as informative campaigns, financial incentives for usage of public transport, park and ride facilities, bike sharing systems etc. and examine their impact, to model more measures' combinations and to study the effect on other transportation network users (pedestrians, cyclists).

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Application of Big Data Technologies in Transport

Applying Unsupervised and Supervised Machine Learning Methodologies in Social Media Textual Traffic Data

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Abstract. Traffic increasingly shapes the trajectory of city growth and impacts on the climate change in modern cities. Traffic patterns' monitoring can provide with innovative practices in understanding city traffic dynamics, especially via utilizing sensory and textual data analytics. State-of-the-art research recently has focused on processing voluminous real time data in vast quantities by capturing real time sensory observations and/or social network (textual) data regarding city traffic. In this paper, we investigate the feasibility of using Big Data produced by Twitter textual streams for extracting traffic related events. After describing a generic yet innovative application used for data capturing, we preprocess this data so they fit into the structuring of the machine learning models for clustering (unsupervised learning) and classification (supervised learning). For the case of clustering we use Apache Spark on a MapR sandbox with the use of KMeans algorithm. For the classification case we compare various machine learning methodologies including Multi-Layer Perceptron Neural Networks, (MLP-NN), Support Vector Machines, (SVM) and a Deep Convolutional Learning, (DCL) approach to contextualize citizen observations and responses via tweets. The criteria of precision, accuracy, recall and F-score are used as statistical metrics to determine the accuracy and performance of each model. Our experiments include clustering, a 2-class and a 3-class classification, where, MLP-NN gave accuracy of 89.6%, SVM 92.73% and DCL was inferior performing at 81.76%.

Keywords: Unsupervised · Supervised · Deep Learning · Big Data Textual · Traffic

1 Introduction

It has been noted by many researchers, lately, that the recent accelerated urbanization has altered the equilibrium state of urban road systems in modern cities. Traditional Transportation Systems (TS) in big cities can no longer meet the needs of today's complex transport and congestion caused by the continuous increment of vehicle use.

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This global urbanization trend delivers a new set of challenges to authorities as they must reconfigure city services according to the new priorities imposed for planning and mitigating unforeseen traffic incidents. For this reason, the Intelligent TS (noted as ITS) research topic was created having as primary goals to: (a) advance the traffic monitoring methodologies and (b) offer better transportation planning and traffic management in congested cities [1]. Present works include sensor based monitoring schemes where the sensory equipment is installed/maintained by the city. Additional data generated from a variety of devices installed in vehicles (such as GPS, radio transceivers, small-scale collision radars and sensing devices to enhance travel safely etc.) are also used in recent studies towards the aforementioned goals. However these data cannot be stored centrally since the devices are designed to operate using short-range communication protocols. The tremendous shift in data-induced methodologies has happened due the use of social media platforms (local online forums, Facebook, Twitter) which nowadays are used as the primary and richest source of real time data [1–3]. The utilization of social media traffic related data (traffic jams, collisions, alternative route suggestions etc.) help ITS to improve traffic monitoring and management. But all this comes also with new challenges: (a) ITS have to overcome the Big Data consequences emanating by the rate of data generation (8,000 tweets/sec, hundreds of trillions per week) and the storage inability, (b) new intrinsic spatiotemporal principles of Big Data must feedback innovative machine learning solutions to optimize cloud computing and processing, (c) open availability of data poses social challenges of geospatial significance and (d) textual analysis must coexist with specialized Deep Learning approaches to decode human responses.

After we present in Sect. 2 a concise State of the Art, we formulate in Sect. 3 the methodology of an ITS used for clustering and classification of traffic related data extracted by a Twitter extractor that incorporates the stemming, IDF and similarity index techniques to choose traffic-incident related keywords. The classification methodology is also presented for a 2-class and a 3-class classifier. For the 2-class classification we provide performance metrics incorporating a MLP-NN and a SVM. For the 3-class classification we do the same using a DCL network.

2 State of the Art

There has been a variety of initiatives (both academic and commercial) dealing with traffic alert systems. At the same time all these systems harvest input information from a variety of sources including sensory equipment, human reactions, police traffic reports etc. In relevance to textual incoming sources from social media, while there is a lot of literature regarding data analytics methodologies, there hardly exists research that deals with the stages of data discovery, collection, and preparation from textual data [4]. Recently, Twitter started to provide services where, users can post geo-tagged tweets via the GPS interface of their smart devices [5, 6]. The reported information when relevant can support any traffic monitoring and alerting system by just logging a repertoire of traffic incidents. Towards these lines, TWITRAFFIC, [7] created a smart app that monitors and reports traffic events in UK. MISNIS [8] is another platform that facilitates these issues and allows a non-technical user to easily mine any given topic from Twitter's corpus in order to obtain relevant contents and indicators such as user influence or sentiment analysis but it is focused mainly in the Portuguese language. Lately, [9] developed a clustering tool called I-TWEC, which utilizes Twitter data lexical and semantic similarities. I-TWEC uses the Longest Common Subsequence technique as a similarity metric to produce clusters presented with different visualizations enabling users to merge them based on their semantic similarity. Because the traffic topics attract global attention, such data suffer from the Long Tail Effect [10], thus an effective textual analytics tool must be a traffic event data extraction model, however it must be able to distinguish learning of specific locations utilizing only tweets via geolocation attributes. Even though it is somewhat difficult for travelers to read and/or for drivers to participate in such activities, experience has shown that almost all drivers and passengers during traffic rush hours, announce this on social media. Thus the optimum solution is to analyze the information available on social network platforms, perform sentiment analysis and machine learning methodologies to classify and cluster traffic cases and to predict traffic situations.

With the improvement of big data processing technologies, we now have the ability to perform traffic sensing and learn human mobility patterns from updated location information in network interaction log data (mostly GPS and textual). Recently, [11] extracted traffic patterns from big data using regression models. Also the research shown in [12] adopts Spark on Hadoop and MongoDB technologies to store, handle and process real time and historical traffic data from heterogeneous sources including social media. Similar work is also recognized in [13] where the distributed file system HDFS is used to store urban traffic data and the Spark is used to realize road traffic congestion state detection with lower cost, shorter period and more credible results.

The K-means methodologies are the most popular for data clustering. However, for the case of high-dimensional text data, K-means clustering becomes the only known solution. The cosine similarity property metric [14] is used to measure cohesion between produced clusters since it is a similarity measure between two non-zero vectors of an inner product. Finally regarding the ITS traffic, condition recognition is very important and K-means methods have been tried lately towards this issue [15, 16].

3 Methodology and Results

Gathering of tweets was achieved using the Twitter4J [17] open source Java library. The usage of the Twitter API allows us to mine tweets using criteria based on hashtags, limited time, longitude and latitude and any keyword. In this paper we focus on two main investigations: (a) Clustering of traffic data of numeric nature via the use of KMeans algorithm with the Euclidean distance as a cost function and (b) Classification considering two cases: (i) binary classification regarding tweets related to traffic either due to weather conditions or not and (ii) a ternary classification related to heavy traffic due to accidents, seasonality affected events (for example, Christmas Eve) and external unexpected events (basketball game, strikes, demonstrations etc.).

3.1 Traffic Big Data Clustering Using Unsupervised Machine Learning

We used one of the most commonly used clustering algorithms (KMeans) to cluster twitter data into a predefined number of K-clusters. Data was gathered using the Twitter4J Java library for the city of New York during the Christmas period of 2017 (Dec. 11th 2017–Jan. 3rd 2018). The area of interest was chosen to be the virtual rectangle (left upper corner: Hawthorne NJ Lat: 40.939825, Log: –74.160612, right lower corner: Jones Beach State Park NY Lat: 40.597646, Log: –73.505552). Apart from the geolocation and the date and time searching criterion of data acquisition, an additional searching criterion included keywords such as: congestion, traffic jam, traffic etc. Initial filtering of the aforementioned tweets was performed to mine the ones originated by people riding vehicles and therefore excluding pedestrians. The methodology used was based on the calculation of velocity of the tweet transmitter by taking two consecutive tweets. However, we owe to mention that the method does not guarantee to exclude all pedestrians since in heavy traffic conditions, vehicles may move at pedestrian speeds. Around 2.7 million of tweets are fed to a single machine Spark ML and SQLContext schema. After setting $k = 7$ clusters each geolocated tweet was assigned to its nearest centroid based on the Euclidean distance metric. These centroids depict the epicenters of intensified heavy traffic activities. The centroids were then updated in each pass of the algorithm and the process was repeated until there was a minimum change of the centroids. The structure used in the data frames of Spark was: (Date, Time, Latitude, Longitude, Keyword). Separate runs were performed for the aforementioned keywords. Figure 1 shows the centroid locations of the scenario with the keyword "congestion" (Table 1).

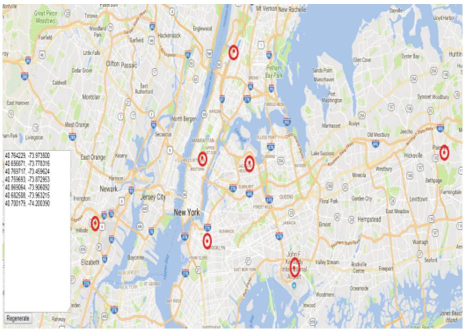

Fig. 1. Centroid locations in Google Maps.

Table 1. Centroid coordinates.

Latitude	Longitude
40.76122883211822	–73.1234999829014
40.69877065064515	–73.7231638518956
40.76971711652399	–73.4544454489798
40.75969284538119	–73.7365292246709
40.869063991800815	–73.3287442854547
40.40856985998673	–73.8958754983675
40.768743687636723	–74.980658943283

3.2 Traffic Big Data Classification Using Supervised Machine Learning

Classification Data Set Acquisition. For the case of the binary classifier, the set of tweets either include the weather condition in a traffic event or not. The tweets were gathered from the same area as in clustering and had the same structure (Date, Time, Latitude, Longitude, Keywords) where an *m*-at most tuple creates the keywords.

For m up to 10 such candidate keywords included the words {traffic, rain, snow, sleet, accident, slowdown, congestion, stuck, thunder, crash} when investigated heavy traffic due to extreme weather conditions. For the case of the ternary classifier the same tweet structure was used with keyword tuples of the form {game, strike, demonstration, flight, Christmas, year, accident, crash, ambulance, shopping}.

Data Set Preprocessing. Data fetching was followed by a set of preprocessing procedures dealing with:

1. *Removal of tweet meta-associations* using a Java Regular Expression Filter [18] to discard hashtags, links, mentions and user-ids out coming a set of strings S_i, $i = 1 \ldots N$. The S_i's are further converted to lower case characters via the *tolower*(S_i) procedure.
2. *Tokenization of S_i's* using a Java tokenizer [19] so that, all S_i's were transformed into a larger set of syllables or words called tokens with the synchronous extraction of non-text characters (apostrophes, hyphens etc.)
3. *Extraction of stop-words* [20] i.e. words with no statistical significance, conjunctions, articles, pronouns etc.
4. *Stemming* of tokens using the Porter's algorithm [21] to remove suffices of tokens and to group words of similar semantics. The outcome of this process was the set of ST_i, $i = 1 \ldots N$ stemmed tokens. N was be the training set for the machine learning algorithms used later on thus is denoted as N_{tr}. For each stemmed token st_j in N_{tr} we compute its importance in the training set using the *Inverse Frequency Index* (IDF) as:

$$w_{st} = \ln(N_{tr}/N_{st}) \tag{1}$$

   where N_{st} is the occurrence index of the stemmed token in N_{tr} [22].
5. For the set of calculated IDF's we built a feature representation vector $F = (f_{j_1}, f_{j_2}, \ldots, f_{j_{N_{tr}}})$ where each element was set according to:

$$f_j^{st} = \begin{cases} w_{st} & \textit{if stemmed token} \in N_{tr} \\ 0 & \textit{if stemmed token} \notin N_{tr} \end{cases} \tag{2}$$

6. *Information Gain,* (IG) calculation for each stemmed token ST_i for the class vector $C = \{c_1, c_2, \ldots, c_m\}$. Note that for our aforementioned scenarios |C| = 2 or 3. The IG(ST_i) is:

$$\begin{aligned} IG(ST_i) = -\sum\nolimits_m P(C_m)\log P(C_m) + P(ST_i)\sum\nolimits_m P(C_m/ST_i)\log P(C_m/ST_i) \\ + P(\overline{ST_i})\sum\nolimits_m P(C_m/\overline{ST_i})\log P(C_m/\overline{ST_i}) \end{aligned} \tag{3}$$

where $P(ST_i)$ is the probability that the stemmed token ST_i occurs in (3), $\overline{ST_i}$ is the occurrence negation, $P(C_m)$ is the probability of the mth class value, $P(C_m/ST_i)$ is the conditional probability of the mth class value given that ST_i occurs and $P(C_m/\overline{ST_i})$ is the conditional probability of the mth class value given that ST_i does not occur.

3.3 Classification Using a MLP-NN and SVM

For the first experiment we used an MLP NN as a binary classifier from the April-ANN toolkit [23]. More in detail, we used the [MLP: ann.mlp.all_all.generate] call to involve an all-to-all connection between the hidden layers of the NN concentrating on the performance of the classifier that has only two classes-positive and negative. This allowed us the investigation of the: True Positive (TP), True Negative (TN), False Positive (FP) and False Negative (FN) instances and the calculation of the performance metrics: Accuracy (4), Precision (5), Recall (6) and F-Score (7)

$$Acc = (TP + TN)/(TP + FP + FN + TN) \tag{4}$$

$$Prec = TP/(TP + FP) \tag{5}$$

$$Rec = TP/(TP + FN) \tag{6}$$

$$F\text{-}Score = (1 + \beta^2)\frac{\mathrm{P}rec \cdot \mathrm{R}ec}{(\beta^2 \cdot \mathrm{P}rec) + \mathrm{R}ec} \tag{7}$$

where $\beta = 1$ for class-balanced datasets.

For the second experiment we used a SVM as in [24] noting that the optimization problem under concern makes use of kernels, which map input features into a different space. This means that finding the derivative of the cost function and using gradient descent does not work, but instead, the SVM only weights examples that are close to the decision boundary. Table 2 depicts the classification results on the 2-class dataset for the two classifiers mentioned above, indicating the best performance in bold.

Table 2. Classification results for the 2-class dataset.

Classifier	Accuracy (%)	Precision (%) by class		Recall (%) by class		F-Score (%) by class	
		Weather caused	NotWeather caused	Weather caused	NotWeather caused	Weather caused	NotWeather caused
MLP-ANN	89.6	90.7	88.9	88.54	90.63	89.22	89.91
SVM	**92.73**	**92.06**	**93.4**	**92.80**	**92.66**	**93.02**	**92.44**

3.4 Classification Using DCL Network for Sentiment Analysis

For the case of the 3-class classifier we used the Deep Convolutional Neural Network shown in [25]. The training of the network was done by stochastic gradient descent via the use of a backpropagation algorithm to compute the gradients. The tendency of the network to over fit in the learning process of the decision function was confronted by augmenting the cost function. The testing of the model was done on the pre-processed tweet data in a 70% to 30% ratio between the train and test datasets. Unfortunately the results were inferior to the 2-class classifier as depicted in Table 3.

Table 3. 3-class deep convolutional learning classifier.

	Due to Accidents	Seasonality affected	External events
Accuracy (%)	81.76		
Precision (%) by class	79.65	80.92	84.72
Recall (%) by class	82.34	82.18	80.49
F-Score (%) by class	82.21	81.28	81.79

4 Conclusions

With the increase of vehicular traffic observed in recent years in urban areas, there has been a significant degradation of the efficiency of the traffic flow. The incorporation of machine learning methodologies is shown to be beneficial in identifying congestion centroids for the case of clustering traffic congestion related data generated by social media. Furthermore, for the case of classification in discovering the reasons of occurrence of congestion events, binary classifiers (MLP-NN and SVM) outperform the utilization of Deep Learning models. We suspect that this limited utilization of DCL is due to the fact that we have not used pre-trained embedding of neural language model thus, further investigation is apparent in justification of this comparison.

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Making Big Data Real in Upcoming Future: The Dynamic Toll Prices in the Portuguese Highways

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Abstract. In the present context, it is frequent for urban and national road networks to be highly congested, resulting in increased travel times and delays. At the same time, due to toll charging, some high-quality highway networks, particularly in Portugal, are underused. Dynamic charging on highway networks can contribute towards the optimization of the network performance and understanding the behavior of logistic operators as one of the main users of the network is of great importance for the development of any dynamic charging toll model. Within this context, one of the pilot cases of the H2020 project OPTIMUM includes the development of such a forecasting and dynamic (toll) charging model with the key objective of transferring heavy traffic from the urban and national roads to highways. The first run of pilot occurred between March 09th, 2017 and April 07th, 2017, performance indicators (KPI) were highly positive in terms of freight traffic shift from the national roads to the highways and, consequently, an increase in toll revenues and freight operations efficiency was registered.

Keywords: Dynamic charging · OPTIMUM project · Heavy traffic Toll prices · Traffic model · Route choice model · Freight operations efficiency

1 Introduction

Urban and national road networks in many countries have become more and more congested, resulting in increased travel times, operational difficulties, greater travel and maintenance costs and a higher inconvenience level for both drivers and passengers, increased number of traffic accidents (particularly the ones involving pedestrians), and negatively impacting to the environment.

At the same time, Portugal has a good underused tolled highway network, most of the times closer to urban or national toll-free road. Frequently, Portuguese drivers prefer using toll-free roads, disregarding their own safety and relying their decision-making process only on the more easily and objectively identifiable criteria, such

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available time, fuel costs and toll prices [1] leading to an increased use of the network increasing maintenance costs and pollutants emissions.

Expanding the road network, or its capacity, is both extremely costly and harmful to the environment, thus the way to accommodate growing travel demand is using existing networks more efficiently. The implementation of a dynamic pricing scheme can help to reduce congestion by shifting some traffic demand from national roads to underused highways. Thereby, the European H2020 project "OPTIMUM – Multi-source Big Data Fusion Driven Proactivity for Intelligent Mobility" considered a pilot case that involves the development of a forecasting and dynamic (toll) charging model.

This paper presents an analysis of the current situation in the Portuguese road sector and the toll collection strategies in the country. In addition, it presents the pilot case developed under the OPTIMUM project, as well as the results of the defined key performance indicators (KPI).

2 Literature Review

2.1 Implemented Charging Models and Dynamic Pricing

In Europe, several cities have adopted 'congestion charge' schemes, mainly to address congestion and/or environmental problems. Usually, these cities adopt constant prices during the day, although exceptions exist, such as Stockholm (where the amount of tax paid to enter and exit the central area varies with the period of the day) [2].

In the United States of America, one of the most common solutions regarding dynamic pricing is the conversion of high-occupancy vehicle (HOV) lanes into high-occupancy toll lanes (HOT), which consist of allowing lower occupancy vehicles paying a toll to gain access to the HOV lanes [3]. These systems came up in 1995 with the objective of avoiding underutilization of HOV lanes and generating additional revenues [4].

To achieve the objectives efficiently, toll prices should be adjusted in real time, as a response to changes in traffic [3]. This is what happens, for instance, in the dynamic toll system implemented on the "fast lane" of the highway between Jerusalem and Tel Aviv (Israel). This system is based on an algorithm developed by Siemens which ensures that the dedicated lane's capacity is sufficiently used while preventing traffic jams: when traffic is light, the toll fee drops, and when traffic gets heavier, the fee increases.

2.2 Current Situation in Portugal

The first section of Portuguese motorways was built in 1944, and in 1985 the national highway network had an extension of 158 km. Nowadays, there are about 3.000 km of highways in Portugal, and about 84% of them are toll-controlled. The introduction of tolls, from 2008 onwards, in a set of highways with "shadow toll" schemes, had a significantly negative impact on travel demand (and consequently on the region's mobility and accessibility), despite the application of some temporary positive discrimination measures.

Infraestruturas de Portugal, S.A. (IP), with 100% public capital, is a national authority that has now a 75-year concession agreement with the Portuguese State for maintaining the national road network (more than 15.000 km), except for the highway network integrated in other State concessions (Fig. 1), including those former "shadow toll highways".

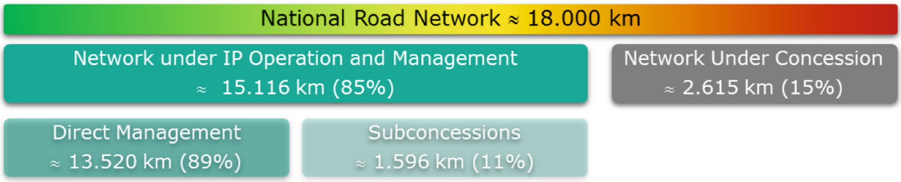

Fig. 1. Portuguese national road network.

All previous "shadow toll" concessions have Multi Lane Free Flow (MLFF) systems, that allow automatic toll collection without requiring vehicles to stop at a toll booth, and have also made crucial the possibility of launching tolling schemes focused on obtaining and retaining frequent highway users.

About 60% of the highway extension had average annual daily traffic (AADT) values lower than 10.000 vehicles [5]. For this reason, about 94% of the highway network registered a higher level of service, representing a clear situation of underused infrastructures.

Since the toll introduction on those highways, IP has been trying to devise strategies to recover traffic, by implementing specific charging schemes such as positive discrimination for local users (private and companies), higher discounts for Heavy Goods Vehicles (HGV) at night period and weekends or discounts applied on highways located in municipalities with lower development rates. Regardless of the effort, the HGV scheme had low acceptance and failed to serve freight sector needs. Also, some of the measures turned out to have a negative impact on toll revenues. Therefore, there is an apparent need for a more commercial approach, providing more flexibility on pricing.

In many situations, highways are underused, and the alternative national road is highly congested, and IP is dealing with two major issues:

- The national roads were not planned to have such a high traffic demand (particularly of heavy vehicles), therefore they are deteriorating faster than expected with higher maintenance costs involved;
- The massive investment that was made on highway networks is not giving back the expected results, with traffic flows lower than initially planned providing, in turn, lower revenues.

3 The Dynamic Charging Pilot Case

3.1 Methodology

The European H2020 project "OPTIMUM – Multi-source Big Data Fusion Driven Proactivity for Intelligent Mobility" involves a pilot case running in Portugal with the collaboration of Luís Simões (LS), one of the biggest Portuguese logistic operators, where a model of forecasting a dynamic toll charging scheme is used in order to reduce the congestion by shifting traffic from national roads to the highway network.

The road network involved in this pilot case is composed by 5 highways (A4, A25, A28, A29, A41) from 4 previously "shadow toll" concessions (Grande Porto, Norte Litoral, Costa de Prata and Beiras Litoral e Alta), whose toll collection revenues are controlled by IP (Fig. 2). Together with these highways, the pilot network integrated the national roads used by Luís Simões as a free alternative to tolled highways.

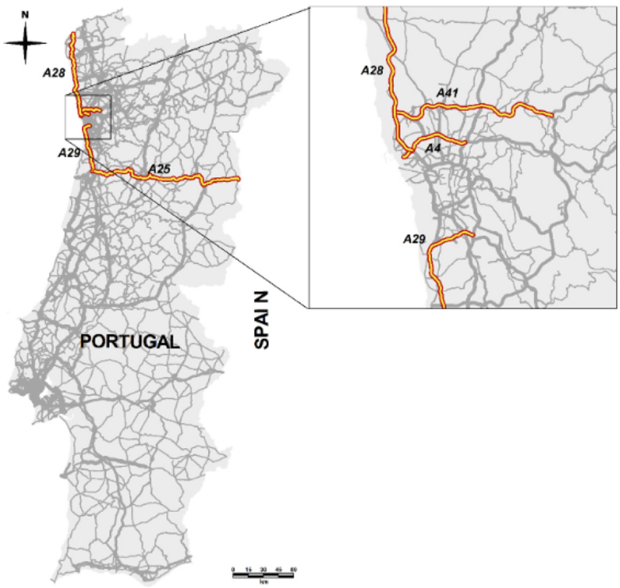

Fig. 2. Portuguese pilot case network.

Toll prices were calculated considering a *variable pricing solution* that aimed to increase highways demand of heavy vehicles and reduce traffic volumes in national roads, combining historical and current data (traffic flows, characteristics of the road networks, quality of service), presenting it in a dedicated web-interface. The pilot case used an econometric dynamic route choice model developed by University of Aegean in Greece.

To support the pilot development, a traffic model developed by TIS (a consultancy company specialized in mobility and transport based in Lisbon, Portugal) was used. With different variations in the toll prices in each section, some reasonable boundaries were calculated (in terms of maximum and minimum values of discount, with the minimum possible price being defined by the road operator) based on the traffic shift registered, as well as the number of traveled kilometers and expected revenues.

The econometric model was fed by these outputs and by an online survey conducted in Portugal targeting to understand the behavior of logistics operators and truck drivers, with both revealed and stated preference data. In the stated preference scenarios tested, the freight operators were presented with two route alternatives for a future trip (one with a tolled highway and one toll-free), as well as a variety of incentives that the toll users might benefit from (discounts in fuel prices, higher speed limits, dedicated truck lanes and toll discounts, for instance). The survey results were used for getting a more realistic value of time (VOT) and for the definition of a better pricing strategy that would respect the road operator objectives.

Both tested models contributed to the assessment of the trucks' route choice (facing the discounts that should be applied to tolled roads). A "toll discount" was calculated for each hour of each day based on the calculated VOT, the traffic conditions in the highway (to avoid new congestion issues in these roads) and the difference of times between the alternatives.

To evaluate the pilot results, three main key performance indicators (KPI) were set:

- Reduction of traffic congestion in national and urban roads, by shifting traffic from national road network to the underused highways – a 15% shift from freight vehicles to the highways is expected;
- Increase in IP's toll revenues reflecting a higher use of highways – 10% increase;
- Improvement in the efficiency of Luís Simões' operations of at least 10% prior to the project estimates.

3.2 Results

This pilot "run" was kicked off on March 09th, 2017, and it was running until April 07th, 2017. From acquired results prioritized suggestions involved some important improvements of the econometric model and of the web-interface (front-end) developed for the consultation of the calculated toll prices.

To undertake this first iteration of the pilot, dedicated training was provided to drivers and route planners by Luís Simões, as well as explanations on the purpose of the pilot and how the web-interface front-end of the software would be used.

During this pilot, Luís Simões had to rebuild their business planning procedure. In fact, a new process was implemented so as to evaluate the competitiveness of the "new" toll price. From Luís Simões' side, the calculation was simple: a toll would be payed if, at the same time, they had an economical advantage regarding fuel consumption, transit time reductions and total number of kilometers.

For each trip conducted, Luís Simões collected information relating to two different route scenarios *applied per trip* for *each singular trip* of the 10 trucks operating in the pilot:

- Scenario 1: Trip using Luís Simões original routes – corresponding to the routes chosen by Luís Simões without applying the dynamic charging model, i.e. using the current toll prices. It defines the "base case" of the pilot;

- Scenario 2: Trip using OPTIMUM routes – these are the routes chosen by Luís Simões using the discounts prices calculated by the dynamic model, which correspond to the routes selected by the logistic operator.

In each trip, Luís Simões made their route planning using their normal route and the alternative route (“OPTIMUM route”), for each singular trip of the 10 trucks operating in the pilot. A total number of 285 trips during this period were made.

As previously described, a set of KPI were defined to evaluate quantitatively the pilot, regarding the shift of freight traffic from the national roads to the highways as an effect to achieve the increase in toll revenues and freight operations efficiency.

The results from the first iteration of the pilot are highlighted in the following sections and summarized in Table 1 depicted below.

Table 1. Results from the pilot case.

		Scenario 1	Scenario 2	Variation (%)
Traffic shifting (v.km)	Total (km)	43.270	43.347	+0,2%
	Pilot national roads (km)	9.807	8.399	−14%
	Pilot highways (km)	33.463	34.948	+4%
Revenues (€)		3.720 €	4.484 €	+20,5%
Operations efficiency (€)	Length (km)	43.270	43.347	+0,2%
	Time spent (h)	963,9	913,0	−5,3%
	Costs (€)	44.316	43.028	−2,9%

(1) Traffic shift from urban/national roads to highways

From the information collected by Luís Simões during their pilot operation, the usage of the highways increased by about 4,4%. At the same time, the reduction of the national road usage was quite significant: a reduction of approximately 14%, which is just 1% away by the target defined by the project (15%).

A closer view to the kilometers run by trucks in each one of the pilot highways shows that only the A41 highway had a reduction in its overall usage. Although the shift from other concessions is not a goal of the pilot, it should be underlined that in many cases a shift was observed from other private concessions (like A1, A3 or A11) to the pilot highways, which leads to better results for IP, in terms of traffic shift and revenues.

(2) Increase on IP’s toll revenues

Even though a discount was applied to make the highway more attractive, it was expected that the increase in traffic and therefore in toll transactions would compensate the lost in revenue originated by the discounts – this is an important aspect for the road operator and crucial for the commercial feasibility of the dynamic model; road operators won’t be interested in the dynamic model if that is translated as a loss of revenues.

For this KPI, the same methodology between the scenario usage of original routes and the “OPTIMUM routes” was used. At the end of pilot’s first run, the performance of this indicator was very good, exceeding more than double the defined value (10%).

It is also important to note that the increase in toll revenues within the pilot network is not the same as the increase in toll costs by Luís Simões, since the route shift of their trucks might happen from the other highways not included in the pilot (namely A1, A3 or A11) to the pilot's highways.

Although the results of the pilot were based on 10 Luís Simões' trucks operating in this pilot (and their respective 285 trips), they could be generalized as counting also in the case of the heavy vehicles fleets of the Portuguese road network to infer a possible measurable impact that this dynamic charging model would have on IP's toll revenues.

In 2016, the 4 concessions that involve this pilot (Norte Litoral, Grande Porto, Beiras Litoral e Alta e Costa de Prata) generated a revenue of near 30 million euros with heavy vehicles (class 4 vehicles). If the results from this KPI are generalized to the universe of the class 4 vehicles in these concessions, it is estimated an increase of about 6 million euros in the toll revenues would be reached.

(3) **Cost improvement in the efficiency of LS operations'**

The daily process performed by Luís Simões using "OPTIMUM routes" increased the efficiency of the operation in almost 3% (i.e., reduced their costs), even considering the payment of the new toll prices in sections they used to avoid. These values are a little far away from the initial goal of increasing in 10% the efficiency.

The reduction of fuel consumption was the main reason for the accomplished reduction of costs: a reduction of almost 1 L of consumption per 100 km (1l/100 km) during the pilot was calculated.

A second factor that contributed to the increase in the competitiveness of the logistic operator was the reduction on transit time. The average time per trip was reduced in about 5,3%, which means that the route was accomplished approximately 11 min sooner than before. This is a crucial indicator for a logistic operator, since it reduces the risk of failing to accomplish their service level agreements with their clients.

Furthermore, since the beginning that the logistic operator kept some doubts about the effect in the total number of kilometers. However, according to the data available, the increase in the distance traveled was about 77 km, which is an immaterial value.

This pilot was also a great opportunity to calculate in a more accurate way the competitiveness of toll prices.

4 Conclusions

The freight operators are responsible for economic benefits but at the same time for measurable road network's greatest environmental impacts as well as road maintenance costs. H2020 OPTIMUM engaged with Luís Simões (one of the biggest Portuguese logistic operators) to test possible solutions offering some assurance that the project developed model will be appropriate for large-scale use and will reflect the needs expressed by the operators.

Indeed, at the end of this first run of the pilot (that lasted for approximately one month), it became clear that the dynamic charging model generated interesting toll prices to logistic operators and, given some conditions, the logistic operators changes their routes from the free national road to the tolled highways. However, it was also clear that evaluating the final prices is an arduous process and could discourage logistic operators to evaluate prices daily.

A second run of the pilot took place by the end of 2017, considering improvements in the pricing model applied in the first run, so as to consider a more accurate comparison between the traffic conditions in the highway and in the free alternatives. Some changes in the web-interface were also included that improved the logistics operator planning process. The conclusive results from the second pilot run are under evaluation, but the project already registered important impact in Luís Simões' daily operations: some of the historical decisions regarding the choice between highways and national roads were already revised by the logistic operator after the first pilot run evaluation results.

Given these results, IP is seeing in this pilot an opportunity to implement a model that could reduce traffic on national roads and maintenance costs, improve client's satisfaction and environmental indicators, as well as increase highways performance with higher revenues. The system is in its first steps, but it is this project's conviction that in a near future it will be the chosen option not only for logistic operators but for the common citizen that may at a certain moment decide the route that suits better their needs.

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Assessment of Dynamic Geo-Positioning Using Multi-constellation GNSS in Challenging Environments

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Abstract. Global Navigation Satellite Systems (GNSS) provide accurate and reliable positioning solutions in open field environments. However, the positioning performance is not the same in dense urban areas, where satellite signals are blocked or reflected by tall buildings.

A 3D city model, 'Urban Trench', is introduced to simulate blockage and reflection of GNSS signals. The 'Urban Trench' model assesses the reflection environment of the city and the non-light-of-sight (NLOS) ranging errors are corrected, based on satellite elevation and a 3D surface model. Subsequently, the metric of NLOS signal exclusion using an elevation-enhanced map is developed and tested using real vehicular data in the test urban network of Nantes. A GPS&GLONASS-constellation single-frequency receiver is used during the experiment. The performance of both systems, stand alone and in combination as dual-constellation, are presented, compared and evaluated, with and without 'Urban Trench' model implementation. Additionally, a fault detection and exclusion test is applied, to check and enhance the integrity of the output.

Keywords: GPS · GLONASS · 3D city model · FDE · 'Urban Trench'

1 Introduction

The road applications encompass traditional areas like navigation, guidance, or fleet management, but in future the GNSS will also be part of more sophisticated and intelligent systems. GNSS information empowers automotive services ranging from precise navigation and satellite road traffic monitoring to location-based information services, ameliorating traffic information processing and user distribution [1]. Intelligent navigation systems shall make road safer, minimizing travel time while reducing congestion. As the most cost-effective and performant source of positioning and timing information in outdoor environments, GNSS has become an essential element of major contemporary technology developments notably including the IoT (Internet of Things), Big Data, Augmented Reality, Smart Cities and Multimodal Logistics.

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Their potential might have been better exploited by combining different available GNSS constellations. The combination of multiple GNSS can significantly improve mobility applications, as the increased number of satellites strengthens the constellation geometry, resulting in an increased accuracy, while the initialization times are reduced and the overall satellite availability is increased.

The development of real-time kinematic applications in urban areas is very challenging. The arrival of city modelling introduced a possible solution to the satellite propagation signal in urban areas. Buildings are prone to create perturbations in the satellite signal propagation, which makes the positioning solution difficult to obtain and often unacceptably erroneous. Not only may signal paths to the antenna be blocked by obstacles in the satellite directions, but also multipath may occur.

The state-of-the-art focuses on the combination of GPS with the modernized GLONASS satellite code measurements with map-aided data, to bring a light in the road user challenging environment.

The performance of the proposed algorithm is analysed using measurements from a low-cost GPS/GLONASS receiver, NVS Technologies AG and a low-cost GPS-only receiver, ublox. Estimated trajectory is compared to a reference trajectory obtained using a geodetic-grade GPS/INS (Inertial Navigation System) [2]. Horizontal error statistics, horizontal protection level will be described for typical urban environments. The area concerned is in Nantes city centre, France.

Overall, GNSS, together with other technologies, satisfies the need of accurate positioning combined with reliability of localisation and improve the efficiency, effectiveness and comfort of road transportation.

2 Position Estimation Algorithms

There are two position estimation methods that are of interest in this research. These methods are the standard ordinary Least-Squares method and the 'Urban Trench' method.

2.1 Standard Ordinary Least-Squares Estimation (LSE)

The satellite positions and observations are read and the following correction are applied [3]: satellite clock corrections, light travel time, Sagnac effect, relativistic correction, troposphere and ionosphere delays.

The least-squares estimator is the most convenient estimator for practical implementations, to guarantee that the linearisation error is negligible.

The observation equation is linear only locally, which makes several repetitions mandatory. Finally, point positioning with code ranges is applicable for each epoch separately. Therefore, a position solution is possible in every single epoch, without being in need of previous epochs to estimate the position, as it happens while phase data are processed. Hence, this model may be used in kinematic applications, where direct positioning is essential.

2.2 Urban Trench (UT)

The ‘Urban Trench’ method uses the city model together with GNSS data to compute the position of the vehicle. Bétaille et al. in [4], have explored this method. The first phase is the characterisation of 3D environment. Urban canyons have been modelled in a very simple manner, with width of the street (W) and height of the buildings (H).

Thereafter, this geometrical modelling makes the distinction between LOS (Line-Of-Sight) satellite signals and NLOS possible. Removing the NLOS satellites from the final computation is a first solution. However, it dramatically decreases the availability of measurements in dense urban areas. Moreover, the remaining visible satellites are only located along the street direction, which results in a degraded geometry of the usable constellation. The shape of the ellipsoid that statistically encompasses the positioning error is distorted across the street direction, which in consequence makes lateral positioning (and lane determination) very difficult [5]. Therefore, the solution introduced in [4], consists in correcting the range of NLOS satellites assuming specular reflection hypothesis, knowing the azimuth and the elevation of the satellite. NLOS are characterized properly, with their number of reflections (1, 2, eventually 3 in case of a very low elevated satellite) (Fig. 1).

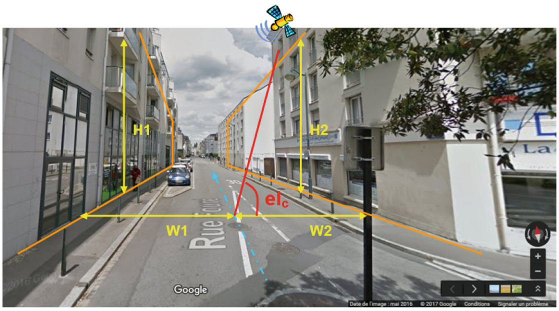


Fig. 1. ‘Urban Trench’ model applied in rue Foure, in Nantes, [6]

After the detection of the NLOS satellite signals, this measurement is corrected by applying additional corresponding distance correction. A schematic representation of the algorithm is given in Fig. 2. Equations of critical elevation and computation of additional path (m_0, m_1 and m_2) are detailed hereafter, in Tables 1 and 2, respectively. Once this is done, the final computation with Ordinary Least-Squares method can be made, using LOS and NLOS satellites. Table 1 gives the threshold in elevation angle below which NLOS conditions, with 1 reflection, are met (and similarly for 2 and more reflections). el_{01} defines the critical elevation angle separating signals with 0 and 1 reflection (LOS and $NLOS_1$). el_{12} defines the critical elevation angle separating signals with 1 and 2 reflections ($NLOS_1$ and $NLOS_2$). W_1, W_2, H_1 and H_2 denote the left and right

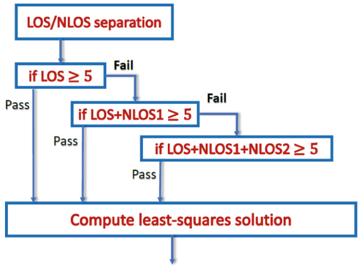


Fig. 2. Schematic representation of the 'Urban Trench' algorithm

width and height of the urban trench. The width is measured from the road centre line to the buildings located in the street on the corresponding side. Both sides are considered and the urban trench can be asymmetric. The road line is arbitrarily oriented similarly as its initial and final points are stored in the database. The azimuth of a satellite with respect to the street direction is β[1] and its elevation el.

The solution suggested uses LOS satellites and as many NLOS ones as necessary to obtain at least the five satellites needed for a least squares estimation. The computation for the positioning solution uses the Ordinary Least-Squares method.

Table 1. Critical elevation angles [6]

Left side	Right side
$el_{01} = \arctan\left\|\frac{H_1}{W_1}\sin(\beta)\right\|$	$el_{01} = \arctan\left\|\frac{H_2}{W_2}\sin(\beta)\right\|$
$el_{12} = \arctan\left\|\frac{H_1}{W_1+2W_2}\sin(\beta)\right\|$	$el_{12} = \arctan\left\|\frac{H_2}{W_2+2W_1}\sin(\beta)\right\|$

Table 2. Corresponding additional distances [6]

Nb of reflections	Left side	Right side
0	$m_0 = 0$	
1	$m_1 = \left\|2W_2\cos(el)\sin(\beta)\right\|$	$m_1 = \left\|2W_1\cos(el)\sin(\beta)\right\|$
2	$m_2 = \left\|2(W_1+W_2)\cos(el)\sin(\beta)\right\|$	

[1] β denotes the angle difference between the satellite azimuth and the street direction, irrespective to the driving direction.

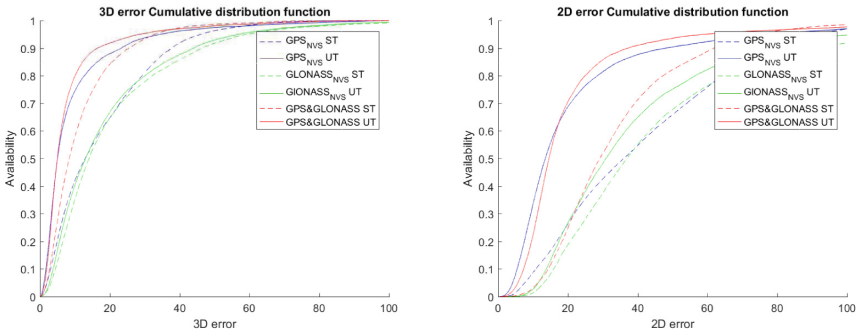
3 Results and Comparisons

Nantes city centre is used as a test network, for the implementation of different cases, in the framework of this research. Experimental results obtained on 27th of February 2014 from 8:36 to 10:20 am, for a total duration of approximately 2 hours. Different GNSS observation data are used and evaluated, namely GPS-only, GLONASS-only and GPS&GLONASS combination. Two methods are applied for the data processing. The first is the standard method, which uses ordinary least squares and considers all the satellites available per epoch to estimate user position. The other one is the 'Urban Trench' model, which introduces information of the street geometry by a 3D city model and corrects (if not removed) NLOS satellites.

The assessment of different constellations and methods is made in terms of accuracy and integrity. The results are compared with a 'ground truth' trajectory. In addition, fault detection and exclusion method is applied in order to compute the protection levels and enhance the accuracy of the output. The Stanford diagram is used to check and illustrate, in a clear way, the reliability of the final results.

In particular, the results show that Fault Detection and Exclusion (FDE) benefits and improves the quality parameters, such as the accuracy and integrity of the user position solution. The recursive consistency-checking method is used to detect and exclude faulty data [7]. Several probabilities of false alarm (PFA) are checked to select the most appropriate for the test data. It is expected that the accuracy of the final positioning solution would be improved. Trials and error analysis show that a confidence interval of $\alpha = 0.01$ is suitable for the test data. The recursive consistency-checking method has a limitation. It is possible to eliminated wrong measurements in cases when multiple signals were affected by NLOS reception or strong multipath interference. Especially in urban canyons, signals come along the street direction and do not necessarily have a higher elevation than other signals.

Figure 3(a) and (b) aggregate all epochs. The cumulative 3D and horizontal error distributions are displayed, for the standard estimator and 'Urban Trench' model. The median error in both 3D and 2D has been reduced. While using the 'Urban Trench' model, there is an improvement globally. Comparing the different constellations and combination of them in terms of accuracy and integrity, one could conclude in the following ranking. For the NVS receiver, the relative results show that the dual-constellation combination has the best performance, GPS-only follows and last comes GLONASS-only. The latter case has the fewer satellites available per epoch and with low elevations. Probably, these are two reasons explaining GLONASS-only poor performance. However, it is derived from the results of GPS&GLONASS combination that GLONASS observation data contribute to the improvement of 3D positioning solution.



(a) 3D cumulative distribution function. (b) 2D cumulative distribution function.

Fig. 3. Cumulative distribution functions

3.1 Overall Matrix

To sum up the results of the study, Tables 3 and 4 are created. The protection level is the usual integrity indicator of a localization algorithm [8]. Horizontal position errors are presented in Tables 3 and 4 because applications for ground transport are considered; the vertical dimension is not regarded. The different scenarios tested are the following:

- GPS_{ublox} without FDE implementation (GPSub-woFDE)
- GPS_{ublox} with FDE and confidence intervals with $\alpha = 0.01$ (GPSub-0.01)
- GPS_{NVS} with FDE and confidence intervals with $\alpha = 0.01$ (GPS-0.01)
- $GLONASS_{NVS}$ with FDE and confidence intervals with $\alpha = 0.01$ (GLO-0.01)
- $GPS\&GLONASS_{NVS}$ with FDE and confidence intervals with $\alpha = 0.01$ (GPS&GLO-0.01).

Respectively, the statistics that referred into Tables 3 and 4 are:

- 3D median position errors, in meters (m)
- 2D median position errors, in meters (m)
- Normal Operation (Norm Oper) for Horizontal protection level (HPL)
- Mis-leading information (MI) for Horizontal protection level (HPL)
- Mean number of satellites used (msat used) each epoch
- Mean number of satellites available (msat available) each epoch.

Measurements have been discarded either due to outlier rejection based on statistics distributions (FDE) or geometry limitations corrections ('Urban Trench' model). Table 4 contains smaller values for all different cases, regarding the median errors and larger values concerning normal operation for integrity, trust of result. In particular, for example for GPS measurements, when 'Urban Trench' model is used the accuracy doubles, from 5.7 m median error, it drops to 3 m, while the integrity increases from 97% to 99.7%.

Table 3. Summary table for standard method.

	Median error (m)		Integrity statistics		Statistics	
	3D	2D	Norm oper	MI	msat used	msat avail
GPSub-woFDE	17.5	5.7	97%	3%	7.3	7.3
GPSub-0.01	16.4	5.3	99%	1%	7.1	7.3
GPS-0.01	35.9	12.9	91%	9%	8.2	9.5
GLO-0.01	36.9	14.0	96%	4%	6.6	7.3
GPS&GLO-0.01	29.1	8.4	90%	10%	14.4	16.8

Table 4. Summary table for 'Urban Trench' method.

	Median error (m)		Integrity statistics		Statistics	
	3D	2D	Norm oper	MI	msat used	msat avail
GPSub-woFDE	11.3	3.03	99.7%	0.3%	5.9	5.9
GPSub-0.01	11.3	3.0	99.97%	0.03%	4.9	5.9
GPS-0.01	13.5	5.0	99.4%	0.6%	6.1	6.3
GLO-0.01	30.9	13.0	98%	2%	5.8	6.2
GPS&GLO-0.01	14.6	5.0	99.95%	0.05%	8.7	8.9

However, these integrity statistics derive from certain assumptions made through the research and their alteration could improve the Stanford diagram results. In particular, the probability of mis-detection (PMD) is set equal to 10^{-2}. From this value, the κ is derived, with four degrees of freedom (three for positioning and one for timing), $\kappa = 3.644$. With smaller PMD, the values of κ are larger, as it is for civil aviation, PMD $= 10^{-7}$ results in $\kappa = 6.18$.

Additionally, the standard deviation of the range measurements was fixed to $\sigma_R = 5\,\text{m}$. These parameters are used for the computation of protection levels and hence influence their values.

Also differences in the performance of the two different low-cost receivers can be found. Therefore, the quality of equipment (here NVS) is also critical for the accuracy and reliability of the outcome.

4 Conclusions

Examining each case, 'Urban Trench' method outperforms in comparison with standard method, both in terms of accuracy and integrity. The 'Urban Trench' approach is of great interest compared to using all satellites with no correction at all, or when only recursive consistency checking test is applied. It is an approximate geometric model and can compute in a deterministic way an accurate position by sorting and correcting the pseudo-ranges subject multipath with 1 or several reflections.

The number of available satellites is a major parameter of the improved GNSS performance. Accuracy can be maximised by selecting only those signals least contaminated by multipath and NLOS propagation to form the navigation solution and discarding the rest. Dual-constellation position solutions show an improved accuracy and reliability. Thus, performance might get higher as the number of GNSS satellites increases.

In conclusion, 'Urban Trench' model in combination with fault detection and exclusion test applied in multi-constellation observation data is a pretty efficient technique in terms of accuracy and reliability. However, this method trades availability for integrity, as data are removed, when not passing the tests.

In a future navigation application, signal reception at multiple candidate positions must be considered, which is more challenging. Thus, it is recommended, in [6], to implement the 'Urban Trench' model while the street is dividing into multiple driving lanes and examine the projection of initial solution into multiple hypotheses in parallel. If the rover was a pedestrian and not a car, sidewalks should be envisaged also as possible hypotheses. This method is expected to outperform conventional positioning in availability and positioning accuracy.

Finally, another future implementation and extension of this technique would be to resolve Low-cost Real-Time-Kinematic GNSS in exploitation of Cooperative ITS. Standard Real-Time-Kinematic GNSS systems are capable of centimetre accuracy, but combine high cost and poor robustness. It is a challenge to adapt 'Urban Trench' model to ITS (Intelligent Transport Systems) needs. Many Cooperative ITS applications, as collision avoidance, payment applications (e.g., road tolling, congestion charging, pay-as-you-drive services), require high accurate and reliable positioning, but at low cost, acceptable for the automotive industry [9]. The incorporation of digital spatial data might contribute to faster and more reliable positioning estimations.

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A Thorough Review and Analysis of Journey Planners

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Abstract. Mobility is highly associated to the ability of the travelers to have access to the proper information on the appropriate time, so that to facilitate their choices regarding the destination, time of the day for the trip, mode of travel and itinerary. Based on this information, travelers optimize their travel in order to reduce travel times and costs, considering also minimizing the footprint of such activities. Journey planner platforms are developed to provide customized information to travelers, and advice on optimum options for the specific trip requirements. They vary in context, contents and functionality, which affect the type, quality and reliability of the information and/or advice. The level of service provided by journey planners is the main aim of the present paper. For this very reason a thorough review and analysis of various Journey Planners was performed. The platforms were selected based on whether they provide route optimization and their detailed characteristics were reported in a structured data collection template. Mystery shopping was selected as the applied method, in order to achieve objectivity and equity in the planners' attributes. Following a statistical analysis, correlational models were developed to associate route planners' components to their popularity and usage. The relationships were compared to the stated significance of the route planners' attributes by users, based on previous research. Findings indicate that both functionality and user interface are important attributes that affect travelers in using the platforms, whereas complex and sophisticated information may deter visiting them especially when a quick response is required.

Keywords: Trip choices · Mystery shopper · User preferences
Qualitative analysis · Evaluation

1 Introduction

The current paper focuses on the broad phenomenon of Journey or Route Planners and on what actually makes Planners popular to users. The modern Planners defy the basic use of transporting oneself from point A to point B and offer a vast range of side information so as to hyper-facilitate the users. Although such practices appear extremely useful, the danger of getting the users baffled lies underneath.

As technology progresses, Journey Planners become more and more complex and the existence of two or more Planners covering the same area more and more common. Especially the Planners of global range have multiplied over the last decade, indicating the increasing need of travelers and passengers for continuously upgrading systems.

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Previous researches have performed qualitative analyses where one ranks journey planners by “functional, operational and visualization features” [1], while the other focuses on developing “a framework of aspects and user groups” [2]. However, there is no research so far, that addresses the interrelations between offered attributes by journey planners and the impact on their popularity on users. This is the aim of this paper, thus to analyse all aspects of journey planners and associate them with user preferences and usability. The methodology adopted for the current analysis is explained in the subsequent part, whereas the analysis of the data collected depicts trends, user desires and gaps. Finally, some guidelines for optimizing services offered by journey planners are provided.

2 Methodology

2.1 The Steps

The identification of the journey planners’ features was done by an initial review on a small sample of such planners. A detailed listing of these features led to the development of a database, which includes both common attributes, but also individual features that existing planners demonstrate. A template was developed for reporting in a structured way the components of the reviewed journey planners. Finally, a thorough search on existing journey planners was conducted on the internet, in two ways. Using keywords in web search machines, planners of global coverage were detected, i.e. planners which do not promote a specific transportation mode. On the other hand, mobility service providers were searched, in order to identify designated itinerary planners, which are in particularly developed to service their customers.

2.2 Data Collection Template

Due to the various attributes of the planners, the need for a template arose, which accommodates all the individual features of each evaluated planner. The template covers all the aspects that a planner may have. Some of these respected features were obtained through testing the websites, others were tested through the nibbler tool and others were identified with the mystery shopper method. Firstly, the apparent features were checked, namely the address, geographical coverage, route optimization, user customization capability, route results, user interface, services offered and presence of real time data.

Following, specific attributes concerning the operation of the website were inspected with the aid of Nibbler, a tool that checks websites offering optimization advice to their owners. The fields concerned were the popularity, the existence of application for mobile phones, the last update of the website and the server behavior. These fields were selected among various options since they are considered of foremost importance to this research. Finally, the method of mystery shopping was applied to evaluate the fields of Service quality and ease of use in terms of friendliness, comprehensiveness and clarity, as an additional aid in reviewing the planners in the most complete and unbiased way possible. The Mystery Shopper’s purpose is the evaluation of each company’s prerequisites. The areas of evaluation include (a) Introduction (greeting of the employee and a presentation of the company), (b) Recognition of customer's needs, (c) Offer, (d) Conclusion. In the case of route planners the evaluation had to be decoupled so that the two areas of usage and outcome, i.e. Website and Instructions, would be covered. On behalf of Introduction, the attribute Visually Attractive and Map Clarity were chosen, as they concern the first page. To cover Recognition of Customer's Needs, the Easy Operation and Explicit Terminology were selected, since the easier the operation is the more content the user will be. In the field of Offer, the totality of Instructions had to be checked. Comparing the instructions to a product then, they had to be easy to use that adds up to the field of Simple - Comprehensible, responsive to the customer's needs, therefore Adequate and of course existent, which led to the field of Realistic.

3 Result Analysis

3.1 General Results

One hundred journey planners were selected, analysed and documented. After the journey planners' data were reviewed and the results recorded on the template, descriptive statistics were performed to identify their components and trends, coverage and gaps. Understanding the popularity of a planner requires combination of information and, of course, the range it covers could be a certain clue that brings the topic of popularity into the game. Figure 1 shows the Geographic Coverage of the route planners. It demonstrates the percentage of the planners that cover Urban areas, Interurban areas and Global areas. As there are planners which have a combined coverage, such cases have also been taken into account i.e. Urban-Interurban, Interurban-Global or all coverages.

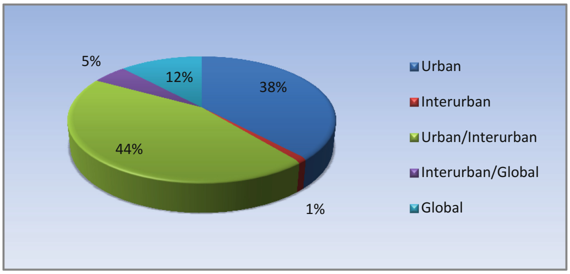

Fig. 1. Geographic coverage.

Of the studied planners, urban planners make up 38%, interurban 1%, urban-interurban 44%, interurban-global 5% and global 12%.

Another attribute that was analyzed concerns the input options for the user, namely whether the planner offers the possibility to provide an address, transit stations/stops, points of interest, intersections, co-ordinates, selected points on the map or another option. Data indicate that 88% of the planners offer the option of entering address, in

57% public transport stops comprise origin and destination of the trip, whereas points of interest can be requested in 72% of the planners (Fig. 2). Moreover, the option of intersections covers the 30% of the analyzed cases, the coordinates option the 20%, while the selection of a point on the map the 45%.

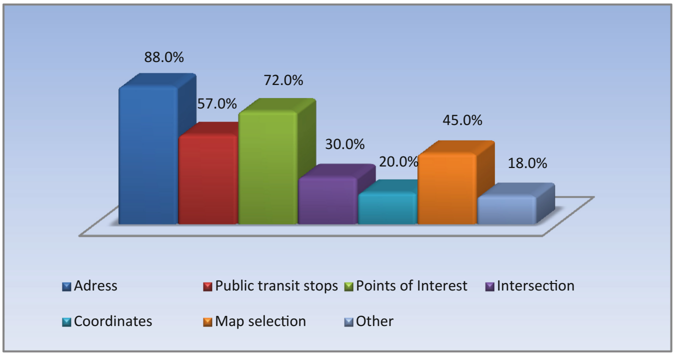

Fig. 2. Input options.

Table 1 depicts the anticipated modes of transportation, as compared to the coverage that the route planners offer. It is interesting to note that only 28,9% of the analyzed planners focusing on urban environment, include private vehicle as a mode. The same can be noticed in Urban-Interurban Planners, where the respective proportion is 34,1%. As the coverage of the planners expands, the option of private vehicle use is offered up to 100%, whereas public transit options tend to decline at the same time. Notably, the option of bicycle use, whether individually or by bike sharing, shows approximately the same percentage in urban and global planners. It may be concluded that public transportation revokes development of designated tools for facilitating each specific organization's customers.

Route optimization in terms of time is proposed in 88% of the planners, 36% in terms of distance, whereas 16% offer the option of adjusting the route according to cost (Fig. 3). More rare user criteria are met in 5% of the planners, where there is the possibility of choosing a route with less carbon footprint while just 1% offer the opportunity to choose a route that promotes health, by associating it to calories' consumption. Finally, 11% of the planners do not offer optimization options at all.

It is notable to mention the compatibility and integration of route planners with mobile applications. Figure 4 demonstrates that 75% of the planners offer applications and are compatible with mobile phones. As most users nowadays make exclusive use of mobile phones instead of home computers, there is a remaining 25% of planners not connected to a mobile application.

Timeliness of information is very important when it comes to travelling, which builds trust and ensures a safely-directed journey. Figure 5 shows that only 6% of the planners have a real time updated database, whereas 33% offer data updated on a daily basis. On the other hand, and in contrast with the fast paced everyday life and the need for up to date information, approximately 1 out 5 planners update their database once every few months.

Table 1. Anticipated modes of transportation.

	Private vehicle	Bus	Tram	Metro	Trolley	Pedestrian	Bicycle	Taxi	Carpooling
Urban	28,9%	94,7%	50,0%	47,4%	23,7%	63,2%	36,8%	5,3%	0,0%
Interurban	100%	100%	0%	0%	0%	100%	0%	0%	0%
Urban-Interurban	34,1%	90,9%	65,9%	65,9%	15,9%	88,6%	27,3%	13,6%	0,0%
Interurban-Global	80,0%	60,0%	20,0%	20,0%	20,0%	20,0%	0,0%	0,0%	0,0%
Global	100,0%	41,7%	25,0%	25,0%	16,7%	66,7%	33,3%	0,0%	8,3%
	Car sharing	*Bike sharing*	*Ship*	*Riverboat*	*Bike*	*Train*	*Truck*	*Combination*	
Urban	2,6%	5,3%	10,5%	7,9%	2,6%	60,5%	0,0%	76,3%	
Interurban	0%	0%	0%	0%	0%	100%	0%	100%	
Urban-Interurban	6,8%	0,0%	40,9%	2,3%	0,0%	72,7%	2,3%	90,9%	
Interurban-Global	0,0%	0,0%	60,0%	0,0%	0,0%	40,0%	0,0%	60,0%	
Global	0,0%	8,3%	33,3%	0,0%	16,7%	25,0%	25,0%	41,7%	

3.2 Attributes Significance

Based on previous survey research regarding the importance of a journey planners' services on users of various ages and occupations, five attributes were concluded as most important [1, 2]. The best preferred way of data input was the address based option with a score of 9.14 out of 10 with the lowest being the GPS based option (2.91). Regarding route planning information, the survey showed a preference towards travel time and duration with 9.51. Moreover, concerning the operational features of the planners, users chose the timetable information as the most important (9.15) and as far as the travel conditions, the alternate routes option was selected as most important (8.41). Finally, weather conditions information as a service received a higher score than other comfort services.

Following the analysis of the initially 82 attributes of the template, five of them were identified as the most important, in terms of frequency of appearance in the analysed planners, and according to literature [1, 2]; input option, route duration, alternative routes, real time traffic information and weather forecast. Along with them, the 7 indicators, which were reviewed through mystery shopping, were selected for describing the analysed journey planners. These include visual attractiveness, operational ease and map clarity (attributes that evaluate the website's quality), and comprehensibility, explicit terminology, rationality and adequacy of instructions (attributes that evaluate the context of the planner). A scale from 1 (inefficient) to 5 (excellent) was used.

In the field Simple and Comprehensible Instructions, items that were examined are, degree of detailed instructions, automatic appearance of results, translation in other languages and instructions on the map. In Realistic Instructions, the correlation to actual information found from other reliable sources was examined. Adequate Instructions, on the other hand, include the type, number or name of each transportation vehicle, the station name, the time of departure or/and arrival, the distance and the icons demonstrating the vehicle type.

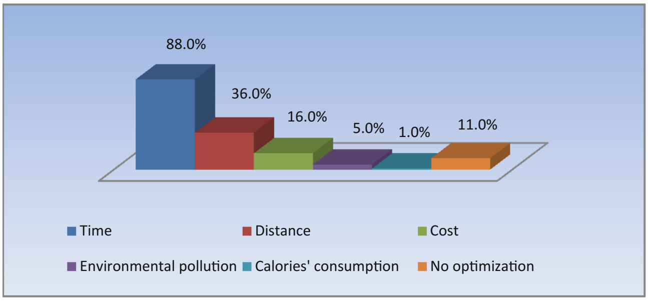

Fig. 3. Route optimization options.

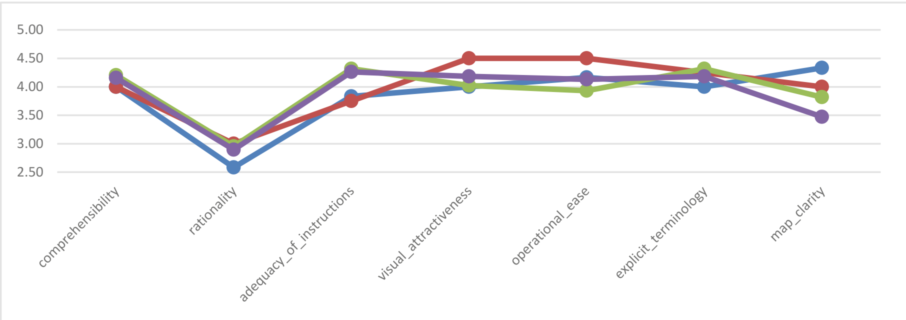

Fig. 4. Evaluation of route planners' attributes.

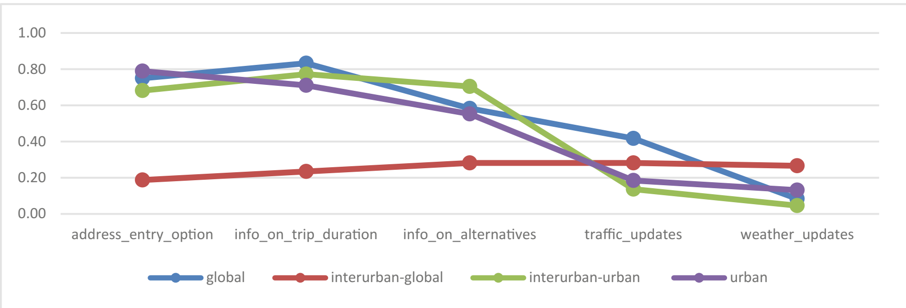

Fig. 5. Proportion of route planners with offered functions.

In the Website Evaluation, the field of Visually Appealing corresponds to a size analogy among maps, images and typing fields on the first page, simple but not simplistic environment, not too bright colours, clear categories or subcategories of links and helpful icons or images. Easily Operated field involves a demonstrative usage tool, indication of addresses during typing, autocorrecting or demonstrating alternatives, vehicle selection option and apparent categorization. The field of Clear Terminology includes the properly translated website, properly translated Planner, icon description, instructions comprehensible to the user and frequently asked questions category. Finally, Map Clarity is marked according to whether it demonstrates the option of map enlargement, the clarity of streets and intersections, whether parks, harbours, rivers, mountains or other points of interest are clearly shown on the map, the names of all the above and their icons.

When examining relations between variables (Table 2), comprehensibility indicated good correlation with adequacy of instructions (spearman's rho = .6), explicit terminology (spearman's rho = .565) and visual attractiveness (spearman's rho = .458). This indicates that the most comprehensive planners provide explicit terminology and adequate instructions, whereas they offer an attractive environment to the users. Average correlation was indicated between adequacy of instructions and terminology (spearman's rho = .492), whereas explicit terminology affects both visual attractiveness and operational, with spearman's rho equal to .475 and .470, respectively. Finally, visual attractiveness and operation ease are correlated (spearman's rho = .547).

Table 2. Correlations among route planners' attributes.

Correlations

			comprehensibility	rationality	adequacy_of_instructions	visual_attractiveness	operational_ease	explicit_terminology	map_clarity
Spearman's rho	comprehensibility	Correlation Coefficient	1.000	.357**	.600**	.458**	.354**	.565**	.373**
		Sig. (2-tailed)	.	.000	.000	.000	.000	.000	.000
		N	100	100	100	100	100	100	100
	rationality	Correlation Coefficient	.357**	1.000	.397**	.251*	.174	.393**	.046
		Sig. (2-tailed)	.000	.	.000	.012	.083	.000	.648
		N	100	100	100	100	100	100	100
	adequacy_of_instructions	Correlation Coefficient	.600**	.397**	1.000	.396**	.359**	.492**	.122
		Sig. (2-tailed)	.000	.000	.	.000	.000	.000	.225
		N	100	100	100	100	100	100	100
	visual_attractiveness	Correlation Coefficient	.458**	.251*	.396**	1.000	.547**	.475**	.325**
		Sig. (2-tailed)	.000	.012	.000	.	.000	.000	.001
		N	100	100	100	100	100	100	100
	operational_ease	Correlation Coefficient	.354**	.174	.359**	.547**	1.000	.470**	.327**
		Sig. (2-tailed)	.000	.083	.000	.000	.	.000	.001
		N	100	100	100	100	100	100	100
	explicit_terminology	Correlation Coefficient	.565**	.393**	.492**	.475**	.470**	1.000	.266**
		Sig. (2-tailed)	.000	.000	.000	.000	.000	.	.007
		N	100	100	100	100	100	100	100
	map_clarity	Correlation Coefficient	.373**	.046	.122	.325**	.327**	.266**	1.000
		Sig. (2-tailed)	.000	.648	.225	.001	.001	.007	.
		N	100	100	100	100	100	100	100

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Further analysis was done in clusters, in terms of geographical coverage of the route planners. The following results were reached (Figs. 4 and 5):

- Urban and interurban-urban planners seem to perform better in terms of comprehensibility, adequacy of instructions, and explicit terminology.
- Interurban-global have better visual attractiveness and operational ease.
- Most planners in all geographical coverage groups except of interurban-global provide address-entry option, information on trip duration and alternative routes.

- Less than half of all planners, regardless their geographical coverage, provide traffic and weather updates, with interurban-urban in the lowest ranking.

4 Conclusions

One hundred route planners were analysed against 89 attributes. High correlation was indicated between some of the most important attributes selected by the users, which indicates a consistency in the quality of the route planners. No significant differences were observed in these attributes performance as compared to the geographical coverage of the planners. However, interurban-urban planners seem to provide less information than the other groups, which may be attributed to the variety of sources from where these planners obtain their data.

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Investigating Multiple Areas of Mobility Using Mobile Phone Data (SmartCare) in Chile

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Abstract. Monitoring large scale mobility patterns is reliant on profiling the day-to-day movements of a significant number of city/country inhabitants. Mobile phone data (interactions with Telecommunication antennas) can be used to perform such profiling. In this paper, we present a program, Analysing Traces to Observe Mobility on SmartCare (ATOMS), to find and characterise user journeys. For Chile, we are able to profile more than 1 million users with approximately 3 million journeys/sub-journeys per day. For each journey/sub-journey, we find the start and end time, distance travelled, an estimate of the speed and further characteristics. Using the journeys stored in our database, Database of ATOMS (DATOMS), we are able to automatically identify commuters thanks to a second program, Neural Analysis of DATOMS for Itinerary Recognition (NADIR), by using a set of features from the journeys found by ATOMS in a Neural Network machine-learning approach. The potential for such a data-set is far reaching. We close by highlighting the potential (future) applications in mobility such as determining the mode of transport and inner-/intra-city Origin-Destination matrices.

Keywords: Mobility · Mobile phone data

1 Introduction

Mobile phone technology is extremely pervasive in our society [7]. In the context of urban mobility, mobile phone telecommunication data therefore stand alone in terms of quantity. Geo-location or mobility tracking of groups of users is available using Global Positioning System (GPS) data, however, within mobile phone applications this is an opt-in source of data. Additionally, GPS data from such sources usually has poor time resolution. These issues can severely limit the application of GPS data in large-scale population analyses.

Census data are also used to probe mobility within cities. However, this method is limited to the information requested within the census. These studies also have poor time precision since journey start and end times are usually recorded at a resolution of 15 min or more. A further disadvantage is the inability

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to record unexpected journeys (referred to in this work as sporadic journeys) such as visits to hospitals or social events.

Other types of data are accessible to telecommunication companies, namely Charging Data Records [1] and SmartCare [5] data (described in Sect. 2). This type of data is larger in size compared to GPS in terms of the number of users and number of events throughout the day with the disadvantage of having lower spatial accuracy: limited by the network of antennas.

Many previous works focused on uncovering patterns of urban mobility have used aggregated CDR data [4,11]. These studies typically aggregate data for a month or more due to the low spatial and temporal resolution. However, due to the large number of events (approximately 90 times more than CDR) this is not necessary in the analysis of SmartCare data. Therefore, using this data we can, for example, search for higher order features within specific locations that may occur within a single day with confidence.

Concerning the profiling of users some efforts have been made to classify user activity using machine learning algorithms or using some ad-hoc constraints [2,3]. Some of these works rely on a set of rules which give little room to modify the classification, which, when applied to different countries and/or cultures can lead to significant problems. Moreover, although users follow general patterns there are aspects of their movement which cannot be modelled, i.e. sporadic journeys. A significant portion of users on a given day do not follow modelled behaviour and have proved difficult to categorise in previous works. Concerning the machine learning approaches to profile users, previous work focused on recognising profiles based on their mobile activity, but not on their spatial movement. For example, they recognise users by their activity during general commuting hours.

In this paper, we present two new programs: ATOMS (Analysing Traces to Observe Mobility on SmartCare) and NADIR (Neural Analysis of DATOMS for Itinerary Recognition) to perform high time resolution analysis of population movement within Chile (inner- and intra-city journeys) and create user profiles. The data are stored in a database DATOMS (Database of ATOMS), that contains only the necessary information to describe user journeys and profiles making it light and fast to perform any further aggregated analysis.

2 Data Sample

SmartCare data: We analysed the anonymous Deep Packet Inspection data (hereafter DPI) provided by Huawei SmartCare SEQ Analyst [6] and collected by Movistar - Telefónica Chile (≈33% of the market share [9]; 7M subscribers and 41 602 network antennas [8]). This data-set contains events collected with 2G (8 843 cells), 3G (26 644 cells) and 4G (6 115 cells) technology. SmartCare is a network event measurement tool which collects various signalling/protocol data from the core network. Particularly, each internet traffic session is measured with its precise corresponding initial/final timestamps, byte consumption and cell ID of origin, as well as further properties. This data-set was originally intended to help quantify the quality of service measurement and operations efficiency.

Antenna dictionary: The antenna dictionary is used to convert mobile data events to a usable input in mobility studies (by matching antenna IDs with locations). This dictionary includes the location of the antenna, its azimuth and any nearby properties associated to the antenna, for example, whether it is within a metro station or a shopping mall.

3 Finding and Storing the Journeys

ATOMS has been developed to find all the journeys undertaken by users of the mobile network through the analysis of SmartCare data. The journeys that are found are stored in our database DATOMS with their associated properties.

The ATOMS code ingests data for one entire day and then performs the following analysis per user:

1. Match antenna IDs to retrieve locations of all events.
2. Clean data using a series of different functions (resampling, removing recurrent transitions, smoothing).
3. Find approximate journey windows using minimum speed, distance and time criterion.
4. Refine journey window and calculate parameters (speed, distance, duration) of all sub-journey windows by grouping contiguous speeds together meeting the minimum speed criterion.
5. Retrieve further properties of events within this window (additional features from antenna locations, data quality parameters, approximate path of user).

In this paper, we will not discuss in detail the approach we have implemented in the analysis of SmartCare data, i.e., the details of item 2 above, rather, we discuss the broad flow of the data analysis and the resultant outputted products and their potential applications.

In Fig. 1 we show spatial and temporal information associated with a single journey for one user. The main problem to overcome in the analysis of such data is to transform the locations of the antenna events into more meaningful locations of the user in order to calculate physical speeds. We highlight this by showing the original data (in red) in and the cleaned data (in blue). Before cleaning the speeds based on the original data are nonphysical in most cases as they are the instantaneous speeds calculated from antenna transitions as shown in the left panel. Additionally, we see in the middle panel that the cumulative distance using the original data is six times larger than the cleaned data. This is a result of events being registered between nearby antennas repeatedly causing the user's cumulative distance to increase when the user can be spatially static. In the right panel we see the path of the user, for the original data (in grey) and the cleaned data (coloured markers, time-ordered from blue to red). We try to remove events that are associated to antennas that have been contacted far from the user's true location (due to antenna availability, coverage, or wrongly assigned cell IDs). Figure 1 shows how the smoothed path closely follows the locations of the original events, however, due to our data processing we are able to recover physical speeds.

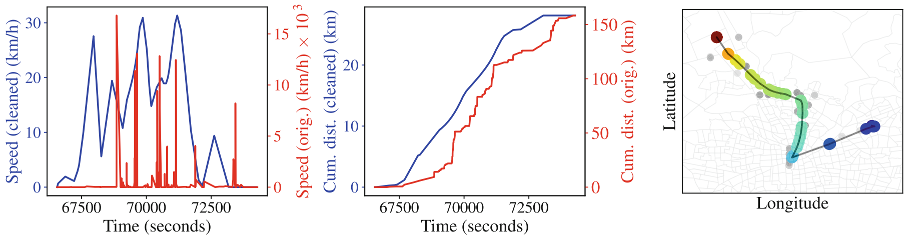

Fig. 1. *Left panel*: Speed as a function of time for original data (in red) and cleaned data (in blue). *Middle panel*: Cumulative distance as a function of time, colours as in left panel. *Right panel*: Path of user from cleaned data as a function of time (shown by coloured markers from blue to red). Grey markers show the positions of the original antenna events. The city microzones of Santiago are shown as grey polygons.

Once each journey and sub-journey window has been identified within one day of data, further parameters are calculated from the events recorded in this time window: data quality parameters, associated city, fraction of Metro antennas contacted, any additional features contacted (such as malls or highways).

These properties allow us to easily query journeys that reach certain quality parameters. Additionally, for example, we can easily query all journeys associated with a certain city. A few typical analyses are discussed in Sect. 5.

4 Classifying Users with NADIR

Once the journeys and associated characteristics are retrieved from the SmartCare data, we can analyse the journey profile for the entire day. We wrote a program called Neural Analysis of DATOMS for Itinerary Recognition (NADIR), that performs this task. NADIR queries all trips made by each of the users for an entire day. For each user, it builds the daily shape, i.e., the initial and final locations and times of each journey during the day (see Fig. 2). A sample of these shapes are manually assigned labels by the user as a first step in a supervised machine-learning scheme.

In our study, we consider the following labels:

1. *commuter*: Travelling to work and returning home the same day.
2. *commuter + special event*: Commuter profile but with an additional feature.
3. *small round trip*: Short round trip (shorter that typical working hours)
4. *passing through*: User moving from one place (city, region) to another.

This sample serves as our training set. For each of the shapes, we compute a set of features that describe them and will eventually be used to label them. Some standard features such as the Euclidean or Dynamic time warping distances between the shape and a selection of shapes from the training sample are already implemented and used in our analysis, but thanks to the modular nature of NADIR, it is straightforward to add other features.

Once the features are computed for both our training and test sets, we train a set of neural networks with different configurations (number of layers, number of neurons) and for each possible combination of features. Only the configuration for which the neural network performs best (based on an average $f1$-score) is kept and used to label the test set. Finally, the unlabelled sample is classified with the previously trained neural network. The outcome of the classification is stored in our database (DATOMS) along with the properties found for the profile. For example, for profiles defined as commuter, the working hours are estimated, the approximate location of the office is kept and so on. As an example, Fig. 2 shows the case of a daily shape that has been classified as a commuter by NADIR. We clearly see that the user stayed at his/her initial location from 12 am to ≈6 am, then travelled to a second location where he/she stayed until ≈18 pm, eventually returning to his/her point of origin. Note that this technique is not limited to processed SmartCare data only, but can be used with any data source from which daily shapes can be constructed, such as, for example, GPS data. At this time we do not have a ground-truth data-set to perform validation of our technique. However, given a data-set covering a week or more recurrent journeys, most likely home-work and work-home journeys, are easily identified. Finally, we note that users with largely different mobility patterns from typical ones (the inputted labelled profiles) will be classified with a lower confidence rate by NADIR. This confidence rate in turn indicates that those users are peculiar and need to be treated differently.

5 Applications

Below we briefly outline a few of the applications of journey parameters and user profiles stored in our database DATOMS. It is important to note that all

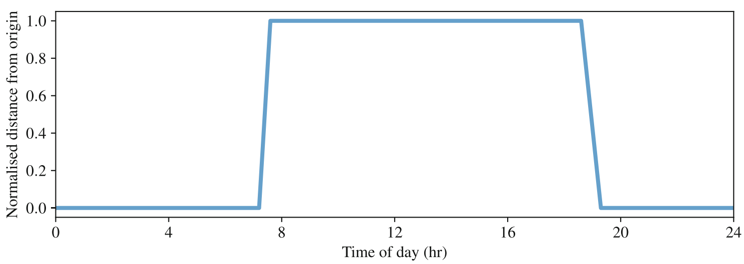

Fig. 2. Example of a daily shape for one user classified as a commuter by NADIR.

the analysis presented in this paper is performed on anonymised data to protect all of the users' identities. Any outputted properties that are shared outside of Telefónica based on this data are aggregated and 'blurred' (spatially and temporally) for further user protection.

5.1 Disentangling Modes of Transport Within a City

One application of the properties of journeys stored within DATOMS is the ability to disentangle modes of transport using a combination of speeds and antenna properties. In Fig. 3 we show an example of this within the city of Santiago. The figure shows two heatmaps, representing the density of users, one for journeys conducted via Metro, the other for the remaining modes of transport between 08:10–08:20. The resultant spatial distribution of people is quite distinct. Of course, journeys conducted via metro are more spatially localised due to the network of metro stations. However, we also see similarities between the two heatmaps showing that at this time the majority of people within the city are located in travelling to the same areas, regardless of their mode of transport. Additionally, the ratio of metro to non-metro journeys (≈1:4) is in accordance with the published statistics in [10].

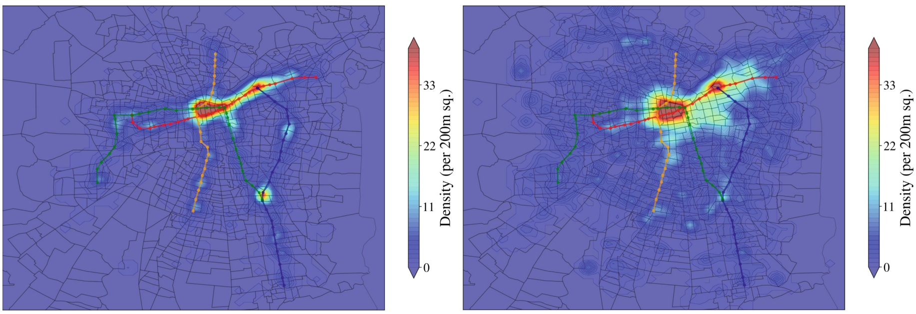

Fig. 3. Heatmaps representing the density of users for metro (left) and non-metro (right) journeys conducted between 08:10– 08:20 for a single day. The network of Metro stations are shown in their respective line colours.

5.2 Identifying Inter-city Travel

Another application is the ability to observe the patterns of plane journeys conducted by users. In Fig. 4 we show an Origin-Destination matrix for journeys between every pair of airports in Chile for a single day. The darker the shade of blue, the higher the number of journeys conducted on this day. Santiago (SCL), the capital of Chile, is easily identified by the cross shape through the centre of the figure as this is where the majority of flights go in and out of in a normal day. We also find significant journeys between PMC and PUQ airports in the south of Chile and have confirmed there is a direct flight between the two airports.

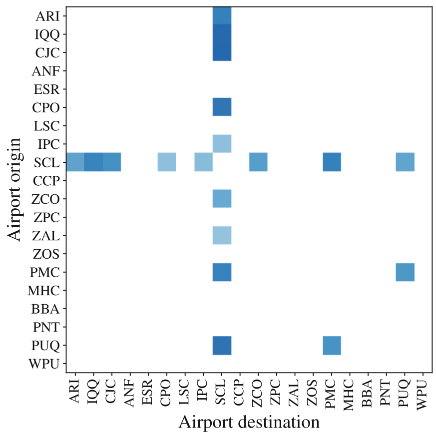

Fig. 4. Origin-Destination matrix of journeys conducted by plane for a single day. The labels are the international codes of each airport. The shade of colour is a measure of the number of journeys, the darker the shade the higher the number of journeys.

5.3 Recurrent Versus Sporadic Journeys

NADIR allows us to distinguish between the different profiles of users. Therefore, we can split the data between recurrent and sporadic journeys. Using only recurrent journeys, we can increase the accuracy of the parameters found (home and work location, working hours, commuting speed) by using aggregated data over a month or more. In turn, this allows us to better constrain the mode of transport associated with each user's commuting journey. Additionally, we can better estimate the mean travel time over a month to capture any long-term change in journey speed. This tool can hence be used to identify weak areas of city infrastructure and monitor the effects of any changes that are implemented over a long period of time. Sporadic journeys can help us to understand how people interact with the city and its services and amenities such as shopping centres, hospitals and so on.

6 Conclusions

In this paper, we have outlined the use of mobile phone data in the study of mobility within Chile. We have presented two programs, ATOMS and NADIR and our database of journey parameters and user profiles, DATOMS. Additionally, we noted a few example applications of the data stored within DATOMS in the context of urban mobility. The obvious advantage of using mobile phone data over survey data is the time resolution. We have the ability to exactly identify user journey start and end times as well as monitor the city as a whole, day to day over a large period of time. Surveys usually only offer a 'snapshot' of a city and are also very costly, therefore, mobile phone data may offer a more efficient alternative in the future. We are also able to better follow the path of the user (compared to CDR-type data that is commonly used in other studies) which can provide crucial help when trying to disentangle modes of transport. A future application of our journeys will be combining the users' paths with route finding algorithms making use of the calculated speed to determine the likely mode of transport. The main disadvantage of NADIR is the reliance on user-defined labels, this could be improved by using a clustering algorithm to define profile types. Additionally, ATOMS uses Smartcare events, which inherently biases our analysis towards more active users. As noted in the previous section, protecting the users' identity is paramount and therefore all data are anonymised (hashed and salted) before any processing takes place and aggregated further once the processing is done to inhibit any potential reverse engineering.

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The Contribution of Open Big Data Sources and Analytics Tools to Sustainable Urban Mobility

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Abstract. Sustainable urban mobility is one of the top priorities in European Union and worldwide, as there is an intense tendency of population density increase in urban areas, which results in traffic, economic, environmental and societal impacts. To allocate smart solutions and address successfully urban mobility, communities need to build awareness and knowledge on the demand for people's mobility and goods transportation, as well as to develop appropriate tools to manage and assess transportation system performance. The above, raise the necessity of data availability. In the era of rapid technological development and endless production of data, electronic devices, including smartphones, personal computers, autonomous vehicles, GPS (Global Positioning System), SDR (Software-defined radio) devices and Bluetooth, have become sources of big data. Urban mobility is a sector that could benefit from using big data by understanding, analyzing and processing data to manage traffic, predict demand, affect travelers' choices and assess level of service.

The purpose of this paper is to identify and review available open big data sources, big data tools and transport related applications in European and international transport platforms. Collected information is used to formulate a roadmap of available and open big data sources, open big data processing tools and applications which aim at improving urban mobility.

Keywords: Open big data sources · Sustainable urban mobility
Data processing · Prediction · Analytics tools

1 Introduction

The term "Big Data" has raised controversial approaches when attempted to explain its definition. As de Mauro et al. propose [1], "Big Data is the information asset characterized by such a high volume, velocity and variety to require specific technology and analytical methods for its transformation into value." Particularly, the terms 'volume', 'velocity' and 'variety' describe the characteristics of information. Volume is the amount of data which could be ranged from megabytes of data to petabytes. Velocity refers to the collection of data in real-time, near real-time, periodic and batch. Social media, mobile phones, video are examples of sources which provide the variety of data. The number of internet connected devices is expected to be almost doubled from 22.9

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billion in 2016 to 50 billion by 2020 [2]. By that time every human on the planet will generate 1.7 megabytes of new information per second. All these data will result in 40 zettabytes (40 trillion gigabytes) of digital information which can be processed with different tools.

'Technology' and 'Analytic methods' are the fundamental requirements needed to make genuine use of such information. Different tools are made by companies and researchers in order to understand, analyze and extract the values of Big Data, which can be useful for economic and societal good. There is a variety of different software which are used as analytic tools. Most companies and organizations, combine, more than one analytic tools to complete a big data task, including statistical functions, mining tools and predictive modeling.

Transport is a sector that utilizes a large number of diverse data sources. In terms of urban mobility, there are emerging transport technologies, new transport services using new business models, and new institutional and financing structures. Greater data availability provides new opportunities for transportation planning and policy making as well as challenges for involved stakeholders [3]. There are two types of data sources, open and private big data sources. The main idea behind open data source is that, many people are able to contribute in the elaboration of large datasets in order to extract desirable results.

This paper aims first to review literature, to identify studies in sustainable mobility that have used big data sets and group them based on the source of the big data they have used and the transport topic that they cover. In the second part the paper identifies open big data sets and uses a typology to characterize each data set, including the transport topic. In this way, it creates a connection between sustainable mobility studies, transport topics and open big data sources.

2 Literature Review

2.1 Methodology

A literature review is conducted to review the existing knowledge on big data analytics and tools, in terms of contribution to sustainable urban mobility. The objective of the review strategy was to identify the relevant studies that address this topic and focus on open source tools. The review was directed with the following main research question in mind: How and to what extent could the available open big data sources and tools be of asset to sustainable urban mobility?

Standard research strategies were used involving proper academic and scholarly sources, including electronic (cross-disciplinary) databases and tools, university libraries, Science Direct, Google Scholar as well as public and private sector's web-sites. Moreover, numerous international journals and conference proceedings were reviewed. Four criteria were used for assessing the quality of literature sources [4]: authenticity, credibility, representation, and meaning. The search keywords included 'big data AND transport', 'open big data sources AND sustainable urban mobility', 'transportation tools AND big data analytics', 'open source big data AND tools'. Due to shortcomings associated with keyword searching approach, the backward literature search (backward authors, backward references and previously used keywords) and forward literature search (forward authors and forward references) methods were used to enhance the review. Over 1000 case studies were examined from 2016 to 2018. This extended and thorough research led to 20 scientific papers that were most relevant and useful for this review (Tables 1 and 2). These publications address topics related to mobility-as-a-Service (MaaS), logistics, traffic operation and management, transportation planning and prediction, assessment and decision making.

2.2 Analysis and Classification

The identified studies were classified based on used datasets and their applications as shown in Tables 1 and 2. More specifically, based on this classification, it can be seen that the applications refer to the objective of each study. For example, mobility pattern datasets, created from GPS devices and vehicles, aim to inspire smart policies for green automobiles. Thus, big data have the opportunity to stimulate and form policies for future mobility and smart cities, with the contribution of public and private investments [5]. Furthermore, the manager of each dataset (i.e. public or private sector or both) and the means of collecting data (i.e. detectors, mobile phones, smart card data, social media, etc.) were identified. The 20 case studies that have been used were published within the last 3 years (2016–2018); as this domain is constantly evolving the latest academic and research paradigms are used. All case studies addressed the issues of smart transport in general and most of them focus in particular in smart cities giving more emphasis also on issues such as pollution, congestion and energy savings.

The most common means of collecting data in transport are sensors, such as road sensors, vehicle sensors and park sensors. Additional sources include cameras, GPS, mobile phones, surveys, image collectors and smart cards. These sources are fairly often used in public and private transport sector for different applications. There are miscellaneous kinds of datasets, all of which serve their reason of each case study, ranging from traffic data and surveys to randomly generated data.

In order to analyze and process these datasets, to understand and export solutions, advanced tools have been developed. The necessity of processing big data has led not only to the development of suitable software but also to the implementation of a great number of challenges involving them.

The most common tool used for processing big data datasets in the reviewed studies was Hadoop (1, 2, 3, 5, 14, 15). Moreover, other frequently used tools include Spark (2, 5, 15), Matlab (8) and programming model MapReduce (1, 14, 15).

3 Available Big Datasets in Transport

3.1 Open Source Big Data

Open source datasets are available online in almost every country in the world. They are categorized according to field of their collection and the region which have been obtained. More specifically, datasets sources can be governmental, global data, academic, science and health, marketing and social media, journalism and media,

Table 1. Big data sets and application per study.

	Reference	Datasets	Application
1	[6]	Traffic data, parking lot data and pollution data	Smart decision supervision and control
2	[7]	Daily water usage, smart parking, pollution, city traffic, weather	Smart system to make municipalities smarter and digital
3	[8]	Water consumption, city traffic, parking lot	Smart city architecture
4	[9]	Smart cities generated datasets	Real-time smart city security system (communication security protocol)
5	[10]	London Tweets	Use of social media for the detection of spatio-temporal events related to logistics and planning
6	[5]	Driving and Mobility pattern	Promotion of green vehicles
7	[11]	Capacity Sharing, Smart City Transport, Logistics	Illustrates how sharing transport load in a smart city can improve efficiencies in meeting demand for city services
8	[12]	Warehouses, Shopfloors	Uses of RFID for advanced decision-makings
9	[13]	Logistics (Mileage, procuring items, Carrying load, Holding inventory, Distance)	Sustainable procurement and transportation decision
10	[14]	GPS coordinates, traces	Recommend the shortest and feasible path for passengers to reach their destination
11	[15]	Geographic location (GPS)	Commuting patterns in Beijing in 2015
12	[16]	Speed, engine monitoring, mileage, number of stops, miles per gallon, safety aspects, etc.	Better organization in supply chain management and further solving the remaining issues of supply chain
13	[17]	Railroad and rail traffic	Predicting the behavior of the assets in operation and maintenance
14	[18]	Data traffic parameters	Carry out rapid big data retrieval and analytics to serve as part of business intelligence
15	[19]	Ship traffic	Port safety management
16	[20]	Real-Time Traffic	Real-time congestion and operation warning strategy for improvement
17	[21]	Vehicle Traffic	Solve problems of traffic data distribution storage and processing

(*continued*)

Table 1. (*continued*)

	Reference	Datasets	Application
18	[22]	Call detail records, census data, road networks, surveys	Travel demand estimation
19	[23]	Traffic flow	Adjust the waiting time for the traffic lights
20	[24]	Trajectory data	Dynamic modeling for ITS

miscellaneous. For example, governmental sources are European's Union Open Data for Europe, U.S. Census Bureau from U.S.A. and globally collected Facebook API.

Some open source services that currently exist, as well as companies and tools that cooperate with this idea are framework (Hadoop MapReduce, Spark), coordination (Apache Zookeeper), visualization (Rodeo), collaboration (Anaconda) and security (Sentry, Apache Ranger).

Table 2. Typology of datasets referring to transport sector.

Dataset	File type	Transport topic	Data source	Data type	Ownership
Cargo 2000	Csv	Logistics	Machine	Track	Private
Human Mobility during Natural Disasters	Csv	Mobility as a service	Social Media	Location	Private
1.6 million UK traffic accidents	Csv	Traffic planning and prediction	Human	Measurement	Public
US Traffic Fatality Records	Bigquery	Traffic planning and prediction	Human	Measurement	Public
UK Traffic Counts	Csv	Traffic operation and management	Human/Organization	Sensor	Public
US Traffic, 2015	Csv	Traffic operation and management	Machine/Organization	Sensor	Public & Private
US open policing projects	Csv	Transportation planning and prediction	Human	Measurement	Public
NYC Transport Statistics	Csv	Traffic operation and management	Machine	GPS	Public
NYC Taxi with OSRM	Csv	Traffic operation and management	Human	Sensor	Private
Uber Pickups in NYC	Csv	Traffic operation and management	Machine	Location/measurement	Private
Traffic Violations in USA	Csv	Traffic operation and management	Human	Measurement	Public
2016 NYC Real Time Traffic Speed Data Feed	Csv	Traffic operation and management	Machine	Sensor	Public
NYC Taxi trip durations	Csv	Traffic operation and management	Machine	Measurement/location	Private
NYC Bike trip duration 2016	Csv	Traffic operation and management	Machine	Measurement/location	Public
Historical Air Quality	Bigquery	Transportation planning and prediction	Machine	Measurement/location	Public

3.2 Transport Data Typology

As mentioned in Sect. 2, identified publications were found to address topics related to MaaS, logistics, traffic operation and management, transportation planning and prediction, assessment and decision making.

In order to explore what open big dataset are available and their connection to these transport topics a thorough search has been deployed containing over 100 open datasets. The 15 datasets that have been selected, are summarized in Table 2. These have been obtained mainly through the Kaggle website and have been grouped into 5 groups: file type, transport topic, data source, data type and ownership.

File type refers to the format of available dataset; the most ordinary file type is Comma-separated values (csv). The transport topic refers to the transport topics that identified publications were grouped in. Data source refers to the way the data is generated; this can be either machine-based (social media), human-based or organization based. Data type refers to the data that are provided by the sources. These are location, track, measurement, GPS coordinates or sensor which combines all of them. Finally, ownership refers to the owner of legal rights of datasets (private and public).

4 Discussion and Conclusions

This paper, attempted to create a roadmap and reveal trends regarding open source big data and related applications in sustainable urban mobility. The most state-of-the-art tools that make big data processing feasible are Apache Hadoop and Spark. Also, the main transport field that most case studies papers refer to is traffic operation and management, as accident data, environmental data, traffic data etc. and the least used one is logistics and assessment and decision making.

As far as implications are concerned, stakeholders are cautious about involving in transport and the possible threats that may occur. This is, privacy issues especially in logistics and assessment and decision making because the management and operation of the companies are private, and it is difficult without permission to find available large datasets. Without a doubt, an open source dataset is less likely to contain quality data compared to those who are constructed and operated by private sector companies. The main idea behind open source datasets is that anyone can share and manage them, so researchers have to take this fact into consideration when working with such datasets.

What becomes clear from this review is that despite the big number of research papers in big data and transportation, this field has many aspects that academics, researchers, transport engineers and industry could focus, in order to achieve a richer legacy for transport and urban mobility. Some of them, which could be part of future research, are process and classification of unstructured data or deployment of tools for artificial intelligence to take place into real time decision making.

Finally, a lot of opportunities can be distinguished as sustainable urban mobility aims to promote green cities and people look adaptive to this shift. Also, big data can help in reduction of costs in the transport field and it can promote employment in online retailers, storage companies, networking companies, software companies, health industries and service companies.

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Beyond Travel Time Savings: Conceptualizing and Modelling the Individual Value Proposition of Mobility

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Abstract. Sustainable urban mobility planning (SUMP) plays a significant role as an integrated strategic management tool in enabling, among others, a participatory approach in urban transport development. A relevant aspect of the transition towards sustainable and smart mobility planning concerns the reconsideration of concepts such as Value of Travel Time (VTT). Rather than "cost of time spent in transport", new perspectives on VTT aim at conceptualizing and measuring VTT based on individual needs, expectations and perceptions. Among others, attention is paid to individual experience in using transport infrastructure, services and systems while on the move. The ongoing shift towards a broader view of VTT gives importance to subjective "well-being" (SWB) and describes, in quantitative and qualitative terms, the individual value proposition of mobility (VPM). The opportunity to collect mobility and behavioral data via smartphones, to be processed with advanced analytical and modelling techniques, represents a pillar of such shift, since it allows identifying patterns embedded in individual daily activities and mobility choices. These patterns can be visualized to increase self-awareness and better understand one's own value proposition of mobility.

Keywords: Sustainable urban mobility planning · Value of Travel Time (VTT) Value Proposition of Mobility (VPM) · Quantified Self (QS) Individual preferences · Mobility and behavior data collection

1 Introduction

In a seminal paper from 2008, David Banister presented the sustainable mobility paradigm as an alternative approach to transport and mobility to meet the needs of contemporary societies facing both local and global challenges [1]. In Banister's view, two fundamental pillars of the conventional transport planning approach should be reconsidered: the first pillar to question is the consideration of travel as "a derived demand and not an activity that people wish to undertake for its own sake". The second pillar to reconsider is the assumption that "people minimise their generalised costs of travel, mainly operationalised through a combination of the costs of travel and the time

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taken for travel". There is an increasing body of research supporting the view that there can be value, not necessarily just of hedonic nature, associated to the travel experience [2–6] and that additional factors than cost and time when play a role in travel and mobility decisions [7–9]. This paper builds on Banister's approach to sustainable mobility (Table 1) and it focuses on value of travel time (VTT). In this respect, our aim is to introduce the concept of Value Proposition of Mobility (VPM), the subjective, dynamic and contextual valuation of available (or preferred) mobility options. Adopting a VPM perspective is timely and relevant not only because this is compatible Banister's view of sustainable mobility but especially to support the ongoing shift from an economic-centered VTT valuation to a broader and more complex process that puts the individual at the center of the stage.

Table 1. Banister contrasting approaches to transport planning – selected dimensions [1].

The conventional approach—transport planning and engineering	An alternative approach—sustainable mobility
Physical dimensions	Social dimensions
Mobility	Accessibility
Traffic focus, particularly on the car	People focus, either in (or on) a vehicle or on foot
Large in scale	Local in scale
Motorised transport	All modes of transport often in a hierarchy with pedestrian and cyclist at the top and car users at the bottom
Modelling approaches	Scenario development and modelling
Economic evaluation	Multicriteria analysis to take account of environmental and social concerns
Travel as a derived demand	Travel as a valued activity as well as a derived demand
Demand based	Management based
Speeding up traffic	Slowing movement down
Travel time minimisation	Reasonable travel times and travel time reliability

The "behavioral shift" of research on VTT is supported by two important parallel trends affecting its conceptual and methodological underpinnings: the first one, of conceptual nature, concerns the ongoing efforts in economics research to move from merely economic indicators to "utility functions" incorporating the notions of happiness and subjective well-being (SWB) [10, 11]. As underlined by Duarte et al. [10], "*existing behavioural travel choice models should be enhanced with regards to their behavioural validity incorporating the impacts of travelling happiness/satisfaction*". The second trend, of methodological nature, is about the possibility to "quantify the self" [12] by voluntarily collecting, processing and interpreting personal data (e.g. manually or with the support of advanced AI techniques). The data collection, also known as personal life-logging [13] or self-tracking [14], is carried out via smartphones or wearables (e.g. smart watches). The notion of quantified self (QS) was unofficially introduced in a 2007 by Wired editors Gary Wolf and Kevin Kelly [15], who later promoted the QS movement to use self-tracking technologies for better understanding oneself through indicators, trends and statistics. It is assumed that a person can use this knowledge to optimize decisions and improve aspects of his/her daily life. Another underlying assumption is that human behavior is, to a certain extent, rather predictable [16]. It follows that personalized recommendations are optimized for routines and ordinary behaviors, although there are efforts to support serendipity [17].

The assessment of SWB via a QS approach is an area of increasing academic interest, with relevant applications [18, 19]. In the context of travel behavior, the concept of quantified traveler [12] was introduced to promote sustainable travel behavior and smart tourism [20]. This approach does not only make use of contextual information related to a specific travel (e.g. routes, mobility choices, mood and feelings), but it also crosses this information with personal historical data generated in other life situations. The QS approach is part of a broader interdisciplinary research and application area that has emerged in last fifteen years and it is known as computational social science [21, 22]. Together, the possibility to assess individual behavior based on a computational social science approach and the adoption of hedonistic approaches to value estimation have the potential to advance the field of VTT research and applications [23]. In the long-term, it is expected that knowledge in this area will generate significant opportunities for public and private actors, as well as the civil society, involved in the transition towards sustainable mobility. As an example, if the full door-to-door traveler's experience was considered, decisions on transport infrastructure planning may pay more attention to travel quality rather than speed [6]. In other words, it might be a more efficient, also from a cost viewpoint, to invest in enhancing the overall travel experience – in and between transport modes - rather than attempting to increase time gains on single points and links of the transport infrastructure.

In the following sections, the relevant trends reviewed in this introduction in the context of VTT will be used to introduce the notion of VPM. Next, we will describe how VPM will be developed and applied in the recently granted H2020 project "Mobility and Time Value" (MoTiV), which aims at advancing VTT research and related sustainable mobility applications. Since the theoretical concepts introduced in this paper will be tested in the MoTiV project, at this stage there are no results yet allowing an initial assessment of the notion of VPM. Nevertheless, we believe it is relevant to introduce this concept to stimulate debate and potentially considering useful feedback from the research community into the MoTiV project.

2 Conceptualizing the Value Proposition of Mobility

The "behavioral shift" of studies on VTT calls for an integration of models and frameworks of individual needs, motivations and preferences adapted to the mobility context. In this respect, which personal values and expectations should be generally fulfilled and addressed by mobility solutions? The conception, development and deployment of mobility infrastructure, services and solutions adapting to individual needs and expectations defines and shapes a VPM. This represents a promise of value to be delivered, communicated, and acknowledged to the individual traveler. Time and costs savings will continue to play a key role in individual travel and mobility decisions. However, other relevant factors affecting travel experience such as comfort [24] should be acknowledged and included into an enlarged conceptual framework for VTT estimation. Each transport mode, or a travel option based on a combination of transport modes, provides a different value proposition to the traveler in a specific mobility situation. Time and cost savings represent only one of these factors, not necessarily the one contributing the most to VTT. Depending on the situation, other factors such as increased safety or well-being may influence traveler's choice more than time and cost, hence considered more valuable.

As individual valuation of available (or preferred) mobility options, the VPM can be regarded as the value embedded in individual mobility choices. As such, the VPM is focused on the individual traveler and his/her perceived travel experience. Knowledge on barriers and factors playing a role in the traveler's choice is therefore key to align expectations and actual experience. Previous research on behavioral factors influencing mode choice underlined the importance of habits [25–27]: hence, information on traveler's routines is very useful to quantify the subjective view of the VPM, based on the appreciation of its different dimensions. The adoption of the VPM to assess VTT implies the consideration of a range of aspects of mobility behavior, which are tightly connected to motivational factors. The VPM cannot be reduced only to the value proposition of a single product, technology, and brand (e.g. the Tesla Model S car), but it must be referred to a set of products, services and technologies used within activities and mobility situations. This is particularly relevant with current trends of digitalization and diversification of transport: integrated mobility solutions such as Internet-based travel planners, peer-to-peer real-time mobility services (e.g. ride-sharing, Uber), and, Mobility as a Service (MaaS), are shaping and redefining the value of technologies, products, and services. A common aspect of these efforts is the aim to enable a smooth door-to-door, multimodal experience for the traveler. However, being a complex ecosystem, there is no single actor in charge of shaping travelers' VPM. It is rather a joint outcome of actors, including end users, co-creating meaning and value to transport and mobility options through policy, implementation, deployment, and participation.

As a starting point to understand the expected determinants of individual happiness and subjective well-being linked to transport and mobility choices, we refer to a classic model proposed by Sheth [26] to analyze motivational factors influencing travel choices. In line with Sheth's approach, multiple decision factors contributing to shape the individual value proposition of mobility should be considered (Table 2). Other studies presented similar models: for example, Johansson et al. [28] proposed a model including safety, comfort, convenience, flexibility and environmental preferences (which in Table 2 are considered as part of the "well-being" dimension). This and other related studies demonstrated the importance of considering not only socio-economic factors, but also socio-psychological variables in the study of transport and mobility preferences and decisions. Sheth's model allows accounting for travel as a valued activity in itself [2] and also for assessing the value of activities within mobilities, and the value of mobilities within activities. From this viewpoint, VTT is not only about the value of the activity at destination but it should also capture the value of activities carried out while on the move, as well as the value of travelling for the sake of it.

The notion of VPM allows developing a conceptual framework for estimating VTT from a broader perspective that goes beyond the conventional optimization of travel

Table 2. Dimensions of the value proposition of mobility.

Decision factor	Objective
Time	To be minimized to reach destination rapidly
Cost	To be minimized (as personal expenditure) to reach destination at the lowest cost, or to be maximized in case personal mobility plans are compatible with possibility of earning by transporting people or goods
Comfort	To be maximized in line with travel service expectations
Safety	To be maximized to reach destination safely
Curiosity	To be maximized in line with travel experience expectations
Prestige	To be maximized in line with social status aspirations
Pro social	To be maximized to maintain and/or extend personal social relationships (e.g. it may involve volunteering/charity activities)
Well-being	To be maximized in line with health and well-being aspirations and objectives. This includes also commitment to reduce environmental impact of transport (in terms of CO_2 emissions)

time and cost savings. It is a multi-dimensional construction that, in line with the theory of self-determination [29], includes both intrinsic and extrinsic motivations contributing to VTT. To our knowledge, there is currently no conceptual framework for VTT estimation that captures the individual value proposition of mobility by accounting all the soft factors described in Table 2 (e.g. cost, curiosity, comfort, safety). Each of the dimensions, especially those who are under-researched (e.g. prestige, curiosity), would deserve a more detailed and elaborated described, which is out of the scope of this paper but certainly of relevance for future research.

The acknowledgement of the soft factors illustrated in Table 2 goes beyond academic interest and has practical applications. As a matter of fact, the design of public and commercial transport services already embeds such knowledge: journey planners query results include information on trip itinerary, duration and cost as well as some additional details supporting the user travel decision (e.g. environmental impact, available services such as 1st or 2nd class, Wi-Fi availability). In the future, such services should be able to incorporate all soft factors that play a relevant role in the traveler's experience, making personal mobility more flexible and customizable. To achieve this objective, a prerequisite is the ability to deliver a personalized range of travel options matching personal expectations and contextual needs (e.g. daily commute to work, long-distance business trip, week-end leisure trip).

Recent technological advances allowing continuous self-tracking of mobility and activity behaviors (e.g., via smartphones or wearables), combined with the potential of real-time personal data analytics, are expected to open up a wide range of personal door-to-door multi-modal mobility solutions enhancing one's travel experience.

3 Modelling the Value Proposition of Mobility: The MoTiV Approach to VTT

Smartphones are ubiquitous and, as an extension of the self, they are endlessly recording our life. Until now, digital content (e.g. photos, videos, audio-recordings) has been used either as digital memories or as part of conversations with our social circles. Other digital logs (e.g. our information searches, movements and activities) are collected and used by virtual agents and assistants such as Siri or Cortana to anticipate and fulfil our personal needs [30], including travel and mobility. With the emergence of computational social science, researchers collected mobility and behavioral data to better understand human mobility patterns and behaviors [1], as well as our use of time, including travel time [31]. Based on the idea that the "smartphone knows ourselves better than we do" [32], the QS approach allows going beyond the traditional travel survey and to measure the travelers' evolving view of their VPM. Defining and validating such a methodology for VTT estimation based on the VPM is one of the key objectives of the recently granted research project on Mobility and Time Value (MoTiV), which is funded under the EC Horizon 2020 framework program [33]. The project started in November 2017 and will end in April 2020, for a total duration of 30 months. In the MoTiV project, value of travel time is conceived as the individual happiness/satisfaction for the time spent on transport. As such, VTT is conceptualized as a multi-dimensional entity consisting of several relevant indicators aligned with the VPM.

The MoTiV conceptual framework will be validated by carrying out a European wide data collection campaign, enabling identification and comparison of behavioral patterns across gender, generations, and socio-cultural contexts. Data will be collected via the MoTiV smartphone app developed within the project. The app will combine features of personal mobility/time tracker, travel/activity diary and journey planner supporting a qualitative and quantitative description of the traveler. It is expected that the campaign will involve at least 5,000 participants from at least 10 EU countries, who will actively use the app for at least two weeks. To collect sufficient and high-quality data, particular care will be devoted to address user engagement while addressing privacy concerns through usability, gamification and privacy-by-design.

Similarly, to the "quantified traveler", the MoTiV app aims at enhancing self-awareness and contributing to a better understanding of one's own VPM. These goals will be supported by visual representations of personal mobility and behavioral patterns, trends and statistics. An open mobility and behavioral dataset is planned to be released at the end of the MoTiV project. This dataset, representative of travel behaviors at a EU level, will stimulate further research on VTT and will also serve as a reference for analysis and assessment of the measures connected to SUMP and other EU key policy indicators on citizens' quality of life.

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Future Technologies in the EU Transport Sector and Beyond: An Outlook of 2020–2035

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Abstract. The aim of this paper is to deliver a brief synopsis of the transport research landscape by conducting a review of the transport projects across the four modes of transport on European level (FP7, H2020). This synoptic review identifies dominant technology themes (i.e. small electric urban vehicle design, battery materials and design, cleaner conventional engines, Automated Driver Assistance System, cleaner and quitter aviation engines, developments of Computer Engineering tools, morphing aircrafts, cleaner multifuel maritime engines, new freight wagon design, satellite positioning for rail Train Control & Management System). Future recommendations and conclusions are also provided.

Keywords: EU transport research · Future transport innovation EU transport projects

1 Introduction

According to the Paris Agreement, the reinforcement of innovative transport technologies and innovation should be a priority in the policy agendas. It is particular important to collect, analyse and disseminate information on technology development to support action on transport and climate change [1]. At a time of economic crisis, major demographic changes and increasing global competition, Europe's competitiveness, depends on its ability to drive innovation [2]. This is why innovation has been placed at the heart of the Europe 2020 strategy. It is also best means of successfully tackling major societal challenges, which are becoming more urgent by the day: Increased demand in transport, Dependency on oil, Congestion, Ageing, Travel optimisation using Information and communication technology (ICT) and satellite based technologies, Cutting edge technologies/focus on Research and Technology Development (RTD), Better infrastructure (completion of the TEN-T) and Security [3, 4]. The European transport companies are leading innovators with an increased RTD share

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over the last year on the automobiles sector [5]. Based on scientific breakthroughs in recent years, the explosion in the knowledge on transport systems is set to deliver a continuous stream of new applications [6]. The aim of this paper is to deliver a brief synopsis of the transport research landscape by conducting a review of the transport projects on European level (FP7, H2020) and presenting the technologies that are being researched. In addition, the paper presents some further innovative enabling technologies that are expected to become dominant in the near future. The overall aim is to produce future recommendations for research directions.

2 Methodology

The methodology followed in this research is based on a systematic review of 354 EU transport related research projects, funded under FP7 and H2020 programmes, with their main focus on technology development and innovation (Research and Innovation Action and Innovation Action types of projects). The initial step was to identify such transport projects from EU research databases like Cordis and TRIMIS using key word search terms and filters that the two databases offer. Specifically, the key terms that were used were road transport, air transport/aviation/aeronautics, rail transport, maritime/waterborne transport. In addition, for the Cordis database the “programme FP7- transport” filter was used while for H2020 projects “transport”, “energy”, “environment”, “infra”, “industrial leadership”, “security” filters were applied. In the TRIMIS database, projects were already available in modes i.e. air, road, urban, rail, water and multimodal transport and can be filtered by funding programme (FP7, H2020). After obtaining a list of projects that was built from the search results of the two databases, additional criteria were applied. Specifically, only projects from 2010 until currently were selected, assuming that further technology advancement would have been carried out on the topics that were researched earlier. The project reviews that were carried out, are based predominantly on the final reports, “results in brief” and periodic reports that are available on the two aforementioned databases depending on whether a project has been completed or is ongoing.

3 EU Transport Research Projects

The following section presents a segment of the technology themes that are being researched or have been researched by the various EU transport projects.

3.1 Road Transport

The shift towards cleaner Electric Vehicles (EVs) is evident in market shares of EVs which are constantly growing and could account for 25 to 40% of new vehicle registrations worldwide until 2030 [7]. The EC’s focus on electrification is evident by the amount of projects funded to work on this subject while a special interest in small urban lightweight vehicle designs has been identified (WIDE-MOB, ALIVE, AMBER-ULV, ELVA, EPSILON, SAFEEV, URBAN-EV, BEHICLE, STEVE, DEMOBASE, RESOLVE, ESPRIT). Electric trucks and vans with modular structural architecture were also the main themes for freight related projects (OPTIBODY, DELIVER, CONVENIENT, V-FEATHER). In the field of vehicle technologies, autonomous driving systems are currently one of the major trends emerging on a large scale. The progresses made over the past decades in the development of various kinds of driving assistance systems represent important milestones towards automated transport systems in the future [8]. Although autonomous driving would already be technically possible, non-technical issues such as lagging legal framework conditions inhibit currently a breakthrough of this technology [9]. The CITYMOBIL2 project is a good example were autonomous buses were pilot tested under real city conditions.

Development of new lightweight materials for vehicle structures such as Fibre Reinforced Polymers, or advanced metal materials (aluminium, magnesium, and high strength steel) is part of the research relevant to developing new more energy efficient lightweight vehicles while retaining crashworthiness (ALIVE, AMBER-ULV, E-LIGHT, PLUS-MOBY, EPSILON, BEHICLE, QUIET). Projects like H2ME, H2ME 2, HIGH V.LO-CITY, HYTRANSIT, HyTEC and CHIC are all major fuel cell vehicle demonstrators on passenger transport that included the deployment of refueling infrastructure, while taking in consideration hydrogen production on site.

Cleaner engine design is one of the most important themes in the road sector due to the significance it will play in the short and perhaps longer term, until EVs become more dominant. Some of the main themes that have been researched were advanced low emissions Spark (SI) or Compression Ignition (CI) engines; Downsized engines for hybrid EVs; Electric forced induction; Ultra lean combustion; Dual fuel engines for trucks and Waste heat recovery (GASTone, CORE, POWERFUL, ORCA, EAGLE, GasOn, COLHD, HDGAS, REWARD, ECOCHAMPS and UPGRADE). Integrated emissions control is not a new technology, yet there is room for improvement in the way air pollutants are captured before leaving the vehicle. Projects like CORE, HCV, EAGLE, GasOn and UPGRADE studied the development of Advanced Selective Catalytic Reduction (SCR); Integration of the advanced SCR catalysts onto a Diesel Particulate Filters (SCR/DPF); AdBlue processors; Gasoline particulate filters and three way catalysts without precious metals; Electrified (DPFs).

Although, electrification of vehicles is one of the major developments that is currently influencing the industry, several constraints remain concerning the overall eco-balance of EVs. An example is the production of a single Tesla battery that accounts to 17.5 tons of CO_2 [10]. Projects like GreenLion, OSTLER, SMARTBATT, HCV, DEMOBASE, ECAIMAN, iModBatt, EVERLASTIN, GreenLion, EUROLIS, EASYBAT, EuroLiion researched battery modularity and how the batteries should be integrated into the vehicle design rather the other way around including new battery materials. Development of electric motors is a way forward for road electrification. The most interesting concepts were delivered by projects that looked into Magnet free Switched Reluctance Motors (SRM) and Permanent Magnet Assisted Synchronous Reluctance Motors that do not use rare earth material (SYRNEMO, ARMEVA, ReFreeDrive and ModulED).

Advanced driver assistance systems (ADAS) projects (COVEL, GENEVA, CITY MOVE, ERSEC, ADAS&ME, VI-DAS, ROBUSTSENSE) took various directions in the implementation of such systems with more focus on accurate satellite positioning, collision avoidance, advanced sensors, machine learning and cloud data integration.

In the course of digitalization, Intelligent Transport Systems (ITS) are rapidly developing. ITS-technologies optimize traffic flows and the use of infrastructure by intelligently managing and directing the different traffic elements. The following types of communication can be differentiated within ITS-technologies: Vehicle-to-Infrastructure (V2I), Infrastructure-to-Vehicle (I2V) and Vehicle-to-Vehicle (V2V) [11], examples of such projects are SMARTFUSION, ELVITEN, SAFESTRIP, INTERACT and HIGHTS. Further emerging innovations is truck platooning, where several trucks are connected together through V2V-communication or collective/swarm intelligence, where specific actions of individuals evoke intelligent behaviors in the community through communication and networking activities [12]. A relevant example project is COMPANION.

Furthermore, several new mobility products and services have emerged in recent years. According to a recent study, more than 20 million vehicles could be removed from urban roads in the future, given the predicted growth in new mobility solutions (e.g. ride-sharing, on-demand systems, etc.) [13]. One of the main trends that can be observed are sharing systems, which are based on a fundamental rethinking in the ownership of mobility products, turning from ownership of transport modes to the use of transport modes [9]. Especially in mature economies and societies, a shift towards shared economies is evolving especially, for younger generations where car ownership in general is highly affected by new attitudes and behaviors [14]. Another trend is the growing range of Mobility as a Service (MaaS) (STEVE project). Several MaaS projects are currently running in Europe and cities such as Helsinki have already announced their intention to eliminate the need for privately owned cars by 2020 only through implementing a wide range of MaaS offers [15]. On-demand systems - a specification of MaaS - are transport services that are ordered individually and on demand. Autonomous operations of on-demand systems could offer a huge potential to lower individual travelling costs for mobility users in the future [16].

3.2 Aviation

Future aircraft design is one of the most dominant themes in the EU aviation research sector with many projects introducing designs that will improve energy efficiency of the aircrafts. Innovative concepts like Blended Wing Bodies, C shaped wings, supersonic designs have been researched by various projects (ALaSCA, AHEAD, ATLLAS II, HEXAFLY-INT, DIsPURSAL, Ce-Liner, WASIS). Morphing concepts, the idea that parts of the aircraft like wings, fuselage, wingtips, trailing edges can adapt their shape based on the operational environment, have been investigated by NEVEMOR, SARISTU and SABRE. Aerodynamic design of wings and fuselages has concentrated in methods of controlling air flow and reducing turbulent flow by plasma actuators and Turbulent boundary layer control (MARS, AFDAR, TFAST, DRAGY). Computer Aided Engineering (CAE) tools such as Computational Fluid Dynamics (CFD) or Finite Element Analysis (FEA) and other simulation tools will require further development in order to provide more accurate and real test-like results, thus minimizing cost of development (IDIHOM, MAAXIMUS, EXTREME, AEROGUST and DAEDALOS).

Materials development will be crucial for future aircraft designs. Examples of such materials are nanomaterials, composites, advanced alloys, ceramic matrix materials and high temperature materials for hypersonic speeds (ELECTRICAL, SARISTU, CERFAC, TICOAJO, ATLLAS II, HEXAFLY-INT). In addition, additive manufacturing methods like Selective Laser Melting (SLM), Laser Metal Deposition (LMD) and Electron Beam Melting (EBM) have been further developed by projects like MERLIN, Bionic Aircraft, AMOS, MMTech and AMATHO.

Noise from aviation is a major issue that can impede the future growth of the sector. Its control and mitigation have been covered extensively by research projects NINHA, ORINOCO, RECORD, ENOVAL, ARTEM and IMAGE through methods of studying engine noise and how engine stages interact with each other.

Engine and engine components development will be key enabling technology themes for future aviation. Projects like LEMCOTEC, FACTOR, IMPACT-AE, SOPRANO, ULTIMATE, SHEFAE 2, DREAM, and FIRST have worked in the development of ultra-high pressure ratio compressors, lean combustion and combustor design, interaction between combustor and turbine in order to improve engine efficiency and reduce emissions. Hybrid electric propulsion has also been studied by projects like MAHEPA, AHEAD, ASuMED and DIsPURSAL.

3.3 Rail Transport

The EU rail sector will need to become more attractive for the customers, while remaining environmentally sustainable, increase its high-speed network and offer modal shift for goods transported by road while also offering connectivity with ports and airports. Wagon design was being a considerable technology theme with projects like CAPACITY4RAIL, VIWAS, HERMES and VEL-WAGON all offering their own design for modular lightweight freight wagons. Project Marathon has proposed an innovate concept of coupling two trains together with a slave locomotive in the middle of the convoy, which proved to offer considerable fuel savings during the trials. Project such as ACEM-Rail, ROBO-SPECT, SAFTInspect, DTD SYSTEM 2, SAFT, INTERAIL developed solutions for inspecting rail infrastructure with advancements in non-destructive testing methods such as remote robotic systems, ultrasonic inspection and eddy current methods. Within a similar context projects MAXBE, AUTOMAIN, DIAG-PANTOGRAPH, WARNTRAK, INNOWAG developed solutions that can monitor health/condition of train components.

Reducing noise emissions from the rail sector remains a high priority and potential growth impediment factor. Projects like QUIET-TRACK, RUN2RAIL, FFL4E, FINE1 and RIVAS have all studied solutions ranging from on board noise & vibration monitoring, noise simulations and human perception of noise and noise mitigation methods for tracks.

Train Control Management System will play a greater role in the control in the input/output of information regarding position of train, train operation, traffic management and communications. The integration of GNSS and EGNSS satellite positioning into various aspects of TCMS has been the subject of many projects (SMART RAIL, GRAIL-2, SATLOC, X2RAIL-2, ASTRail).

3.4 Maritime Transport

The EU maritime industry remains competitive offering high value added products, rapid innovation, high safety standards and a leading position in terms of green technologies [17]. Project MUNIN, studied the development of a smart and autonomous or remotely operated cargoship. Such vessels will also require V2V and V2I systems including onshore infrastructure of remote control. Other projects like E-Ferry and SEABUBBLE, BB Green, GFF worked on the development of electric ferries and small electric boats for passenger transport. The design, manufacture and assembly of ships will also require change. CAE tools assist engineers in the design process of the vessels and various components, including the ship building process. Projects like PerSEE, No-Welle, SMARTYARDS, FIBRESHIP carried out research based on more accurate tools for CFD, FEA of ships including shipyard assembly simulation.

Integrated emissions control seems to also affect considerably the maritime transport sector, due to the emissions control impacting the vessels. Project like DEECON, RETROFIT, TEFLES worked on the further development of 2nd generation scrubbers for reducing SO2 and Particulate Matter (DEECON, RETROFIT, TEFLES) while other projects worked on SCR and DPF (HERCULES-C, HERCULES-2, JOULES). The innovative use of a Non-Thermal Plasma Reactor and Electrostatic seawater scrubber for reducing PMs, SO2, NOx, VOCs and CO was tested by DEECON.

Research on resistance and propulsion issues such as trim monitoring control, propeller design, ship stability, use of combinators and podded propulsion, was carried out by project like RETROFIT, TRIPOD, TARGETS TEFLES, STREAMLINE. In addition, multifuel engines using (1) LNG/Diesel, (2) Fuel flexible two stroke and four stroke engines, (3) Compressed Natural Gas (CNG) and/or Liquified Natural Gas (LNG) as an alternative hydrocarbon fuel to Heavy Fuel Oil (HFO) or (4) LNG-Liquified Petroleum Gas (LPG)/Diesel were developed under RETROFIT, JOULES, HELIOS and HERCULES-2. Projects like HERCULES-C were one of the major projects in terms of engine development and optimization for ships. The electrification of secondary energy converters on board such as fuel cell generators, waste heat recovery, electric motors and hybrid propulsion are technologies that can offer potential energy savings (JOULES, INOMANS^{2}HIP, H2MOVE, TARGETS, TEFLES, Auxilia, MARANDA). Furthermore, the integration of renewable energies such as wind and solar into propulsion has shown to be innovative concepts that will require further future research (ULYSSES, JOULES, SeagateSail, TARGETS, Rotor-DEMO, INOMANS^{2}HIP).

In addition, ports are begging to increasingly use renewable energies into their port equipment such as Rubber Tired Gantry Cranes or trucks. Such initiatives were studied by the GREENCRANES project while RETROFIT, INOMANS^{2}HIP and TEFLES investigated the use of Alternative Maritime Power.

4 Conclusions

The transport system is under transformation leading to a fundamentally new system and frame-conditions for mobility in the future. The European Union has been investing on RTD in the transport sector in order to prepare its transport system for the future challenges of decarbonization, retaining a competitive advantage over developing economies, while meeting changing societal needs in a global scale. The main technology themes that have been identified under this paper were the following: **(1) Road transport:** Lightweight EV design, autonomous vehicles, hydrogen fuel cells, engine design and integrated emissions control, batteries and electric motors' development, ADAS, ITS and MaaS systems. **(2) Aviation:** Aircraft design and morphing concepts, aerodynamics, CAE, new advanced materials for engines and structures, efficient and quiet engines including electric hybrid propulsion. **(3) Rail transport:** Train design and modularity, inspection and testing for infrastructure and vehicles, health & condition monitoring of trains components, noise and vibration of trains, train control systems and satellite positioning. **(4) Maritime transport:** CAE tools, autonomous vessels, Integrated emissions control, electric propulsion and secondary energy converters and integration of renewable energies, Alternative Maritime Power, greening of port equipment and operations.

Although, new technologies have been identified, their adaptation by the industry or the market itself, does not always occur. An example is the design of small urban vehicles as identified. Regardless, such vehicles are only a portion of automakers' available models. Furthermore, strategies of policy, planning and research are required. There is a need for new mobility paradigms to deal with both (1) the options arising from new technologies, mobility solutions and systemic change, and (2) the negative side effects of transport. Thus, to deal with burdens of increasing mobility demand, mobility has to be decoupled from aspirations for economic competitiveness, wealth and quality of life. This should lead to qualitative development of the transport system instead of growth. Especially a resource efficient organisation of given infrastructure via new technologies, selective amendments of the system and the realignment of strategies to principles of green and circular economy by using developments of industry 4.0 are essential in this context. People's mindset including those of companies will need to change towards future technologies. Finally, demonstrator initiatives could help the penetration of future technologies into markets by making people more familiar with technologies and increase attractiveness of the products.

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Spatial Heterogeneity, Scale, Data Character, and Sustainable Transport in the Big Data Era

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Abstract. I have advocated and argued for a paradigm shift from Tobler's law to scaling law, from Euclidean geometry to fractal geometry, from Gaussian statistics to Paretian statistics, and – more importantly – from Descartes' mechanistic thinking to Alexander's organic thinking. Fractal geometry falls under the third definition of fractal given by Bin Jiang – that is, a set or pattern is fractal if the scaling of far more small things than large ones recurs multiple times – rather than under the second definition of fractal by Benoit Mandelbrot, which requires a power law between scales and details. The new fractal geometry is more towards Christopher Alexander's living geometry, not only for understanding complexity, but also for creating complex or living structure. This short paper attempts to clarify why the paradigm shift is essential and to elaborate on several concepts, including spatial heterogeneity (scaling law), scale (or the fourth meaning of scale), data character (in contrast to data quality), and sustainable transport in the big data era.

Keywords: Scaling law · Living structure · Data character

In light of the emergence of big data, I have advocated and argued for a paradigm shift from Tobler's law to scaling law, from Euclidean geometry to fractal geometry, from Gaussian statistics to Paretian statistics, and – more importantly – from Descartes' mechanistic thinking to Alexander's organic thinking. Fractal geometry falls under the third definition of fractal – that is, a set or pattern is fractal if the scaling of far more small things than large ones recurs multiple times [1] – rather than under the second definition of fractal, which requires a power law between scales and details [2]. The new fractal geometry is more towards living geometry that *"follows the rules, constraints, and contingent conditions that are, inevitably, encountered in the real world"* [3], not only for understanding complexity, but also for creating complex or living structure [4]. This editorial attempts to clarify why the paradigm shift is essential and to elaborate on several concepts, including spatial heterogeneity (scaling law), scale (or the fourth meaning of scale), data character (in contrast to data quality), and sustainable transport in the big data era.

Current geographic information systems (GIS), which were first conceived and developed in the 1970s, are still largely based on the legacy of conventional cartography [5]. Although computer technology has advanced dramatically since then, the legacy or the fundamental ways of thinking remains unchanged. For example, GIS

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representations of raster and vector and even so-called object-oriented representation are still constrained among geometric primitives such as pixels, points, lines, and polygons [6]. These geometry-oriented representations help us to see things that are more or less similar, characterized by Tobler's law [7], or commonly known as the first law of geography. For example, the price of your house may be similar to those of your neighbors, but there are far more low house prices than high ones. This notion of far more lows than highs – or far more smalls than larges in general – is what underlies scaling law for characterizing spatial heterogeneity.

The concept of spatial heterogeneity, as conceived in current geography literature, is mistaken because it does not recognize the fact of far more smalls than larges [8]. This notion of far more smalls than larges adds a fourth meaning of scale; that is, a series of scales ranging from the smallest to the largest form the scaling hierarchy [9]. The scaling hierarchy can be further rephrased as: numerous smallest, and a very few largest, and some in between the smallest and the largest. In order to see far more smalls than large ones, we must adopt a topological perspective on meaningful geographic features such as streets and cities instead of the geometric primitives. In other words, we must shift our perspective from geometric details to overall data character (which will be further elaborated on below). Tobler's law depicts a fact on a local scale. However, geographic space is governed by not only Tobler's law but also by scaling law. These two laws are complementary to each other (Table 1). Calling for a shift from Tobler's law to scaling law is not to abandon Tobler's law, but to shift from thinking that is dominated by Tobler's law to thinking dominated by scaling law because scaling law is universal and global.

Table 1. Comparison of the scaling law versus Tobler's law.

Scaling law	Tobler's law
Far more small things than large ones	More or less similar things
Across all scales	Available on one scale
Without an average scale (Pareto distribution)	With an average scale (Gauss distribution)
Long tailed	Short tailed
Interdependence or spatial heterogeneity	Spatial dependence or homogeneity
Disproportion (80/20)	Proportion (50/50)
Complexity	Simplicity
Non-equilibrium	Equilibrium

(Note: These two laws complement each other and recur at different levels of scale in geographic space or the Earth's surface.)

Benoit Mandelbrot, the father of fractal geometry, remarked that unlike things we see in nature, Euclidean shapes are cold and dry. Christopher Alexander, the father of living geometry, referred to structures with a higher degree of wholeness as living structures. Wholeness is defined mathematically as a recursive structure, and it exists in space and matter physically and reflects in our minds and cognition psychologically [4, 10]. A cold and dry structure versus a living one vividly describes the difference between Euclidean shapes and fractal or living structures. A shift from Euclidean geometry to fractal or living geometry is not to abandon Euclidean geometry, but Euclidean geometric thinking. Euclidean geometry is essential for fractal geometry, since one must first measure a shape in order to see whether there are far more smalls than larges in it. However, Euclidean geometric thinking differs fundamentally from that of fractal geometry. For example, Euclidean geometric thinking tends to see things individually (rather than holistically) and non-recursively (rather than recursively); refer to Jiang and Brandt [9] for a more detailed comparison about these two geometric ways of thinking. The shift from Euclidean to fractal or living geometry implies that fractal or living geometry is to be the dominant way of thinking. To present a practical example, a cartographic curve is commonly seen, under the Euclidean geometric thinking, as a set of more or less similar line segments; however, it should more correctly be viewed, under the fractal or living geometric thinking, as a set of far more small bends than large ones, and importantly small bends are recursively embedded in the large ones.

According to Tobler's law, the price of your house is similar to those of your neighbors. In other words, averaging your neighbors' housing prices would lead to your housing price. In this case, the average makes a good sense for predicting your housing price, as all neighboring housing prices can be characterized by a well-defined mean. In order for the prediction to make sense, there is a condition to meet; namely, the neighboring housing prices are more or less, or with a well-defined mean. This is indeed true for housing prices on a local scale. This condition is violated on a global scale, since there are far more low prices than high ones. In this case, the average does not make good sense; it lacks an average or scale-free or scaling. Things with more or less similar sizes can be well modeled by Gaussian statistics, whereas things with far more smalls than larges should be well characterized by Paretian statistics. In this regard, we have developed a new classification scheme for data with far more smalls than larges. This classification scheme is called head/tail breaks [11], which recursively breaks data into the head (for data values greater than an average) and the tail (for data values less than an average) until the condition of a small head and a long tail is violated. A head/tail breaks-induced index called the ht-index [1] can be used to characterize the notion of far more smalls than larges or underlying scaling hierarchy. As mentioned above, the new definition of fractal is based on the notion of far more smalls than larges.

Under Euclidean geometric thinking that focuses on geometric details, data quality or uncertainty is one of the priority issues in GIS. This kind of thinking is evident in many scientific papers and talks about, for example, data quality of OpenStreetMap (OSM). I believe that the GIS field has over-emphasized the data quality issue, so I would like to add a different view, arguing that data quality is less important than data character. By data character, I mean some overall character of geospatial data, or the wholeness, or living structure as briefly mentioned above. To illustrate, this link (https://twitter.com/binjiangxp/status/985322539625967618) shows a cartoon and a photo of Kim Jong-Un. The photo on the right has the highest geometric details, and the cartoon on the left has the lowest geometric details. However, the cartoon on the left captures the highest character or personality. This link (https://twitter.com/binjiangxp/status/985322961342263296) further illustrates the living structure of the street network of a small neighborhood. The street network on the right has the highest data quality, while the graph on the left captures the highest data character – far more less-connected streets than well-connected ones. What I want to argue is that if the street network on the right suffers from some errors, this would not have much effect on the data character on the left. It is in this sense that quality is not super-important compared to data character. If data quality or geometric details were compared to trees, then data character would be the forest. To present a specific example, Jiang and Liu [12] adopted a topological perspective and examined the scaling of geographic space based on OSM data of three European countries: France, Germany, and the UK. There is little doubt that there were numerous errors in the OSM data, but they have little effect on the finding – the scaling or living structure of geographic space in which there are far more small things than large ones.

The legacy of GIS has been driven substantially by the mechanistic thinking of over past 300 years of science [14]. Everything we have achieved in science and technology benefits greatly from mechanistic thinking, but it is limited in terms of how to make a better built environment [4]. This mechanistic thinking is reflected in the GIS representations of raster and vector, and in the box counting for calculating fractal dimensions. It is also reflected in top-down imposed geographic units such as census tracts; these are clearly very useful for administration and management, but of little use for scientific purposes. Space is neither lifeless nor neutral, but has a capacity to be more living or less living [4]. In other words, space is a living structure with a high degree of wholeness. A country is a living structure that consists of far more small cities than large ones. Figure 1 shows all the natural cities of Austria, derived from street nodes of the country's OSM data. Seen from the figure, all cities have very natural boundaries, and they are quite coherent, with a topographic surface that reveals the underlying living structure of far more small cities than large ones. Natural cities are objectively defined cities, from a massive number of geographic locations, such as social media locations [15]; please refer to the Appendix of the paper for details on the derivation of natural cities.

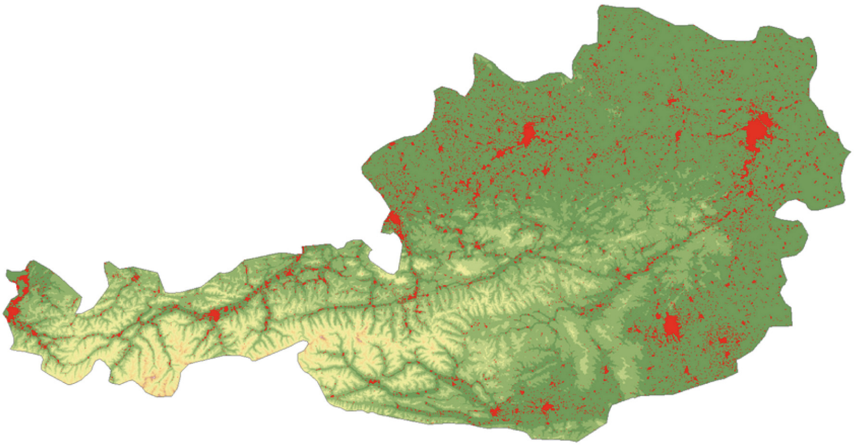

Fig. 1. Living structure of all natural cities derived from Austria's OSM data.(Note: This topographic rendering is based on head/tail breaks [11, 13]. Unlike traditional renderings, this head/tail breaks induced rendering clearly shows the living structure of far more low elevations than high ones.) (Color figure online)

Geographic space is a living structure, not just at the country scale, but also at the city scale. Figure 2 shows natural streets of Vienna and Linz, which demonstrate striking living structures with far more less-connected streets than well-connected ones. The natural streets are able to capture the underlying scaling or living structure of far more the less-connected than the well-connected, and are therefore able to predict up to 80 percent of traffic flow. In other words, traffic flow is mainly shaped by the living structure and has little to do with human travel behavior. In this circumstance, human beings can be thought of as atoms or molecules that interact with each other, and with the natural streets to shape the traffic flow. Traffic is not a phenomenon, but an outcome of the living structure. This is in line with the famous statement by Winston Churchill – We shape our buildings and afterwards our buildings shape us. With respect to sustainable transport, we can paraphrase Churchill: We shape our transport system, and it will shape us, so make sure we shape it well so that we will be well-shaped too. To be more specific, we shape our transport system as a living structure and it then shapes our sustainable mobility.

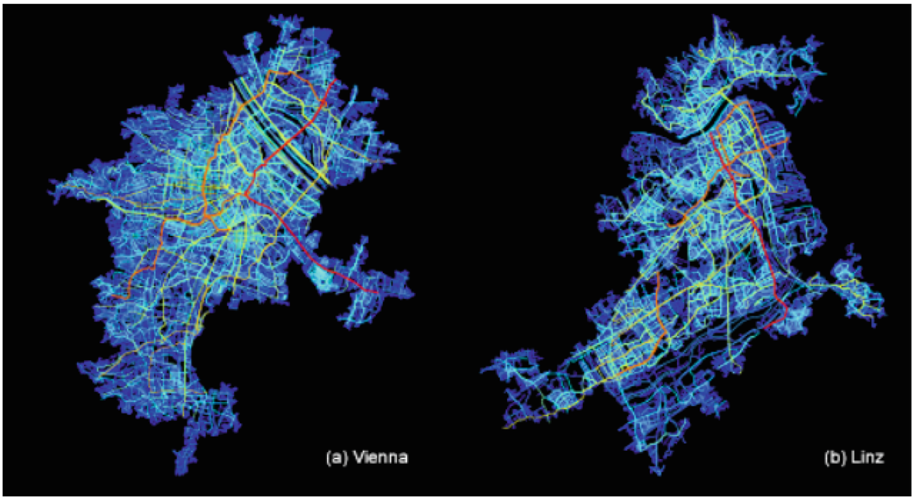

Fig. 2. Living structure of natural streets of (a) Vienna and (b) Linz. (Note: The living structure shows far more less-connected streets – indicated by many cold colors than well-connected ones – indicated by a very few warm colors.) (Color figure online)

This social physics perspective offers new insights into traffic flow. To this point, I would like to end this short paper with the following excerpt [16]:

> *"There's an old way of thinking that says the social world is complicated because people are complicated ... We should think of people as if they were atoms or molecules following fairly simple rules and try to learn the patterns to which those rules lead ... Seemingly complicated social happenings may often have quite simple origins ... It's often not the parts but the pattern that is most important, and so it is with people."*

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Data Security and Legal Issues

Major Limitations and Concerns Regarding the Integration of Autonomous Vehicles in Urban Transportation Systems

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Abstract. Autonomous (or Driverless) vehicles are expected to be the future of urban transportation. As autonomous is defined a vehicle that is capable of sensing its environment and navigating using a variety of sensors and methods without human input. It is estimated that driverless cars will be technically sufficient for common usage by the end of 2025. In this paper, advantages of the autonomous vehicles are pointed out while limitations and other significant concerns are examined thoroughly. The most important advantages of the integration of autonomous vehicles in the circulation are related with the enhancement of safety, sustainability and accessibility of urban transportation. On the contrary, privacy and data protection issues are arising. Another critical issue is the cyber security of autonomous car's system and its vulnerability to hacker attacks. Furthermore, there are some legislation gaps concerning the usage and ownership of driverless cars, as well as responsibility in case of accidents. In addition, many complex ethical issues are arising, as autonomous cars will be programmed to act in a predefined way towards unexpected situations. Finally, human adoption to autonomous vehicles will prove a very serious matter; it may take long until people feel fully comfortably inside a driverless car.

Keywords: Autonomous vehicles · Safety · Privacy issues · Legislation Ethical issues · Urban transportation

1 Introduction

Autonomous or Driverless vehicles have the potential to revolutionize travel and road safety, therefore they have been a field of research over the past decades. Some of the most significant automotive and technology companies, such as Google, Mercedes, Tesla and Ford, have invested in developing their own autonomous cars [1, 2]. As autonomous is defined a vehicle that is capable of sensing its environment and navigating using a variety of sensors and methods without human input [3]. To detect their surroundings, autonomous cars use radar laser light, GPS, odometry and computer vision. Using artificial intelligence techniques to analyze data gathered from the aforementioned sensors, advanced control systems identify appropriate navigation paths between other vehicles, pedestrians and other obstacles, with respect to driving laws and rules [4, 5].

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There are six levels of automation, which are described below together with their basic attributes [6, 7]:

- **Level 0 – Warning Systems:** may provide the driver instruction or suggestions but without taking decisions or control of the car (e.g., Lane departure system, Blind spot checking system).
- **Level 1 – Automation of single operations:** Driver and vehicle share control, vehicle takes control of only some standardized operations (e.g., Adaptive Cruise Control, Dynamic Braking Assistance, Park Assistance).
- **Level 2 – Automation of multiple operations:** Vehicle takes full control, including steering, accelerating and braking, driver must be prepared to intervene in case the system fails.
- **Level 3 – Conditional Automation:** Vehicle capable to handle almost every situation, including emergency ones, driver may be asked to intervene but only within some reasonable time.
- **Level 4 – Semi – Automated Driving:** Vehicle capable of coexisting with other vehicles, realize and cope with every situation but only in delimited areas (highways) and circumstances, driver may even leave their seat.
- **Level 5 – Automated Driving:** No human intervention required at all, vehicle is capable of driving itself from the starting to the ending point under every circumstances and the existence of steering wheel is even optional.

Autonomous vehicles, as every new technological achievement, are intended to improve people's everyday life. In case of autonomous vehicles, are expected to make urban mobility safer, easier and more efficient. On the contrary, numerous concerns do exist regarding the dangers such a change poses, since people tend not to realize them a priori. Therefore, in this paper, advantages of the integration of autonomous vehicles in transportation systems are pointed out, while limitations and other significant concerns are examined thoroughly.

The remainder of the paper is organized as follows: Sect. 2 offers a quantitative review of the literature, while Sect. 3 presents the most significant benefits of the integration of autonomous vehicles in urban transportation systems. Section 4 presents thoroughly limitations and potential obstacles arising from the literature review. Finally, conclusions are included in Sect. 5.

2 A Quantitative Review of the Literature

In order to offer a deeper understanding of the research on autonomous vehicles, a quantitative analysis of the corresponding literature has been made based on ScienceDirect's (https://www.sciencedirect.com) database of scientific articles. To gain a good insight of the development of research field regarding autonomous vehicles over the last decades, search has been performed using the words "autonomous vehicle" or "car" appearing on the title, abstract or keywords of any scientific article of the database. Chart 1 presents the results of this search with their corresponding trend line.

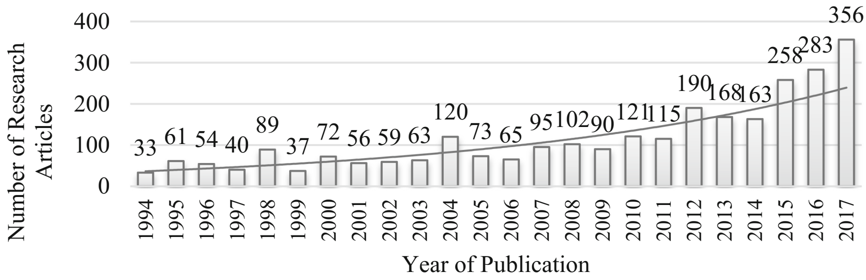

Chart 1. Research articles referring to autonomous vehicles over the years.

Subsequently, searches were made with the keywords "advantages", "benefits" and "limitations", "concerns" respectively. The results of the comparison are shown below, in Chart 2.

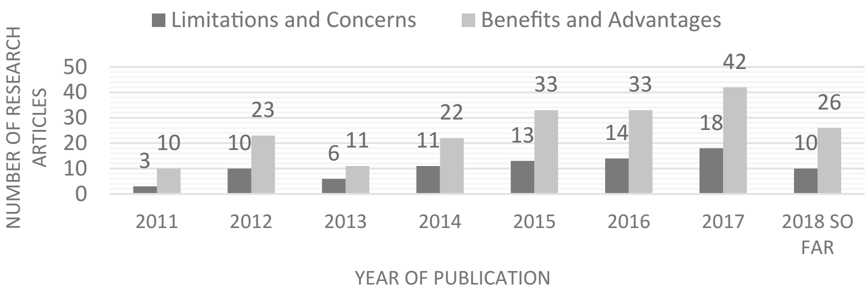

Chart 2. Number of research articles concerning "limitations and concerns" and "benefits and advantages" of autonomous vehicles.

According to the results presented above, is clear that interest in autonomous vehicles is growing over time and is expected to continue to do so. Most articles refer to technology aspects, safety and advantages of autonomous cars. The research gap that arises refers to the limitations and concerns regarding the integration of autonomous vehicles in urban transportation systems, such as ethical issues, human adoption, cyber security etc.

3 Potential Benefits of Autonomous Cars

Over the last decades car technology and reliability have reached a very high level and as a result they are safer than ever. In addition, road safety and designing engineers, after hundreds of years of research, are constructing roads that are tolerant to most drivers' mistakes and carelessness. However, road accidents still happen and will continue to happen due to the human factor. Road safety experts agree that it is the worst "bug" of the road system and the one with the highest impact, but also the one that cannot be improved [8, 9].

In order to limit human error during driving, researchers and manufacturers have invested in the development of driverless vehicles that appear to have a number of advantages over the conventional vehicles. These advantages are briefly presented below.

3.1 Safety

Autonomous cars are considered being much safer than the conventional. That's because they react much faster than humans do, they do not get distracted, they are not inattentive and of course they do not violate the law as many drivers do [10–13]. In fact, it is estimated that road accidents will be reduced by 90% if autonomous vehicles are used exclusively [14]. Any accident that may happen will be caused by unexpected situations that cannot be prevented due to mechanical limitations of the braking system, for instance [15].

3.2 Sustainability

Driverless cars will also lead to a more sustainable urban transportation system, due to more efficient driving and road usage by driving at higher speeds, decreased safety gaps and increased road capacity [16]. This would also lead to less congestion and furthermore to lower harmful emissions. Moreover, driverless cars of level 5 would also be able to leave their users to their destination, park in certain areas or outside the city center and return later to pick them up. This would solve the parking problem many large cities face [2, 16]. In addition, a single driverless car would be able to serve a whole family by transferring one member and returning back to pick another. This would lead to decreased rate of number of cars per household [16].

3.3 Accessibility

Finally, another potential benefit worth saying is that autonomous cars will be accessible to people that conventional cars are not, namely elderly, children and blind people. That's because, as already mentioned, autonomous vehicles of level 5 would not require passengers that know how to drive, because they will never be asked to intervene [17].

There are also plenty of other advantages that are related to the integration of autonomous vehicles, such as cost reduction of transportation or further adoption of car-pooling services [18]. However, the purpose of this paper is to focus on potential limitations and concerns, so they are not explicated.

4 A Review of Major Concerns and Potential Limitations

Over the last decades, there have been a number of radical changes in everyday life. Some of these changes are the result of the rapid advances of science and technology, such as the wide use of personal computers, the internet and smart portable devices. The integration of autonomous vehicles is considered to be one of the next breakthroughs in years to come and, like all the previous, may pose various threats. To this end it is crucial to analyze the most important concerns and limitations of the integration of autonomous vehicles in circulation in order to develop the relevant strategies and techniques to adjust them properly.

4.1 Technological Efficiency

The first obstacle that must be overcome is that of the development of the appropriate technology. Despite the great technological progress that has been made, the wide use of level-5 autonomous vehicles requires both the ability of the latter to respond to all circumstances and the reliability of their software [19]. Artificial Intelligence algorithms which are used for recognizing the surroundings and navigating the car are not able yet to properly operate in chaotic city environments [20] and under different weather conditions, such as heavy rainfall or snowfall [21]. Furthermore, autonomous cars require maps of higher quality, detail and accuracy than the ones which are currently available [22]. Lastly, as far as concerning the communication systems between cars or between cars and servers should never fail or get down, since the consequences of such a failure would be unpredictably destructive [23].

4.2 Data Protection - Privacy

Another serious concern is the safety of data they share in order to make the car functional. This concern already exists nowadays among internet users. Some personal information is essential to be sensed and uploaded in real time to software provider's servers [24]. The sensed data may contain sensitive information of drivers, such as home or workplace location, mobile phone number, gender and so on. Until now, it is unclear who would have access to such information and how they may use it (e.g., commercial use) and most people do not feel comfortable sharing them, even if confidence terms are agreed between the car owner and the company [25]. Moreover, examples of inappropriate usage of such data are very recent [26, 27].

4.3 Cyber Security

Another major concern about autonomous vehicles is the vulnerability of their software towards hacker attacks. Hacker attacks is a usual phenomenon nowadays, with email or social media accounts, PCs and Smartphones and even government websites being easy targets of such attacks. The threat that arises from such an issue is that if someone manages to hack a driverless car's system, they could also get access to all personal information of the user and they could even take control of the car [25, 28, 29]. There are also worries that autonomous cars being hacked could be used for terrorist attacks [30]. It is clear then that autonomous cars' system should be 100% safe before their integration in circulation.

4.4 Legislation – Liability

Every country has its own legislation concerning who is eligible to drive a car, at which age and after passing certain examinations. There are also terms of liability in case of accidents according to each country's driving code. Since autonomous vehicles still constitute an innovative mode of transportation, there is no legislation concerning their usage and ownership yet, neither the specifications they should meet in order to be integrated into urban circulation. Moreover, many issues arise regarding the case where an accident occurs [31, 32]. On the one hand, the owner of the driverless car has no responsibility, because they do not drive the car. On the other hand, the constructor of the car isn't either responsible, if the vehicle has successfully passed the essential technical tests. All these legislation gaps should be addressed before autonomous cars start being sold [33, 34].

4.5 Ethical Issues

As it has already been mentioned, one of autonomous vehicles' most important advantages is the potential reduction of car accidents, but this does not mean that car accidents will stop happening. The main reason of car accidents would be unexpected occurrences that take place all of a sudden, for example a pedestrian or an obstacle falls in front of the car's wheels.

At this point a very complex ethical issue is arising, since in such situations which involve difficult choices, the car will act in a predefined way. Unlike human drivers, who would act instinctively and therefore randomly, an autonomous car, or more specifically its constructor, will be pre-programmed for how to react and which decisions to make in such situations [35]. Whatever the choice may be, it is considered unethical for someone to have to choose between them and each decision would lead to controversiality. An approach that is being taken into consideration in order to solve such issues is that of the "smallest damage to society" [12]. According to it, a car should choose, for example, to injure as few as possible people, even if its own users are among them. The above assumption is not accepted by everyone and it can get a step further: is it acceptable if autonomous vehicles sort people according to multiple variables (their age, health, profession etc.) in a list of possible victims?

All these issues are very complex, and nobody has the authority to decide about them, so it may take years to get them addressed. However, is it ethical to allow people driving until then?

4.6 Human Adoption

It is considered to be very difficult for people that are aware of all the above to trust autonomous cars and it may take too long until they feel comfortable inside them. Surveys that were held in many countries tend to prove this [13]. In addition to these objective reasons, people feel also uncomfortable with the idea of a driverless car, despite the fact they may realize how safer it is [36]. A possible solution to this would be the adoption of autonomous vehicles in public transportation so that people get used to them before they get their own.

5 Conclusions

Autonomous vehicles are expected to completely reverse the future of transportation. The integration of autonomous vehicles in circulation has many advantages with the most significant of them being the enhancing of road safety and transportation sustainability as well as the ensuring of accessibility for all road users. This paper summarized the major concerns and potential limitations that may arise from the widespread usage of autonomous vehicles. Although many researchers and stakeholders claim that the implementation of fully automated driving will start from 2025, there are still some gaps concerning the technological efficiency of autonomous vehicles. Moreover, data protection and privacy issues must be addressed. Autonomous vehicles just like every other device connected to the internet, are exposed to hacker attacks. This risk must be eliminated before placing vehicles in circulation. Another critical issue that should be addressed is the legislation gap and the ethical issues that arise during the formation of the relevant legislation and the development of the operating systems of autonomous vehicles. Lastly, when the above-mentioned limitations have been overcome, the issue of accepting these vehicles by the user himself should be addressed.

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Data Protection in Smart Cities: Application of the EU GDPR

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Abstract. Urban growth, combined with the development of digital technology, has led to the recent boom of smart cities worldwide. Smart cities make use of all available information and communications technology in the built environment to control their operation and in this way to enhance the quality of life and to drive economic growth. This phenomenon also raises legal issues regarding data protection. The key questions that smart cities already face concern the rights and treatment of data. Currently, further to the Data Protection Directive 95/46/EC, each Member State of the EU has in place its own legislation to govern data protection. This translates into a lack of harmonization within the European Union, which does not contribute towards uniting even more the various Member States. This is something that the introduction of the EU General Data Protection Regulation 2016/679 (GDPR) on 25 May 2018 aims to change, as it shall be directly applicable as is and shall not require different legislation in each country, thus requiring all smart cities and related businesses throughout the EU to ensure their treatment of data complies with the same set of provisions. Therefore, since smart cities are the cities of the future and legal compliance shall be a cornerstone of their operation, the objective of this paper is to examine the relationship between smart cities and data protection under the emerging common EU legal framework and the effect it has upon them.

Keywords: Smart cities · Transportation · Data protection · Data security GDPR

1 Introduction

The information and technological revolution during the last decades has raised many issues regarding the data protection. Technology has advanced greatly and processing and collecting followed course; they became more common in all areas of life, more advanced and certainly more complex. Nowadays, through the smart devices, the Internet of Things etc. a huge volume of data is being exchanged not only in private sector but also in public one.

The daily life of people has largely been reformed during the last decades due to the rapid spread of digital technology, which also extended to the functioning of cities. Smart cities are associated with great production of data. Regarding the operation of a

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smart city, data is collected from several applications of a smart environment, like smart economy, smart living, smart mobility, smart environment, smart grids, smart people, smart governance, etc. [1, 2]. These large amounts of unstructured data are stored in the cloud or data centres [1].

Consequently, the everyday activities and transactions of citizens using smart phones, digital IDs, credit cards, personal travel cards, etc. raise concerns for the respect and the protection of privacy. The use of all this data produced and their sharing is a real challenge and requires innovative approaches.

This paper aims to answer the main questions about the implementation of the EU General Data Protection Regulation 2016/679 (henceforth "GDPR"). Following May 2018, handling personal data of EU residents or monitoring of the behavior of data subjects in the EU falls under the coverage of the GDPR. GDPR will be applied in every single sector; however, this paper focuses on the application on smart cities. The remainder of this paper is divided into three sections. Section 2 gives an overview of previous literature for the legal framework of the data protection, and the general aspects of the GDPR. In Sect. 3, smart cities and smart transportation are described and the application of the GDPR in smart mobility is analyzed. Finally, Sect. 4 concludes the paper and outlines some future research directions.

2 GDPR: Framework

2.1 General and Historical Background

The Data Protection Directive 95/46/EC (henceforth, the "95 Directive") aimed to harmonize the different European frameworks on this area and protect individuals in personal data processing situations. Objectively, it does not offer the harmonization it sought to provide, given its nature as only a directive. By all accounts, the 95 Directive is outdated and redundant [3–7].

The GDPR will replace the 95 Directive on 25 May 2018 and looks to the future, particularly through its open inclusive wording, offering clearer rules and solid requirements, thus improving the protection afforded to personal data. Given that it is a regulation, rather than a directive, it also offers harmonisation across the EU. It is viewed as such good news that even the UK will hold on to its elements [3, 5–7].

2.2 Legal Framework Changes

The GDPR proceeds to a fundamental change and extends the geographical coverage of the provisions. Henceforth and in contrast to the past, it shall cover EU-based controllers and processors, irrespective of where the processing takes place, thus covering cases where this happens outside the EU. Moreover, it covers cases of controllers and processors outside the EU who, however, process personal data regarding goods and/or services provided to EU data subjects or monitor the behaviour of such data subjects. Processing personal data requires a legal basis [3, 5, 6].

New definitions are also introduced, e.g. "pseudonymisation", "genetic data" and "biometric data". The transparency of data processing (in addition to the lawful and fair processing under the 95 Directive) and the principle of accountability (i.e. the controller must ensure as well as demonstrate compliance) also add to the arsenal of provisions for further protection [3].

Controllers shall also have to provide transparent, easily accessible and understandable information on their processing, as well as on the controllers themselves, maintain relevant records and in certain cases co-operate with the supervisory authority, in addition to providing an easier environment for data subjects to exercise their rights. Further to this, new conditions are introduced regarding erasure and restriction of processing. A massive step forward has also been the extension of coverage to processors, thus now covering more people than ever before [3, 5, 6].

The principles of data protection by design and by default (i.e. designing and constructing systems with privacy in mind) are also strongly highlighted as an aid to improving protection. Many authorities have embraced them and was also glanced at in the 95 Directive. These must be implemented by taking into account cost, thus inserting a degree of realism [3, 4, 8].

In line with the notion of further clarification, the controller has to notify the respective supervision authority of any breach to any personal data (within 72 h from becoming aware of the breach) and proceed to also inform the concerned data subject (however, exceptions exist, e.g. if data lost poses no risk). Along the same lines of this obligation, the processor also has to notify the controller of any data breach. As can be understood, the underlying obligation is that notifications must be made without any undue delay whatsoever. Crucial to this is knowing where data is stored [3, 6, 7].

What is now known as a data protection impact assessment must be carried out by controllers prior to risky operations in order to evaluate those cases better, with exceptions existing however, such as in the case of public authorities processing personal data with a legal basis in the law of each member state or the EU. What is also simplified is the authorization needed to process personal data, consultation with the relevant supervisory authority is only needed if the data protection impact assessment shows that a high risk is present or if of course the supervisory authority requests it [3, 8].

Another introduction by the GDPR is the data protection officer and it applies to both controllers and processors. In essence, they are required to have one if processing is carried out which requires regular and systematic monitoring of data subjects or special categories of data processed or the processing is carried out by a public body. The data protection officer's duties are also provided and include liaising with the supervisory authority and advising on compliance, as is naturally expected. It should be borne in mind that the data protection officer, in respect of relevant matters, should be seen as an independent party [3, 7, 8].

Compliance with all the obligations imposed by the GDPR can be demonstrated, as required, through a variety of methods, including some new ones introduced in the GDPR itself - voluntary certification, seals and marks [3].

As mentioned above, obligations now also extend to processors, therefore, both controllers and processors are liable for damage, whereas in cases of joint controllers/processors, each one is held liable for the entire damage. Fines have also increased, now reaching €20 million or 4% of the annual global turnover (whichever is higher) [3, 5–7].

3 GDPR: Application

3.1 Smart Cities

Urbanization is undoubtedly characteristic of the European population, since over 75% of it lives in urban areas, while this is expected to rise up to 80% by 2020 (Khan et al. 2017). The development of the urban areas has been affected by the concept of smart cities which is associated with better connectivity and huge information sharing (Khan et al. 2017).

Cities which use widely Information and Communication Technology (ICT) are defined as smart cities, although there are more definitions [2, 9–11]. The broad application of IoT technologies, such as Radio-Frequency Identification (RFID), environmental sensors, smartphones, cloud computing etc. has further contributed to the further development of smart cities (Khan et al. [9]).

Nowadays there is a transition from the digital city to the smart city [10]. The main difference and the reason why the smart city surpasses the digital one is that in digital cities, information is used in a database and in internet applications, aiming at doing many works through the computer network, while a smart city aims to have an urban information network which achieves automatic monitoring, information collection, analysis and processing and even decision making [10].

The concept of digitized smart cities is based on a huge volume of up to date data produced by the citizens [9]. This data through transformation, publishing and finally integration with existing city data into higher-level services contribute to the improvement of the service quality of smart cities by enhancing the knowledge-based decision making (Khan et al. [9]). Therefore, the data streams constitute the cornerstone for the proper functioning of smart cities.

Over the last years, the various dimensions of a smart city are under development, such as smart governance, smart industry, smart waste management, smart health, smart transportation, smart home, smart people etc. [2, 12]. Since the number of urban residents increases, as it was pointed out hereinbefore, mobility – especially on a daily basis for commuting – constitutes a real challenging dimension of the developing smart cities [12–15]. Smart Mobility initiatives are relatively well represented in non-Nordic Northern Europe, Spain, Hungary, Romania and Italy, but less represented in Nordic Member States [2].

3.2 GDPR Application in Smart Transportation

Smart city data comes from various domains, such as transportation, homes, retail, environment etc. [2, 9]. The data derived from smart cities has the characteristics of Big Data, high volume, variety, velocity and value [1, 9].

In the context of smart cities various smart transportation services are delivered, such as provision of real time and multi-modal public transport information, smart traffic lights, intelligent traffic management etc. [12].

The main practical implications can be found in the GDPR flowchart (Fig. 1). This paper shall look at the main practical implications in the light of three smart mobility services which can be found in most smart cities – smart traffic lights in conjunction with RFID aiming at resolving traffic congestions, real-time driving guidance in order to save time, cost and improve commuting efficiency and smart pass/card for paying different mobility services (public transport, parking spaces, etc.).

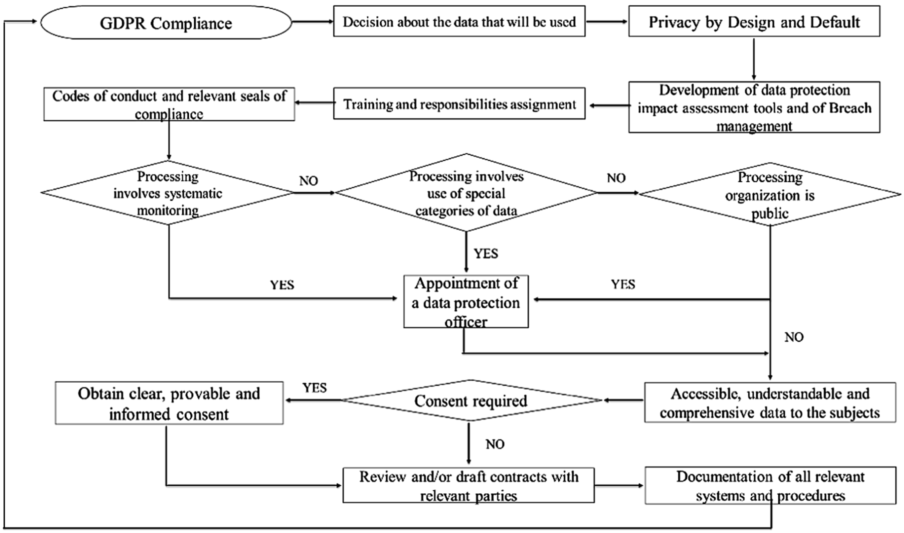

Fig. 1. GDPR compliance flowchart.

Such smart transportation services will attract the application of the GDPR from 25 May 2018 when it comes into force. Furthermore, "location data", which is the main data collected by many modern transportation systems, is now considered "personal data" and therefore within its scope.

Organizations shall need to keep their processing to the absolute minimum necessary, through deciding exactly what data they need, whether it is within the scope of the GDPR and in what format it will be stored, allowing for savings in storage, speedier use and easier and more complex analysis. Although in cases of smart passes/cards data needed could extend to biometric data, such as a photograph and/or height, etc., the same cannot be said for applications in regard to smart traffic lights and real time driving guidance. Therefore, in the latter cases, location data could be argued to be the absolute minimum necessary and so no further data such as biometric should be used.

Privacy by Design and Default are now concepts which should be taken into consideration, in conjunction with other factors such as cost, throughout an organization, on all levels and procedures, before adopting measures and during their enforcement. Mechanisms which collect the minimum data necessary, store them accordingly and in a secure manner must be present. Of course, processors should also embrace those measures as they are responsible too. All three abovementioned smart mobility service organizations could invest in new systems which have been designed with privacy in mind and as a default. If the cost is great, modifications or safeguards could be included in the current systems. All could also use the concept of pseudonymisation for the data collected through developed techniques, such as the k-anonymity model [9] or the generalization and suppression methods [9].

Along the same lines, the aforementioned smart mobility service organizations must also develop processes not only to provide adequate data security but also to deal with breaches when they occur. On this topic, the controller must be able to quickly find the breach and then find what has been damaged and which user has been affected. In addition, they must then notify the affected user as well as the supervisory authority, whilst the processor is equally obliged to quickly notify the controller if a breach arises under his control and provide the same information. Data protection impact assessments shall also be needed prior to risky situations, such as in the case of the smart card/pass which deals with sensitive personal data. This presupposes the existence of assessment processes, which in turn means establishing them in the first place.

Furthermore, personnel training through seminars and other training by relevant providers, which have already started emerging, should be a given, as should the assignment of responsibilities regarding all aspects of the process.

In all of the abovementioned smart mobility service organizations codes of conduct will need to be drafted/revised demonstrating compliance with the GDPR where that arises. Membership of relevant organizations, certifications and seals and marks of excellence (similar to ISO certification) are also steps which can be taken to demonstrate compliance, as is seeking consultation by relevant third parties.

The next step involves deciding if a data protection officer shall also need to be appointed. In particular, in the cases of smart traffic lights and real-time driving guidance, where processing involves systematic monitoring (usually by a public body such as the municipality as the processor in the former case), a data protection officer is required. Similarly, such an officer will also be required in the case of the smart card/pass, due to the systematic monitoring which also involves special categories of data such as data revealing racial and ethnic origin.

Information must also be available to the concerned data subjects, in a form which is accessible, understandable and covers all aspects, whilst also allowing them to easily exercise their rights. The three aforementioned smart mobility services should implement procedures and systems which makes access easy, as well as re-write data and/or relevant policies to give effect to the abovementioned objectives. If the users of those services (data subjects) end up requesting the deletion of their data or a copy of it, that must be followed. Therefore, relevant processes need to be put in place to quickly find the relevant data – which ideally is in electronic form for ease of use – and delete it or copy it accordingly.

Where consent is to be provided, it must be informed consent (e.g. which personal data is collected, the location and duration of the storage and type of processing) and must be clearly obtained, with the controller being able to prove it actually obtained it. In particular, during the issuance of the smart card/pass, consent should be requested and provided. If the organization intends to use said data for further purposes, such as marketing, consent requests regarding all uses should be used and not rely on consent given for a single use only. Similarly, in the case of real-time driving guidance application, consent could be requested at the download stage. In terms of the smart traffic lights and the RFID tag on cars consent has to be provided prior to the installation. If profiling of clients takes place – i.e. any form of automated processing of personal data to analyse or predict aspects concerning that natural person's personal preferences, interests, location or movements – they must be informed accordingly and to the furthest extent.

In the aforementioned cases, whenever the controller is not also the processor, for example in the case of smart traffic lights where the municipality could be the controller and assign the processing to an outside agency, contracts will also need to be reviewed or be put in place governing obligations regarding processing and compliance with the GDPR by all parties.

Finally, having implemented all the relevant systems and procedures, documentation shall also need to be maintained on all relevant aspects, such as having an electronic application for data deletion requests by users and maintaining a detailed log of all breaches. This will require new systems as current ones may not be up to the task.

It should be noted that if data is to be transferred and processed outside the EU, more secure safeguards must be put in place for the transfer and the processing and an audit must be carried out prior to the transfer to assess the situation and take relevant actions, with authorization by the supervisory authority also possible to be required.

4 Conclusions

Due to the extent of urbanization, each of the big cities needs to leverage smart technology solutions. The rapid growth of smart cities and the consequent growth of shared data have elicited the attention of many researchers in different research domains.

The great amount of produced and shared data has also raised an increasing focus on privacy protection. The upcoming implementation of the GDPR will affect every organization that controls or processes data, as well as the data subjects. Each one of these organizations has to adopt and apply a system compliant with the GDPR. In this context, smart city services have to comply with it too.

In spite of the fact that the GDPR makes increased obligations for entities that process personal data, it also aims to encourage a Digital Single Market across the EU. The GDPR plans to promote innovation, as long as organizations use the suitable shields.

Future research should focus on the changes that arose after the implementation of the GDPR, how all concerned parties were affected and the problems faced during implementation by organizations, so new proposals could be put forward for tackling said issues.

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Connected and Autonomous Vehicles – Legal Issues in Greece, Europe and USA

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Abstract. Autonomous (AV) and Connected Vehicle (CV), often mentioned as CAV's, rush their way into automobile market. Consumer cars are increasingly equipped with systems that perform driving functions, either by themselves or by communicating with external systems, thus cancelling the need for a person to be driving. Given the fact that road traffic is a highly regulated area, as it bears huge risks for all traffic users, redefining current regulations is more than ever a necessity.

Many countries in the EU and many states of the USA are making effort to create the appropriate legal conditions for full CAV distribution, through amendments of current regulation or introduction of new more sufficient laws and standards. Most of legislative efforts so far, aim in introducing definitions or determine on road testing procedures though there are few more invasive regulations. Two parameters are taken into consideration on most cases: tort liability and data privacy. Tort liability is used to define who is to blame in case of an accident. Data Privacy is also very important as data sharing is greatly involved in CAV's operation. This paper presents current legal framework in EU, USA and Greece along with the most significant efforts in adopting new CAV friendly legislation, leading to a variety of issues that need to be addressed so as to ensure public safety and to ease CAV's deployment.

Keywords: Autonomous vehicles · Connected vehicles · Legal issues

1 Introduction

Autonomous (AV) and Connected Vehicle (CV), often mentioned as CAV's, rush their way into automobile market. Consumer cars are increasingly equipped with systems that perform driving functions, either by themselves or by communicating with external systems, thus cancelling the need for a person to be driving.

Vehicle automation changes the driving risks in many regards and therefore requires an assessment of all traffic and vehicle related regulation and standards. Liability in case of an accident, in which an Autonomous or a Connected vehicle is involved, is hard to be attributed following current laws.

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Other issues, which may concern both manufacturers or suppliers and the public, are vehicle testing and registration, driver licensing and specifications of the car insurance policy and the special terms it may require. Finally, CAV's operation demands data sharing, thus complicating regulation concerning privacy issues. This paper presents a review of proposed or enacted regulation in the Europe, the USA and Greece regarding vehicle deployment and data security.

2 Tort Liability in Case of an Accident

In most countries worldwide, the law governing crashes is a mixture of state tort law and state financial responsibility laws that define insurance for drivers. Literature [1, 2] defines there are three theories of tort liability for drivers (a) traditional negligence, (b) no-fault liability and (c) strict liability. Liability is due to (a) negligence, (b) strict liability or (c) breach of warranty [3], which involves product defects as well. In the case of breach of warranty, accident liability could originate either from (a) manufacturing defect, (b) failure to provide adequate information regarding product warnings to the buyer at the time of sale and (c) design defect. Therefore, three parameters must be examined in order to determine who is responsible for the accident: (a) driver's liability, (b) vehicle's liability and (c) occurrence of other factors that cannot be predicted such as bad weather conditions or the existence of an obstacle on the road.

Another assumption that is common in the current legal framework is that of a person being behind the wheel. The driver's fault is proven to be right in most of the cases, approximately in 94% of the accidents, as statistics show [4]. However, things change when an autonomous or connected vehicle is involved in the accident, and vary depending on the level of automation. Especially in the case of a fully automated vehicle where no driver is expected to be sitting in the driver's seat, the current legal framework does not apply. Things become more complicated when liability is to be defined when partially automated vehicles are involved in accidents. Liability in these situations depends equally on the driver's ability to respond to the emergency and his notification from the vehicle's systems upon the need of taking control.

3 Data Sharing and Data Security

Data sharing plays an important role in the deployment of CAV's. A different kind of technology has been proposed for use or has already been installed on CAV's. One of the most popular technologies, if not the most popular one, is the use of GSM systems, that make use of the user's mobile phone in order to transmit data. According to [5], relying upon the user's phone is probably the right choice because people tend to trade in their smart phones for more sophisticated models every 18 months. Other ways of sharing data include Dedicated Short Range Communications – DSRC Systems, Bluetooth and WI-FI connection. Sending and receiving of data (personal or not) through the internet, can lead to its exposure in case of security failure.

Therefore, there are a lot of issues that need to be solved and questions to be answered, before CAV's are put to public use, which include the definition/standardization of: (a) the kind of data transmitted and the kind of systems receiving it, (b) who is collecting the data, the purpose of data processing and the purpose for data collection, (c) possible use of the collected data and of the cases in which this may happen and (d) the security systems that are used as to protect personal data.

4 European Legislation and Regulation

Being members of the UNECE (United Nations Economic Commission for Europe), European countries are obliged to conform to all regulations and standards that are set by it. When it comes to traffic, the UNECE Inland Transport Committee (ITC) is the platform responsible for facilitating the international movement of people and goods through the adoption of international agreements and conventions. Although new proposals are under investigation, in most European countries drivers' behavior is covered by traffic rules, criminal and civil law, the regulations of the 1968 Vienna Convention, depending on whether it has been ratified or not, and Directive 2006/126/EC [6].

The 1968 Vienna Convention treaty is one of the biggest hurdles in the EU's connected and autonomous vehicles deployment efforts due to Articles 8 and 13. According to Article 8 "Every moving vehicle or combination of vehicles shall have a driver" and according to Article 13 "Every driver of a vehicle shall in all circumstances have his vehicle under control…". These two statements ban the implementation of highly automated driving in all Countries that have ratified the treaty, as it only permits partially autonomous systems to be used under a driver's supervision.

In 2014, an amendment of articles 8 and 39 that allows vehicles that are equipped with automation systems to be in accordance with the Vienna Convention treaty as long as a driver is sitting behind the wheel at all times and is capable of taking charge of the vehicle and overriding these systems, in case of an emergency. Along with the Vienna convention treaty requirements, another set of technical demands that are described in UNECE Agreements of 1958 and 1998, should be fulfilled. In 2014 the European Union proceeded to the ratification of 118 Standards of the 1958 Agreement and 16 Standards of the 1998 Agreement, aiming at the modernization of its legal framework that affects new cars. It is worthwhile to mention that regulation No 79, which concerns the steering equipment, specifies that full automated steering is not permitted when the vehicle is moving with a speed higher than 10 km/h [17].

European Union's efforts on CAVs' regulation are ongoing. Since 2008, the EU has initiated a number of research projects examining the potential of CAV's, like DRIVE C2X, HAVEit, CITYMOBIL 1 & 2, ADAPTIVE, COMPANION and HORIZON 2020, defining new needs and problems that are still not predicted [6]. Along with these projects, three new directives are on the way and are expected to comply with national legislation between 2017 and 2023 [8]. These directives will ensure that testing of roadworthiness, road inspection and vehicle registration checks take place regularly so as to ensure road safety. Similar acts have been proposed by some European countries, like France, Sweden, the Netherlands and Spain.

However, none of these acts has led to new obligatory CAV friendly legislation. Bartels et al. [9] mention that there are few legal issues, mentioned in 1968's Vienna

Convention treaty and Regulation 79, which should be addressed through new legislation like maneuver automation, driver's location or maneuver coordination.

Recently, new approaches to ethical and legal issues were presented by the UK and the German Government. UK's "Automated and Electric Vehicles Bill 2017-19" was published on 18th October 2017. The first part defines the insurance issues that come up when an automated or self-driving car gets involved in an accident while Part 2 defines another aspect by including the human "driver" as a person that should be compensated in case of an accident when the vehicle is driving itself. Germany's Ethics Commission "Automated and Connected Driving" Report aimed to "develop the necessary ethical guidelines for automated and connected driving". It concluded in eleven issues concerning, among others, dilemma situations, where in critical conditions the vehicle has to take a decision between two unfortunate outcomes, equality, subjugation to technical systems, liability and utilization of collected data.

Regarding data privacy and sharing, European Union's Directives 95/46/EC, 2005/58/EC, 2006/24/EC, 2009/136/EC, 2016/680/EE and 2016/681/EE, as long as the EE Convention for the "Protection of Human Rights and Fundamental Freedoms" [10], and Regulation 2016/679 on the "protection of natural persons with regard to the processing of personal data and on the free movement of such data", are in force. Furthermore, several European Commission Organisations such as DG MOVE, DG JUST, DG CNECT & DG GROW are working towards an easy, safe and more effective way of universal data. As mentioned in European's Commission report [11] "the protection of personal data and privacy is a determining factor for the successful deployment of cooperative, connected and automated vehicles".

5 USA Legislation and Regulation

US Department of Transportation through the National Highway Traffic Safety Administration (NHTSA) has been making efforts to embrace new technologies that make driving safer. Apart from the US DOT, which sets rules for all state members, each state has the ability to act on its own. As of 2011 twenty-one U.S. states have voted in favor of amendments to their legislation or proceeded in adopting new legislation concerning CAVs, while governors of 5 other states issued executive orders related to autonomous vehicles.

The first state that adopted automated vehicle legislation was Nevada. Nevada's AB 511 (2011) did not contain much detail on how automated vehicles should be regulated, but triggered the adoption of necessary legal terms for vehicle testing. In 2013 enacted Bill SB 313 allowed the testing of autonomous vehicles on highways as long as a human operator was seated in a position that would allow him to take manual control, if necessary. Apart from setting driver specifications, the bill clarified liability issues concerning the manufacturer. Bill SB 313 was amended in 2017 so as to allow the operation of a fully autonomous vehicle without a human operator as long as certain requirements are satisfied.

In 2012, Bill SB 1298 was enacted, which required the Department of the California Highway Patrol to adopt safety standards and performance requirements so as to allow the safe operation of autonomous vehicles for testing reasons. Complementary bills were enacted in 2016 and 2017 so as to set requirements concerning the testing of vehicle platooning and driver's authorization [12].

Florida's first bill concerning CAVs was enacted in 2012. The 2016 bill (HB 7027) eliminated the requirement for a human operator to be present and allowed the operation of autonomous vehicles for non-testing reasons. Michigan was also one of the first states to introduce "CAVs friendly" legislation. In 2013 Bill SB 169 was enacted. Subsequent legislation was voted to address liability issues and permit operation on public roads. Other states have also voted laws concerning autonomous vehicles' definitions or testing requirements, as shown in Table 1. For example, Louisiana and North Dakota are states that have only introduced key terms into their state legal code and mentioned the necessity of new appropriate legal policy. According to some of these regulations, authorities are expected to supply manufactures, suppliers or others, with special permits or license plates and in return, manufactures are expected to write and deliver reports explaining test results, accident data and conclusions [13]. Apart from these states, Pennsylvania and Virginia have also introduced legislation indirectly connected to autonomous driving. Table 1 summarizes US legislation, based on the information available at [12, 14]. Data is categorized upon legislation context, aiming to demonstrate the different approach of each state.

The biggest problem in US legislation is the fact that there are too many different standards since each state adopts and enacts its own laws. That is a major issue for manufacturers and suppliers. The need of a common legal framework is stated in NHTSA's report [4] and led to a Federal Automated Vehicles Policy aiming "to accelerate HAV revolution". However, NHTSA's Policy is introduced as guidance

Table 1. Review of US legislation on CAVs (up to February 2018).

STATE / CONTENT	Definitions / Committee on CAVs	Testing	Platooning	Public Operation	Liability Issues	Bill, Year
Alabama	X					SJR 81, 2016
Arkansas	X	X	X	X		HB 1754, 2017
California	X	X	X		X	SB 1298, 2012 / AB 1592, 2016 / AB 669, 2017 / AB 1444, 2017 / SB 145, 2017
Colorado	X	X			X	SB 213, 2017
Connecticut	X	X		X		SB 260, 2017
Florida	X	X	X	X	X	HB 1207, 2012 / HB 599, 2012 / HB 7027, 2016 / HB 7061, 2016
Georgia	X			X	X	HB 472, 2017 / SB 219, 2017
Illinois	X					HB 791, 2017
Louisiana	X					HB 1143, 2016
Michigan	X	X	X	X	X	SB 996, 2016 / SB 997, 2016 / SB 998, 2016 / SB 169, 2013 / SB 663,2013
Nevada	X	X	X	X	X	AB 511, 2011 / SB 140, 2011 / SB 313, 2013 / AB 69, 2017
New York	X	X				SB 2005, 2017
North Carolina	X		X	X		HB 469, 2017 / HB 716, 2017
North Dakota	X					HB 1065, 2015 / HB 1202, 2017
South Carolina	X		X			HB 3289, 2017
Tennessee	X	X	X	X	X	SB 598, 2015 / SB 2333, 2016 / SB 1561, 2016 / SB 676, 2017 / SB 151, 2017
Texas	X	X		X	X	HB 1791, 2017 / SB 2205, 2017
Utah	X	X				HB 373, 2015 / HB 280, 2016
Vermont	X					HB 494, 2017
Washington, D.C.				X	X	DC B 19-0931, 2012

rather than rulemaking. Therefore, it is up to each manufacturer to comply or not with its content.

According to current legislation and NHTSA's guidance, all vehicles that are compatible with Federal Motor Vehicle Safety Standards (FMVSS) are allowed to travel on public roads. That requirement applies to Highly Automated Vehicles (HAVs) as well. So, if a HAV meets that requirement, there are no legal obstacles that would prevent a sale. Regarding legislation, the report makes it clear that states' and NHTSA's responsibilities should not change for CAVs but should remain different and clearly separated as they are for non-CAV vehicles. Specifically, states' authorities should remain responsible for licensing drivers and registering vehicles, enacting laws, performing safety inspections and regulating issues that concern vehicle insurance. In NHTSA's project, a model regulatory framework is proposed, for States that wish to regulate procedures for testing, deployment and operation of AVs.

Regarding data protection and data privacy, literature and legislation review leads to three categories of used legislation [15, 16]:

1. **Constitutional protections.** The Fourth Amendment of the U.S. Constitution guarantees the "*right of the people to be secure in their persons, houses, papers, and effects, against unreasonable searches and seizures*".
2. **Federal laws.** There are several federal privacy laws that regulate the collection, use and disclosure of data in the finance and health sectors. Among them are the Privacy Act of 1974, the Electronic Communications Privacy Act (ECPA) and the Computer Fraud and Abuse Act (CFAA). Additionally, the Federal Trade Commission has introduced the FTC Act to focus on *"unfair or deceptive acts or practices in or affecting Commerce"*.
3. **State laws**. There are numerous additional privacy protections under U.S. state law covering a broad array of privacy-related issues, such as data disposal, privacy policies and security breach notification. California is considered to be a leading legislator in the privacy arena.

6 Greek Legislation and Regulation

In Greece, driver behavior, driver liability and vehicle registration are covered by traffic rules, civil and criminal laws. The Government's "Road Traffic Regulation" was amended in 2012 and it consists of four parts. Along with the 2012 Regulation, legal issues are handled in accordance with governmental law "On Vehicle Criminal responsibility and Liability" which was established in 1911.

The 2012 Road Traffic Regulation sets a huge obstacle for AV implementation in the Greek market. As mentioned in paragraph 1 of article 13 "All moving vehicles or combination of vehicles must have a driver". Further information on the necessary skills of the driver is then provided, making it clear that no self-driving car should be allowed to move on the road. An exception to that rule was established in 2014 (Government law No 4313), to allow registration of a self-driving bus, integrated with city Mobil 2 EU's project. The bus was monitored through cameras and a licensed driver was responsible to remotely stop the vehicle in case of an emergency. The driver was also considered liable in case of an accident as if he was actually driving the vehicle.

Regarding data privacy and sharing, Greece's legal framework is more sufficient. Hellenic Data Protection Authority (HDPA) is responsible for taking decisions, establishing acts and providing information on personal data privacy and protection in Greece. Apart from the European Union's directives, there are the following laws and Regulation Acts that determine the way personal data is handled [17]:

1. Law 2472 established in 1997, titled "Protection of people from processing of personal data", stating that processing of personal data is legal only if it is collected in legally defined ways, under specified purposes, on the amount that is absolutely necessary in order to serve these purposes and only after authorization is granted. It was amended in 2006 to embody Directive 2002/58/EC and involve electronic communications (Law 3471).
2. Law 3783 established in 2009, managing the way mobile phone users and service providers are identified.
3. Law 3917 established in 2011 to embody Directive 2006/254/EC of the European Union to Greek legislation, determining how data is stored after processing.
4. Hellenic Data Protection Authority's (HDPA) Acts on Traffic Management Cameras (Decision 58/2005), on the operation of CCTV systems in public areas (Opinion 1/2009), on the destruction of personal data after the end of the period that is required for the accomplishment of the processing purpose (Directive 1/2005) and Decision 91/2009.

Given the fact that vehicle technology is rapidly evolving, the need to establish an appropriate legal framework is becoming more crucial day by day.

7 Conclusions

The paper presents the current legislation and the issues that derive from it concerning Connected and Autonomous Vehicles' deployment, in the US, EU and Greece. Although efforts have been made to clarify and resolve such issues, the need for constant and rapid development of the legal framework is still present, as many questions are still to be answered. Liability in case of an accident is an important issue, originating from the fact that current legislation requires a driver to be sitting behind the wheel. As far as CAVs are concerned such legislation cannot be applied. Data privacy and security are also under investigation. Based on the fact that CAV require personal data exchange, new regulations should be established to ensure safety and protection of such data.

Although US States have introduced new laws on CAVs, many more than EU Country members, the lack of federal legal framework opposes to the deployment of such vehicles. Greece, as a member of the European Union, will eventually comply with EU Directives. However, supplementary work should be done to achieve full correspondence to the needs of the upcoming technology. Overall, efforts are ongoing, new laws are under vote and legal framework is expected to change globally in the years to come.

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Implementing a Blockchain Infrastructure on Top of Vehicular Ad Hoc Networks

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Abstract. Vehicular ad hoc networks have attracted a lot of research recently, because of the multiple possible applications. Blockchain is a new approach to designing distributed storage infrastructures. In this paper the implementation of a blockchain infrastructure on top of vehicular ad hoc networks is presented. The main motive is to create a peer to peer shared storage between vehicles traveling in a specific area that may enable them to collaboratively produce data that can be used by them or even sold to other vehicles. A proof of concept experiment has been conducted through simulating the proposed system functioning by using a real world dataset containing vehicles GPS coordinates.

Keywords: Blockchain · Road traffic congestion · Vehicle to vehicle Peer to peer · Tokens · Crypto-currencies · Monetization

1 Introduction

One of the most interesting technological advancements in automotive industry is vehicular ad hoc networks. The latter are formed by the connection of nodes installed at vehicles moving in relatively short distances. The vehicles participating in such networks can exchange data regarding different applications and provide various services to passengers.

In this paper the design of a blockchain infrastructure on top of such networks is discussed. The use of blockchain technology is being researched regarding multiple domains. In vehicular ad hoc networks multiple nodes which do not trust each other have to collaborate, so blockchain seems like an appropriate approach. The application of blockchain technology in vehicular ad hoc networks is researched and a traffic congestion estimation scenario is presented, in order to demonstrate a real world use case.

The presented approach contributes to the application of autonomous vehicles technology in real world scenarios. One of the main use cases for blockchain technology is to let machines interact with each other and with people. As autonomous vehicles is one of the main research aspects in automotive industry,

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such machine to machine interaction schemes will be required in order to build sustainable urban mobility solutions.

Related research efforts discuss the use of ethereum [1] for replacing central units of vehicular networks [2], the use of blockchain in order to strengthen the security of cryptography keys management in vehicular networks [3] and the implementation of an infrastructure that would enable payments between vehicles or sharing of vehicles [4].

Vehicular ad hoc networks are presented in Sect. 2, blockchain technology is briefly discussed in Sect. 3, while the system design is analyzed in Sect. 4. Section 5 presents the simulation run to test the system and in Sect. 6 the conclusions are discussed.

2 Vehicular Ad Hoc Networks

2.1 General Description

Vehicular Ad hoc Networks (VANETs) stands as an important network category aiming at connecting mobile nodes (private and public transportation vehicles) in common road networks. Similar terminologies for this category are also Vehicle to Vehicle (V2V) or Vehicle-to-Roadside networks, Vehicle-to-Internet, as well as Intelligent Transportation/Transport Networks (ITNs).

VANETs are actually a class of Mobile Ad hoc Networks (MANETs) as they perform as a continuously self-configuring wireless network of mobile devices, which is purely independent from the infrastructure needs [5]. Due to the large spectrum of different application domains, this kind of wireless networks developed a significant field of research in networking [6].

The main scope of VANETs is to allow vehicles to move independently in any possible route direction, by dynamically changing the communication links among other vehicles, and forwarding data upon the benefit of all peers. As types of VANETs we have those that operate internally in a "closed" mesh-type network and those that can be connected to Internet.

2.2 Applications

VANET technologies present several challenges for the wireless communication research community. There are many interrelated issues that need addressing with respect to performance, reliability, scalability, as well as security and privacy preserving. An important application domain considered is Smart Cities and mainly Intelligent Transportation/Transport Systems (ITSs).

As far as Intelligent Transportation Systems (ITSs) is concerned, the authors in [7] present three types of communications namely (i) inter-vehicle, (ii) vehicle-to-roadside, and (iii) routing-based communication. In the first type, we have applications that transform vehicles in "intelligent peers" capable of communicating between each other, aiming at achieving autonomous driving, event detection, etc. The second category mainly deals with real-time high-velocity data streams between multiple peers and roadside stations, trying mostly to solve efficiency, integrity and security issues for the network infrastructure, as well as to tackle privacy issues for the end users. The third category of communication, handles organizational aspects such as peer discovery, network sustainability and related optimization matters, as well as economic issues.

Finally, smart cities as an ecosystem of intelligent sensors around an urban area, will significantly benefit, since sustainable growth applications can be implemented over the network and data exchanged across vehicular communications. Some of them include road-traffic applications (e.g. real-time traffic congestion and routing information for citizens and drivers, fleet management in logistics), information sharing applications (e.g. media and content sharing), as well as applications over the power-providers infrastructure (e.g. charging scheduling with minimal waiting, optimization of charging stations etc.).

3 Blockchain

Blockchain [8], introduced through bitcoin cryptocurrency [9], is one of the most popular technological advancements in recent years. The basis of the technology is a mechanism that enables multiple nodes to maintain a shared ledger of information. The innovation of blockchain is based on the fact that this collaboration is made possible without requiring any central node or pre-established trust between the nodes. In this notion the use of blockchain has been proposed in different domains whenever there is a need for establishing trust between nodes, maintaining the integrity of stored information or incorporating payments functionality in an application.

The most used consensus mechanism is proof of work [10], in which a fraction of the nodes participate in the mining process and maintain the integrity of data stored at nodes. Specifically each mining node consumes electric power and tries to solve a mathematical problem that is too demanding in terms of resources. Miners compete against each other in order to be the first who constructs (mines) and shares the next block of certified information. In return the node that manages to mine the next block first is rewarded with an economic benefit.

The main applications of blockchain technology are found in the economy domain. Transactions between users or organizations can be efficiently served by blockchain solutions. Additionally the technology has been incorporated, in order to record property rights or even intellectual property rights. Another industry that seems to be a good fit for blockchain is sharing economy applications, as it can set the interaction between participants feasible without requiring a trusted third party.

4 System Design

4.1 Architecture

Each node (vehicle) is associated with an account (a pair of public and private keys). A token (coin) is used to enable economic transactions and each account holds a specific balance of such tokens. The nodes are able to communicate, with other nodes that are in a relatively short range. In practice they create a dynamically and partially connected peer to peer network. At each time point, each node connects with a subset of all nodes (the nodes around it). In the next time point this subset of neighboring nodes may change, due to vehicles movement.

The main idea is that nodes can form a peer to peer network that even if it is not fully connected, it can emulate the propagation of transactions happening in bitcoin network. The flow of information is adequate, in order to let the nodes maintain an up to date ledger of information submitted by all nodes.

In our scenario each node submits its GPS location. The aggregate information may then be used to estimate traffic congestion.

4.2 Transactions

Each one of the nodes transmits to the peer to peer network a tuple that contains the time-stamp and the latitude and longitude coordinates of its location. The node also adds its public key to the tuple and signs it by its private key, to certify its identity.

$$tr_{loc} = ((t, x, y, pub), sig) \tag{1}$$

The node transmits this transaction to all the neighboring nodes. The nodes that have received the location transaction, can now transmit it to their neighbors that have not yet received it. In this way these transactions propagate to the whole network.

4.3 Blocks

In order for these transactions to be validated, some of the nodes act as miners and compete to each other, in order to successfully mine the next block. Before they start mining they first validate all location transactions as it will be analyzed in Subsect. 4.5. The successful miner typically adds a miner's reward transaction, that sends rew_{min} tokens to his account (public key).

All the location transactions and the fees transactions that have recently gone through are validated and included in the block. Additionally the miner updates the balances record that exists in each block. This record holds the updated balance for each account after all the fees transactions of the block have gone through. This is required as older blocks are discarded as new ones are created and it would otherwise be impossible to validate new fees transactions against history.

$$record_{bal} = ((pub_1, bal_1), (pub_2, bal_2)..., (pub_n, bal_n)) \tag{2}$$

The successful miner signs the block with his public key. The miner sends $((block, pub_{min}), sign_{min})$ tuple. The block is then propagated to the whole network in the same way that the transactions are.

4.4 Propagation

The receiver of the transaction or the block in the first hop pays to the sender a small propagation fee fee_{pr}. In the next hope the received transaction or block is forwarded to neighboring nodes. Those pay half of the previous fee, $\frac{fee_{pr}}{2}$. Each node sells data for half the price he has payed for it. This means that a node can halve the cost by forwarding it to one node, cancel the cost by forwarding it to two nodes or even make profit by forwarding it to more nodes. In this way the nodes will have an important incentive to propagate transactions and blocks to all members of the network.

4.5 Validation

A protocol for validating information tuples is presented. The goal of this protocol is to give the nodes a way to validate each tuple and be sure that the data are not tampered with. Two conditions must be true for a tuple to be valid, a node must have realistic speed and the position must be able to be cross referenced through the network.

As mentioned the data consists of a longitude and a latitude as well as a time-stamp. For the first predicate to be checked this is enough information. Each node has a maximum speed, hence checking the distance between two tuples with time-stamps t_i, t_{i+1} suffices for answering the first condition. Formally, let the two tuples be (t_i, x_1, y_1) and (t_{i+1}, x_2, y_2), if $\overrightarrow{u} = (x_1, y_1)$, $\overrightarrow{v} = (x_2, y_2)$ and $d(\overrightarrow{u}, \overrightarrow{v}) = \|\overrightarrow{u} - \overrightarrow{v}\|$ then the first condition is as

$$d(\overrightarrow{u}, \overrightarrow{v}) \leq max\_speed \cdot (t_{i+1} - t_i) \tag{3}$$

For the second condition extra information is needed. Particularly, the information of data propagation inside the network. That information is defined as an ordered list of the public keys of the nodes the data has passed through.

Let node v_1 send information about his position to v_2. Then, v_2 has to check if the position of v_1 is inside the allowed radius to send that information. If that is true for the first two nodes, then inductively it can be assumed that the integrity of the information is maintained until the last node that receives the data.

Formally, if v_i with position $\overrightarrow{u} = (x_1, y_1)$ sends information to v_j with position $\overrightarrow{v} = (x_2, y_2)$ (for $i \neq j$) and $d(\overrightarrow{u}, \overrightarrow{v}) = \|\overrightarrow{u} - \overrightarrow{v}\|$, then the second condition is defined as

$$d(\overrightarrow{u}, \overrightarrow{v}) \leq max\_distance \tag{4}$$

where the maximum distance is the radius of the sender.

5 Testing Platform Applicability

In order to test the applicability of the proposed system a simulation with real world data has been conducted. In particular the scenario that has been tested is whether a group of vehicles of a medium sized city could collaborate in a decentralized way and produce information regarding the road traffic congestion.

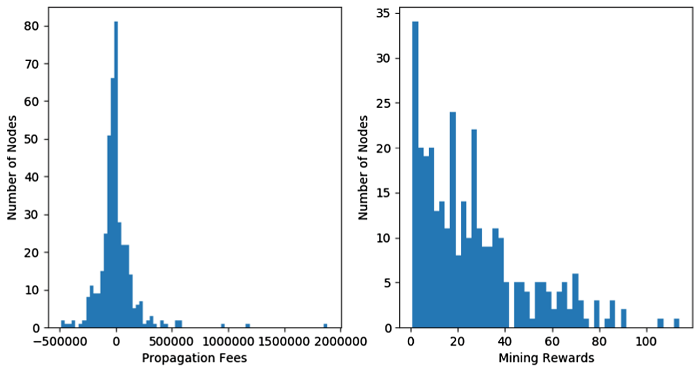


Fig. 1. Propagation fees and mining rewards

5.1 Dataset

The real world dataset[1] that has been used is related to the GPS locations of 442 taxis in the city of Porto in Portugal [11]. We have tried to test if this group of vehicles would be able to collaborate according to the proposed scheme. We try to estimate the economic outcome of the collaboration for the nodes that make up the blockchain infrastructure. By calculating the fees mentioned in the previous Section we try to depict if the group of vehicles can monetize their collaboration and what is the relation between the traveling pattern of a taxi and its income throughout the simulation.

5.2 Methodology

Each GPS location record in the dataset is used in order to construct a location transaction and propagate through the network. At specific time intervals, every five minutes, a miner successfully mines the next block and this is also propagated to the network.

5.3 Results

We have conducted a simulation for the first month of the dataset. The results depicted in Fig. 1 show the balance for all taxis with respect to the propagation fee fee_{pr} and the mining reward rew_{min}. The histogram on the left hand-side shows the distribution of nodes' total propagation fees. Nodes that are favored from the protocol have received more in propagation fees than what they have spend and have positive balances, while others are not favored by the protocol and end up with negative balances. The histogram on the right shows the income of nodes from mining rewards. Nodes the traveling pattern of which has enabled

[1] https://archive.ics.uci.edu/ml/datasets/Taxi+Service+Trajectory+-+Prediction+Challenge,+ECML+PKDD+2015.

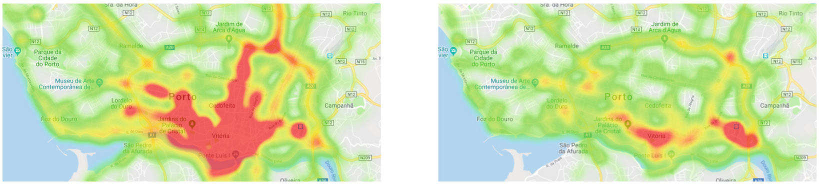
them to participate in the mining procedure more frequently have higher income than others.

In order to find out which are the factors that define the balance of each node we calculated the Pearson Correlation Coefficient (PCC) [12] of balances of nodes against three different parameters; namely total number of points submitted, average distance from city center and average number of nearby nodes. The PCC values were respectively 0.31 (p-value 10^{-18}), 0.07 (p-value 0.19) and 0.23 (p value 10^{-5}). It obvious that the balance is decided mainly by the number of points submitted. Additionally moving in areas with higher nodes' population seems to have a positive effect on the final balance.

In order to depict this correlation, Table 1 shows metrics and balances for two taxis, with ids 351 and 160, while Fig. 2 show the respective moving patterns through the city. The two taxis chosen have very different balances as taxi with id 351 is much more wealthier than taxi with id 160. The main reasons for this is that the first taxi has on average 34.8 neighbors against 20 of the second taxi and that it has submitted 28874 location points against 6859 of the second taxi.

Table 1. Metrics and balances for taxis 351 and 160

Taxi id	351	160
Av. distance	7.7 km	3.9 km
Total points	28874	6859
Av. neighbors	34.8	20
Prop. fees	558564	−11104
Min. rewards	105	18



(a) Taxi 351 (b) Taxi 160

Fig. 2. Traveling heat-maps

6 Discussion

The propagation procedure does not create tokens so it is normal to have some nodes with negative and some with positive balances. The sum of all balances is equal to zero. On the other hand the mining procedure creates new tokens so the sum of balances is positive and represents the tokens created throughout the simulation. It seems that according to the traveling pattern of each node, it is common to have nodes that at the end of the simulation have a negative balance. The mining reward has to be significantly higher (5 orders of magnitude) than propagation fee in order to enable all nodes to have positive balances. Additionally this requirement makes sure that there ill always exist a sufficient total number of tokens.

Finally it seems that collaborating nodes have to submit as much information as possible to maximize their profits. This makes the traffic congestion estimation much more efficient. On the other hand vehicles have to be close to other nodes. This may have negative effect as data for areas with few nodes will be hard to be collected. A weighted (according to rarity) fee may be researched in a future work, to create an incentive for collecting data from all city areas.

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Shared Autonomous Electrical Vehicles and Urban Mobility: A Vision for Rome in 2035

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Abstract. This paper deals with a first attempt to evaluate the technical and economic feasibility of a sharing mobility scenario for the central area of Rome in the year 2035. The main aspects of the proposed scenario focus on the use of electric automated vehicles, on car sharing, on limitations of the use of private cars and on road pricing in the central area of the city. The results indicate a technical and financial feasibility of the scenario.

Keywords: Automated vehicle · Sharing mobility
Travel demand management · Electric vehicles

1 Introduction

Central areas in cities are the ones that most suffer the negative impacts on high volume of private traffic, such as, among others, congestion, air pollution and health risks. Local authorities around the world are putting in practice low-carbon transport policies aimed at reducing use and ownership of private cars in cities. A possible solution is a technological change: it refers to the rising of automated vehicles AVs, which have the potential to substantially affect road crashes and energy use. If combined with eco-friendly technologies, as electric engine, automated electric vehicles (AEVs) could represent a clear opportunity to reduce air pollution and health risks in central areas. Besides, [1] AEVs are an effective candidate to raise a fleet of shared vehicles (SAEVs), opening the way also to congestion reduction.

In general, the main benefits for the community arising from the use of SAEVs services could be:

- the reduction of the number of cars parked on the road;
- the high rotation of the material: shared cars are used intensively, and hence tend to be renewed more frequently than private cars;
- the users have the opportunity to drive newer vehicles than those ones they would use in the absence of car sharing service, whit several advantages:

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- highest road safety [2], as recent automated vehicles are more and more secure;
- less environmental impact [3, 4] due to the evolution of technology in terms of emissions and consumption;
- vehicles will be dismantled for wear and not for aging, so each one can develop a larger mileage;
- gain in road capacity and accessibility [5–7];
- potential increases in travel demand [8].

This paper deals with a first attempt to evaluate the technical and economic feasibility of a mobility scenario for the city of Rome in the year 2035. The main aspects of the proposed scenario focus on the use of electric and automated vehicles, on car sharing, on limitations on the use of private cars and on road pricing in the central area of the city.

The paper is composed as follows. Section 2 reports a literature review, Sect. 3 presents the study area, Sect. 4 presents the strategic transport plan of the city, and Sect. 5 reports a mobility scenario for 2035 for the central area. Finally, some conclusions and future developments of the study.

2 State of the Art

New policies to manage and regulate the introduction of automated vehicles [9] and the simulation of the effects deriving from the introduction of an automated vehicle fleet in a city are needed. Some studies was conducted at Lisbon [10], Stuttgart [11], Zurich [12], Boston [13], to name a few. In EU, the Citymobil2 project was developed [14], devoted to test automated road transport systems (both individual and collective). A general framework to evaluate how the capacity change with the introduction of automated vehicles is developed in [15] with a formulation considering different lane policies (e.g. lane mixed use, lane reservation). The use of reserved lanes for AVs is proposed in [16].

Other aspects explored in literature are: the design and the management of the service to make vehicles available to users [17], the impact on parking [18], the role of charging infrastructures [19], [20]. Besides, some papers deal with the importance of the users perception of automated vehicles [21] and with their behaviour exploring the impact of behaviour to adopt shared services [22] to choose an automated vehicle [23].

3 The Study Area

Population and Mobility
The city of Rome has 2,913 million of inhabitants and extends over an area of 1,283.70 km^2. The area is divided in six zones according to the PGTU (General Urban Traffic Plan). Four of the six zones are inside the main ring road around Rome; the fifth zone is outside and includes urban perimeters of some relevance; the last zone is located in the west part of the city (Fig. 1). The private car fleet corresponds to 856 vehicles every 1,000 inhabitants, one of the biggest among major Italian and European cities.

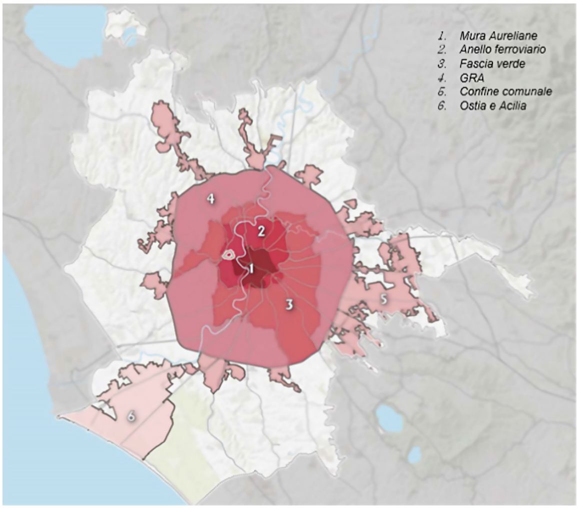

Fig. 1. Rome zones (PGTU 2014).

Trips generated from Rome inhabitants amount to 4.7 million a day, while trips generated from outside inhabitants, which go to Rome everyday especially for working, are 800,000. Trips generated/attracted at peak time (7.00–10.00 a.m.) in the morning are 600,000: 60% of these trips are generated from the middle circle of Rome (zone 3 and zone 4) and 70% of these trips are attracted towards the three most central areas.

The central area of the city is the area inside the railway ring (in the following RRIA), composed by the zones 1 and 2 of Fig. 1. At peak time in the morning, the internal trips are 76,000, trips towards the outside 36,000 and finally the attracted 132,500. The modal division for those trips is shown in Table 1.

Table 1. Modal share.

	Car	Public transport	Car sharing	Other
Internal	17%	54%	0%	29%
To outside	61%	30%	0%	9%
Attracted	38%	44%	1%	17%

Restricted Traffic Areas

Currently three systems of access control are active in the city of Rome: in the historical center (zone 1 of Fig. 1), in Trastevere quarter and in San Lorenzo area. These control systems are active at different time of the day, of the week and of the year. The restricted traffic area of the center is active for the whole year from Monday to Friday from 6:00 to 18:00 and on Saturday from 14:00 to 18:00. The restricted traffic areas of San Lorenzo and Trastevere from 21:00 to 3:00 for certain days of the week.

Public Transport

The subway system is made of three lines; A (long 18 km with 27 stations), B (long 23 km with 26 stations) and the newest C (17.5 km with 21 stations). Further, eight regional railways exist (from FL1 to FL8) and the Leonardo Express railway from Termini train station to Fiumicino Airport. Besides, there are three other suburban railway lines: Roma-Lido, Roma-Giardinetti and Roma-Viterbo with an overall extension of about 140 km. The public transportation on the surface is organized with lines long 3,600 km: 320 lines covered by bus, 4 lines covered by electric bus, 1 line by trolley bus and finally 6 lines covered by tram.

Car Sharing and Bike Sharing

Two private operators offer a “point-to-point” car-sharing service: Enjoy and Car2Go. Enjoy offers a fleet of Fiat 500 and Piaggio MP3 (scooter sharing) and it is present in Rome since June 5, 2014. Car2Go has a fleet of Smart Fortwo. It should be noted that the area covered by the car sharing service is rather extensive, covering the whole RRIA area and in some directions it extends to the main ring road of the city.

It is currently in the experimental phase “Roma‘n’bike”, the bike sharing provided by a fleet of about 200 bicycles, located in 19 distribution points within the limited traffic area of the city.

4 Strategic Transport Plans

Rail Transport Network

For the year 2035 significant expansion of the rail transport network can be assume, as envisaged by the General Regulatory Plan, approved in 2008 (Fig. 2).

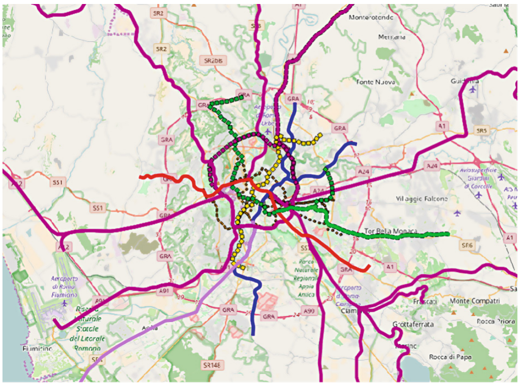

Fig. 2. Rail network at 2035.

An important intervention is the completion of the regional railway ring surrounding the city center, about 12.8 km long and 11 new stations. The opening of seven new stations along the Roma Lido line is also scheduled.

The metropolitan network expansion plans envisaged by the scenario are related to the extension of line A, B and C and the construction the new line D (yellow in Fig. 2). Overall, 84 new stations will be opened and 88.70 new km of railway infrastructure will be built. The reinforcement of the tramway network include the realization of three new lines with a total length of about 17.80 km along which will be located another 107 new stops.

Regulation Measures for RRIA *Planned by PGTU*
From the analysis of the data on the pollutant concentrations, it is apparent that in the RRIA the limits imposed by current legislation in relation to the maximum values are not respected. Therefore, the PGTU considers necessary to implement new regulations for vehicles, tourist buses and freight vehicles. The new rules concerning the RRIA will be implemented through an organic and progressive project that will cover:

1. revision and upgrading of the surface transit network, with more exchange nodes at rail stations and with new tram service corridors;
2. implementation of measures for alternative and/or integrative mobility systems such as bike sharing and car sharing;
3. new RRIA access control system, aimed at moving towards sharing mobility and road pricing.

5 Mobility Scenarios for the RRI Area

Two mobility scenarios for the year 2035 have been considered for the RRIA: the first mainly based on public transport (transit based mobility scenario) and car sharing supply, while in the second also travel demand management measures have been added (sharing mobility scenario).

The scenarios have been assessed through the model system STIT, reported in [24, 25].

5.1 Transit Based Mobility Scenario

Starting from the above indications of the transport plans, a first mobility scenario is hypothesized for 2035 for the rail ring area (in the area, 50 railway stations are located). In this scenario, the SAEVs replace the current taxi, the car-sharing and the ride-sharing services. Besides, it is assumed that the public transport will use automated shuttles with 200 circular lines of about 3–4 km. These shuttles, with a capacity of 20–30 seats, will perform the access/egress from/to railway station with a run every 5 min.

In relation to the modal share in the time slot from 7 am to 10 am, the forecasted travels entering in the RRIA, expressed in percentage, are:

- cars: 30%;
- public transport: 51%;

- car sharing: 4%;
- other: 15%.

In this scenario, the percentage of users using the car is still considered too high. Also for this reason, a comparison between the cost moving with private car and the cost moving with shared vehicles is performed. It emerges that, with current parking fees in on-street parking areas, the cost difference is in average less than the 2%. If the parking is allowed only off-road, using a shared vehicle can reduce the costs up to 50%. So, to encourage the use of the car-sharing, measures to limit the use of private cars are needed.

5.2 Sharing Mobility Scenario

In the transit based mobility scenario emerges the low cost difference between car-sharing and private car: therefore, travel demand management measures to support the car sharing are necessary. Particularly, the imposed rules are:

- on-road parking banned for private cars on most of the main streets (to reserve the on-road parking to the shared vehicles) and on the secondary roads on-road parking allowed only to the resident cars;
- for not resident cars, possibility to use only the routes to or from booked off-road parking;
- road pricing for not resident using the other roads [26, 27].

The introduction of a shuttle service (with automated vehicles) between parking areas and subway or railway stations and improving the bike sharing system [28] integrate these measures.

The New Modal Share
The sharing mobility scenario cause a modification in the modal share:

- cars: 10%;
- public transport: 60%;
- car sharing: 20%;
- other: 10%.

The needed vehicles for car sharing service are about 35,000 (considering an average use of 1.5 h).

Financing the Sharing Mobility Scenario
The financing necessary for the realization of the sharing mobility scenario (not considering the costs for infrastructures, which are already included in the city development plan) are estimated considering:

- 1,000 vehicles for the shuttle service (200 circular lines) with a total investment cost of € 250,000,000;
- 50,000,000 bus * km/year and an unitary cost of 3€/bus * km (service contract), with a total cost of 150,000,000 €/year;

The 35,000 automated vehicles for the car sharing service are on charge to the service private providers.

6 Conclusions

In this paper was reported a first attempt to evaluate (technically and economically) a transportation scenario for Rome in year 2035. The assumptions start from the idea that the RRIA (the zone of Rome inside the rail ring) can be regulated with a policy that permit a change in modal share, from private car to alternative modes. Particularly, are considered a strengthening of the public transport (both in terms of service and infrastructures) and a new mode, like the car sharing with automated electric vehicles (SAEVs). This development of the territory (also called Transit Oriented) would allow to obtain a reduction of the travels with private car from 40% to 10%. In this future scenario, users move from the car mode to public transport and car sharing service. The planned investments concern the purchase of vehicles for public transport and the management of the service (public transport and car sharing) being the costs for the infrastructures already included in the city development plan.

Future developments deal with a deepening of technical and financial analysis with particular attention to the impact on users due to the limitations introduced in the RRIA.

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Geographic Transport Planning Principles in Norwegian City Regions: The Case of Work Travel in Stavanger

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Abstract. The Norwegian Parliament has recently carried out a motion for all Norwegian city regions to curb all growth in private car use and redirect urban travel into public transport, cycling and walking. The county of Rogaland has therefore devised a set of transport and mobility measures for the Stavanger city region, such as a bus rapid system, a cycle highway, toll ring roads, sustainable mobility strategies, but also increased road capacity. This paper examines some of the underlying geographic hypotheses of sustainable transport planning aiming at reduced private car use.

The Stavanger city region is characterised by dispersed development and high levels of car ownership and use, as well as an affluent population. Work travel data is used to investigate geographic factors that are assumed to impact on travel behaviour, such as travel distance, centrality and proximity to public transport. The question is whether the local work travel behaviour confirms typical assumptions about transport-oriented development. This study contributes to a better understanding of urban travel choice and its factors, thus helping to optimise local government efforts to reduce car travel.

Keywords: Transport planning · Transport-oriented development

1 Reducing Car Travel by Understanding Travel Mode Choice

Much effort is invested into making urban transport more sustainable, i.e. less polluting (in terms of CO_2, particles), less area-demanding (in terms of parking), more accessible (for different social groups) and safer, and thus more economically efficient for society as a whole. While technological advances within electric-autonomous vehicles and socially innovative car-sharing concepts can contribute to these ambitions, they will not necessarily reduce car use and depend on private efforts. Therefore, much urban transport planning revolves around changing the modal split towards a lower car share by making private car travel less attractive, and promoting quick, cheap and smooth public transport, and soft travel alternatives (i.e. walking and cycling).

Planning principles such as integrated land use and transport planning, transport-oriented development, the compact city, mixed use, subsidized public transport, parking restrictions, road toll and parking charges, are put in place in order to achieve

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this modal change. These approaches are twofold: on one hand restricting car use through increased taxation, road tolls, and high parking cost; on the other hand promoting sustainable travel modes through providing densely populated areas, with several amenities within walking distance of public transport. Most of these principles aim at factors that subscribe to a rational model of travel decision making (i.e. travel distance/duration, travel cost). In order to affect the modal split more efficiently, however, one has to understand travel mode choice in a broader sense, including qualitative aspects (e.g. public transport frequency and reliability, self-containment), as well as personal aspects of decision making (e.g. demographics, attitudes, motivation, desirability).

This paper attempts to test some of the hypotheses concerning geographic locations with the example of the medium-sized Norwegian city-region of Stavanger.

2 Geographic Urban Transport Planning Hypotheses

Factors impacting on car travel have been vigorously investigated [1–6], and socio-economic factors seem to be among the most significant influences on travel mode choice, while evidence for structural impact is more disputed [5]. The role of psychological factors has recently gained prominence, showing, however, varying results [7–11].

The rational decision making approach in transport planning assumes that the two main factors for travel mode choice are distance/duration[1] and cost. While the cost of transportation might be a decisive factor, this paper investigates the geographic factors, such as travel distance, centrality and proximity to public transport. Many prevalent planning guidelines are firmly based on an assumed relationship between location aspects and travel mode choice. The concepts of densification and walkability (i.e. short distances and high access to facilities) are for instance used as principles to counteract car travel. Some of the underlying hypotheses are described below.

2.1 Shorter Travel Distances Lead to Less Car Travel

Reducing the overall distance between destinations, i.e. reversing the effects of heavily car-oriented zoning of mid-20th century planning, by integrating different land uses in the same area, is one of the main objectives of urban planning principles, such as the compact city and mixed use. The assumption is that shorter distances allow for more sustainable transport modes and reduce the need for car travel. Therefore, intensification is one of the major resolutions of sustainable urban development.

While high density of daily amenities (e.g. grocery shops) can contribute to reduce travel distance to generic facilities, other aspects (e.g. property marked, job marked)

[1] Travel duration is a function of travel distance, travel mode (i.e. speed) and the level of congestion. Therefore, travel duration is excluded here to avoid the tautological assumption that the car always warrants shorter travel duration (particularly for longer journeys in less urban areas).

often heavily influence the location of both residence and work place. This is even more true in medium-sized and sprawling urban areas, where facilities are more dispersed. Also, the journey itself might have a value, and therefore no travel (e.g. home office) might not be the ideal in terms of distance or duration [12].

2.2 Central Destinations Lead to Less Car Travel

Concepts such as decentralized concentration and polycentric urban regions argue that city centres and urban local centres must have a high degree of self-containment and provide mixed-use in order to facilitate more sustainable travel mode choices, this ideally includes the work place. Both Stead, et al. [1] and Næss [2] describe how 'closeness to city centre' is one of the most decisive factors for mode choice. Urban centres are likely to provide a strong public transport system in terms of frequency and choice of destinations. Therefore, policies to locate work places in urban centres, thus promoting a polycentric urban structure, have become widely implemented in local planning.

However, centrality of only residence or work place are not good indicators, since a journey consists of two points and both must be central. Therefore, urban centres must be strongly connected to each other and by public and soft transport infrastructure.

2.3 Proximity to Public Transport Leads to More Public Travel

Transport-Oriented Development (TOD) is mainly concerned with giving urban residents immediate access to public transport. The hypothesis is that if people live within acceptable walking distance they use more public transport. Thus, the 10-minute-city, i.e. the provision of daily local facilities including public transport within ten minutes (i.e. 800 m) walking is a widely implemented ideal for new urban development. Norwegian guidelines recommend high density development around transport nodes, with 300 m to bus stops and 500 m to train stations [13].

An obvious challenge to this hypothesis is that both origin and destination must be accessible by public transport. Given the lack of requirements about frequency, destination or directness of the public transportation on these densified stops, mere proximity to public transport does not necessarily lead to access to good public transportation.

Another challenge with all three discussed hypotheses is that they aim at reducing the need to travel far. However, it has been shown that mixed use development for instance reduces trip length but increases trip frequency [1]. It also remains uncertain whether structural changes to urban form can affect the desire to travel, i.e. differences in quality of facilities might be underestimated or the journey itself might have a value. Also, densification approaches might be less relevant to work destination, since work place location depends on many other factors.

2.4 Other Factors

Affordable Public Transport. With cost being a strong rational factor to impact travel mode choice, and public transport the only travel mode with a discernable price per use, public transport operators often subsidise ticket prices to make public transport more attractive. They can also offer monthly or annual tickets and automated charging systems, reducing the perception of paying per trip [14]. The effect of positive financial incentives might however be mediated in affluent populations.

Road Pricing and Parking Restrictions. Considering the strong foundation of car travel habits in the Norwegian context, road tolls can be an effective measure. Combined with rush-hour charges, this can avert driving in general, but particularly during peak hours. However, the public often meets negative financial incentives with strong resistance and deem them socially unjust. Another measure can be to reduce the amount of available parking and increasing parking fees for residual parking areas.

Socio-economic Factors. Income and household size have previously been shown to be strongly associated with travel mode choice [1, 15]. Gender, age and the level of education might also play a role.

Psychological Factors. Subscribing to a more affective model of modal choice, the level of available information can be related to more sustainable attitudes, such as awareness about the effects of travel mode choice and pro-environmental intentions. Social constructs (e.g. norms, expectations, roles, self-image) and personal psychological factors (e.g. positive/negative emotions) might also play a role [16–18]. The effect of habits, i.e. the absence of conscious decision making, as a mediating factor seems to be underestimated and needs to be further investigated [19].

3 Work Travel Patterns in the Stavanger Region

The Stavanger city region is situated on the southwestern coast of Norway and consists of four municipalities. It is 446 km^2 in area and has a population of 245.115 [20], with two main urban centres, Stavanger and Sandnes. The following analysis is the preliminary study of geographic influences on travel mode. The data is generated through a work travel survey conducted by the personal transport planning initiative ‘Home-Work-Home’. The initiative aims at reducing car travel among companies located within the city region and their employees and it is one of the measures implemented in the region to achieve zero-car growth. The analysis below includes home and work destinations within the county of Rogaland (n = 4923).

3.1 Travel Distance

In theory, shorter travel distances make it easier to walk, cycle or use public transport instead of the car. This seems particularly true for distances under 3 km in urban areas where public transport and soft transport infrastructure is particularly good.

The data (n = 4732) shows that car share is very low for the shortest travel distance (<1 km), where walking seems to be dominant (Fig. 1). The car plays a relatively strong role for distances between 1 to 10 km, together with the bicycle and bus. This dominance of car share indicates an underused potential of sustainable travel modes. The strong dominance of train travel for longer travel distances (>10 km) is surprising and can indicate an overrepresentation of commuters from the south of the region, where district centres have a strong train connection to the urban cores.

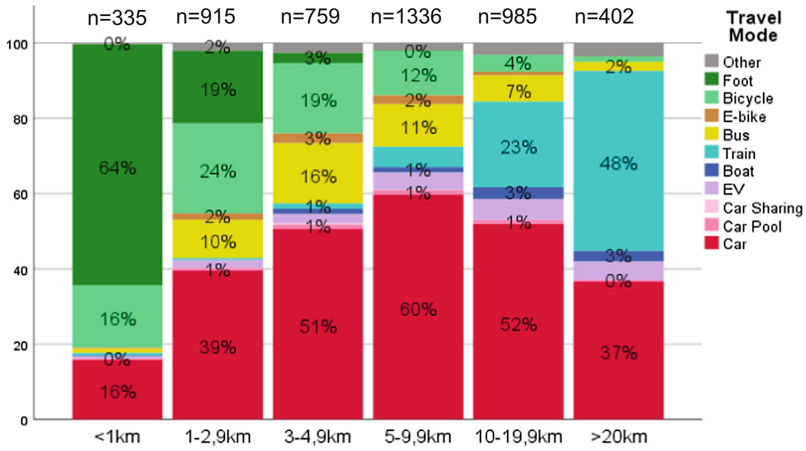

Fig. 1. Modal split of work travel for travel distance groups in Stavanger region, 2016.

3.2 Centrality (Proximity to City Centre)

Central areas providing public transport with high frequency and many destinations, as well as proximity to work places, should lead to more sustainable travel choices.

The transport system in the studied region is duo-centric, with 58% of respondents being closest to Stavanger city centre and 42% to Sandnes city centre. Between these nodes runs a strong public transport corridor served by bus and train. The modal split for the two centres shows clear differences in terms of more walking, bicycle and bus in Stavanger and a distinctly higher proportion of train travel in Sandnes (21% vs. 3%).

Respondents are on average 7479 m from their closest centre (n = 4917). The modal split according to centrality (Fig. 2) shows a relatively steady increase for car travel between 500 m and 10 km, confirming the importance of proximity to urban centres. The car share for the most central respondents, however, is higher than expected, indicating that people use the car regardless of their centrality. This can be due to their work location or the high convenience of car travel. The car share for the least central group is very low, indicating that, while those respondents do not live close to one of the two urban core, they are likely to live in a well-connected district centre.

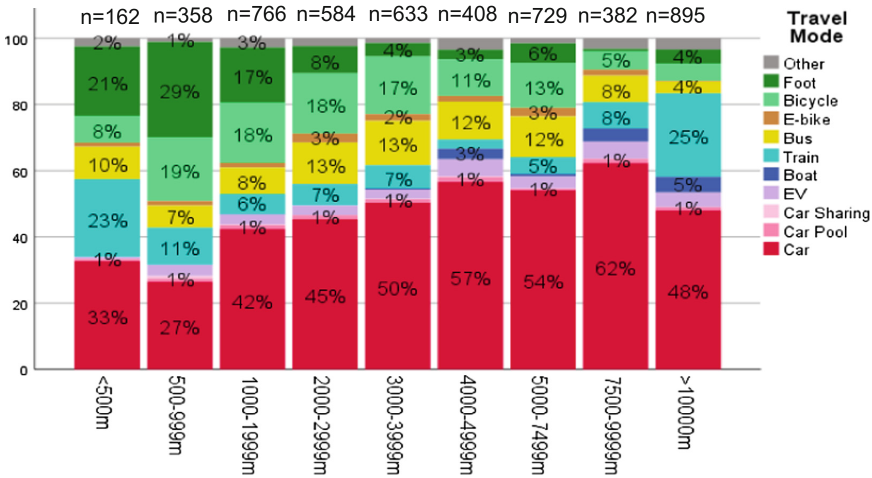

Fig. 2. Modal split of work travel for proximity to urban centre groups in Stavanger region, 2016.

3.3 Catchment Area of Public Transport (Proximity to Public Transport)

Given that public transport provides travel convenience, range and travel time comparable to the car, the assumption that people who live close to public transport facilities are more likely to use public transport seems logical.

With 82% of respondents living within 300 m of a bus stop, public transport coverage in the studied region seems strong. The collected data for work travel in the Stavanger city region (n = 4888), however, shows that differences between respondents living very close to public transport (<100 m) and those living further away (<500 m) are small, ranging from 46% to 48% (Fig. 3). Likewise, bus share only reaches 12% even where public transport is most accessible. Above 500 m, car share is distinctly higher (58%) and bus share lower (3%), again displaying relatively high levels of train travel. Given that 300 m are considered a yardstick for public transport accessibility, the difference for those living within and outside was tested, revealing even less of a difference in car share (47% vs. 50%) and bus share (10% vs. 7%). Thus, more sustainable travel choice for those living closer to bus stops cannot be confirmed without reservations.

Again, the assumption only holds true when both home and work place are close to public transport infrastructure. Also, the quality of the public transportation system in terms of range, frequency, added travel time, and the need for interchanges might be a mediating factor. Other conditions, such as weather or the quality of walking environment, might also mediate the relationship.

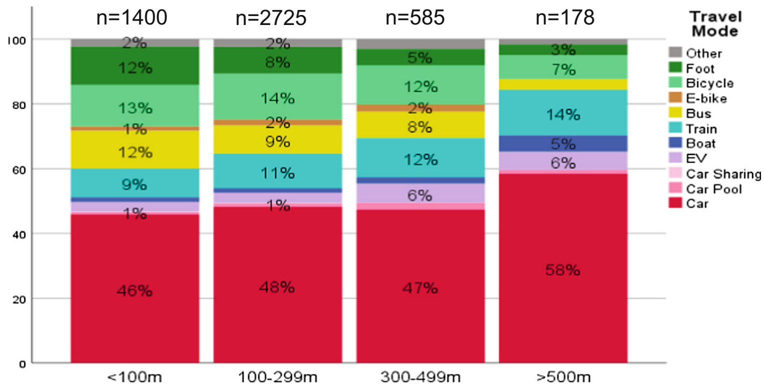

Fig. 3. Modal split of work travel for different proximity to public transport groups in Stavanger region, 2016.

4 Discussion of Mediating Factors

The descriptive examination of the geographic factors above obviously does not take into account the complexity of relationships and mediating factors, and can therefore only be seen as a first step of investigation. It is part of a larger ongoing longitude investigation of work travel habits in the Stavanger city region.

However, planning approaches for reducing car share in urban areas (e.g. densification within 300 m of public transport) are based on these simple hypotheses, without regard for more qualitative aspects (i.e. availability of public transport at origin and destination, frequency, directness, price, quality of service). When treating these factors in isolation, it becomes apparent that, while some relationships between location and travel behaviour become apparent, they seem oversimplified and should be supplemented with more qualitative requirements.

Particularly in medium-sized dispersed city regions, the car is often relatively attractive compared to other modes of travel, with the convenience of the car going up (parking, little congestion) while the efficiency of public transport and cycling goes down (long distances, little clientele). Thus, transit-oriented high-density development should only be applied where relative attractiveness of the car is reduced; otherwise, high levels of car ownership and use might be sustained. The same is true when car-reducing measures are put in place simultaneously as the road network is improved [4]. The quality of public transport service, design of public transport stops and vehicles, as well as the quality of walking environments to and from public transport stops also play a role [22].

Further, negative financial incentives (e.g. high taxation of car ownership, road toll, parking fees) and positive financial incentives (e.g. discounted public transport tickets) might be less effective in affluent communities, such as the one studied [4, 15]. It is also possible that habits are underestimated, seeing that habitual behaviour mediates some of the rational decision-making [19, 21]. In addition, the social and cultural meaning of the car as a symbol of freedom or economic status might be underestimated.

This analysis of work travel in Stavanger city region somewhat confirms location and its role for travel mode choice, with shorter travel distances and centrality catering toward less car travel and more walking, cycling and bus. The effect of proximity to public transport was not clearly confirmed and needs to be further investigated. Generally, the current data needs to be investigated applying more complex modelling of travel mode choice (e.g. frequency, directness, etc.). It will also be studied which groups among travelers showed a higher propensity to change travel behaviour when faced with positive or negative financials incentives (Home-Work-Home, road toll). The main implication of this study is that simplistic assumptions of shorter travel distances, more central living and working, and higher proximity to public transport catering to more sustainable travel choices cannot be upheld, when seen in isolation. Thus, a more differentiated application of TOD and supplementary measures (e.g. restrictions on car use, qualitative improvements) to ensure a competitive relationship between the car and other modes of transport is recommended, particularly in dispersed city regions.

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Health Related Benefits of Non-motorised Transport: An Application of the Health Economic Assessment Tool of the World Health Organisation to the Case of Trikala, Greece

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Abstract. It has been several years now that research coming from various disciplines such as sports science, medicine, urban planning and transport planning has provided strong evidence that sustainable urban mobility (SUM) is not only beneficial to the function of the city but to the human body too. As SUM includes not merely public transport but physical activity (walking, cycling, etc.) and as these can be further combined with exercise, an active urban environment can be created that can contribute to human health. The World Health Organization (WHO) has developed the Health Economic Assessment Tool (HEAT), a software which includes an algorithm designed to estimate the long–term health and economic benefit of a given population's cycling or walking. This paper shows how the HEAT has been applied to the case of the city of Trikala, Greece. It is based on bicycle traffic measurements recorded on September 2016, in Trikala, in the context of the SPACE Erasmus+ EU Programme. The result shows how and how much the increase of bicycle traffic (distance, hours, frequency of use) in the future can increase life expectancy and reduce health care costs, thus being a beneficial investment. The paper, also includes several 'what if scenarios' related to walking, so as to provide a broader picture of a possible urban active environment in the city.

Keywords: Non-motorised transport · Health Economic Assessment Tool Trikala · Sustainable urban mobility · Physical activity

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1 Introduction and Theoretical Framework: Sustainable Urban Mobility (SUM) and Non-motorised Transport: The Benefits for the City and the Human Body

Non-motorised transport as part of sustainable urban mobility (SUM) is considered to have many benefits for the city, as it can provide viable opportunities for urban regeneration allowing for greater flexibility and improving urban sustainability. This is primarily meaningful in the context of the compact city in relation with the transit oriented development idea whereby the city itself is being planned under the perspective of being serviced with public transport and non-motorised transport, i.e. with sustainable mobility modes.

While this might be crucial for modern cities, the trend to grow at high rates and to become bigger and bigger (see population data of UN), affects every day life which becomes more and more problematic resulting to a need for people to humanize their way of life. In big cities, trips are or can become very long, daily trips and commuting can become a huge burden for everyday life and distances can make walking or cycling impossible. Public transport in dedicate lanes (either standard gauge systems or bus rapid transit) can, up to a limit, provide some solutions. The inability and non-affordability (for the average citizen) of these formal transport systems is characterized by high infrastructure costs, environmental impacts (esp. in the case of private cars), a certain degree of institutional complexity and can vary from negative (air pollution) to none or very limited (e.g. some walking) positive impact on health.

A more drastic solution has been acknowledged to be the restructuring or regenerating the city in a way that commuting distances become shorter. But if this were the case, then shorter distances would require less public transport usage and even reduced use of private cars (or taxis), and consequently, at least to some considerable extent, would favour non-motorised transport. Such a solution is in tune with the quest of sustainability which is pursued in today's city and transport planning.

While the benefits of non-motorised transport for everyday life in terms of time consumption productivity, pollution, etc., might be evident, it appears that there is a whole array of additional direct benefits related to the human body as such. This is because non-motorised transport is based on human muscular activity (even ridding does so), i.e. physical activity, which is related to physical exercise. This dimension, directly related to human health, could be understood as a facet of social sustainability, which is one of the four sustainability dimensions, the others being eco-environmental, institutional, and economic [1]. Further on, it has been clearly stated that policies towards this direction cannot be sustained unless steadily supported by the local society with a variety of interventions, hence achieving suitable levels of institutional sustainability [2].

Focussing on the dimension of health in the frame of social sustainability, we argue that, as widely acknowledged, regular physical exercise and physical activity have beneficial effects on the prevention of several diseases and well-being. However, it has to be pointed out that physical exercise and physical activity do not coincide. According to the ACSM's [3] recommendations, physical exercise would mean a programme of moderate exercise of at least five times per week, or at least three times per-week of vigorous exercise, of duration 30 to 60 min, a certain level of pulses, etc. In this sense, non-motorised transport (in our case walking and cycling) would be classified as physical activity rather than as exercise. As ACSM has declared, individuals can benefit even from amounts of exercise less than those recommended [3]. This is especially true of the amount of sedentary time is reduced, something that is achieved when individuals employ non-motorized means of transport. Further, this physical activity may be the basis for enhanced leisure-time physical activity and exercise. That is, there is a carry-over effect of transport related physical activity. This effect may be facilitated by the positive mood created of physical activity and by the availability of respective infrastructure. Third, the increased human energy expenditure caused by non-motorized transport can contribute to weight control. Finally, as reviewed above, increased physical activity is related to individuals' cognitive functioning and their perception regarding quality of life. For all these reasons, non-motorized transport can be considered a health-related physical activity that in conjunction with some more structured exercise can have a significant impact on public health and quality of life.

Conversely, as evident, physical inactivity causes health problems, which according to methodologies that have been developed, can be measured. Yet, physical activity in the city can take place if the urban environment is an active one. The term 'active environment' has recently been coined to denote environments that facilitate the adoption and maintenance of physical activity. (Urban) Active Environments are those that are furnished in a way as to be able to host physical activities by means of the appropriate infrastructure (cycle lanes, foot paths, canal usage, outdoor exercise equipment etc.) and with the support of 'soft' policy measures and initiatives, such as prioritisation of cycling and walking, linking to tourism and active leisure, relevant promotion events, campaigns, games, etc. Cavill et al. [4] have offered the definition of 'active environments' as "physical or social environments that provide positive encouragement in helping people to be physically active, and to make the active choice" (p. 9). If appropriate infrastructures and policies exist, it is meaningful to address the issue of the benefits the usage of these infrastructures and the implementation of relevant policies can bring to the population and, conversely, the problems that can be caused by their absence, their underuse, and/or misuse.

2 Developing a Methodological Framework for the Support of Urban Active Environments

2.1 The Burden of Disease and the Cost of Physical Inactivity

Following this discussion, the research question arising is how can one measure (and why) the positive or negative impact of physical activity in a city. The question expands at two levels: the first concerns the measurement of what has been called the 'burden of disease'[1] and the second the economic impact of physical inactivity. In this

[1] The 'burden of disease' is the impact of a health problem on a given area, and can be measured using a variety of indicators such as mortality, morbidity or financial cost.

paper, we explain both but we attempt an application of the second for the case of Trikala, Greece.

With regard to this issue, the World Health Organization (WHO) has developed the Health Economic Assessment Tool (HEAT)[2] a software that includes an algorithm designed to estimate the long–term health (first level) and economic benefit (second level) of cycling or walking for a given population. The idea is based on the Population Attributable Fraction (PAF)[3] methodology that was developed by Lee, Shiroma, Lobelo, Puska, Blair, & Katzmarzyk, in order to estimate the burden of disease and life expectancy related to physical inactivity [5]. PAF is a measure used by epidemiologists to estimate the proportion of new cases that would not occur at the absence of a particular risk factor. This allows the burden of disease to be compared between different geographical areas, and to predict future health care needs [6].

Following this method, Lee et al. estimated that physical inactivity causes 6% of the burden of disease from coronary heart disease, 7% of type 2 diabetes, 10% of breast cancer, and 10% of colon cancer [5]. More recently, Ding et al. estimated a 4.5% PAF for stroke [7], and Sallis et al. a 3.8% PAF for dementia [8]. Further, Lee et al. reported that inactivity causes 9% of premature mortality, or more than 5.3 million of the 57 million deaths that occurred worldwide in 2008. According to the authors, if inactivity decreased by 10% or 25%, more than 533,000 and more than 1.3 million deaths, respectively, could be averted every year [5]. This is reflected to costs that can be direct or indirect. Indirect costs can be attributed to work absenteeism and work presenteeism (lower productivity due to ill health), and to lost productivity due to premature mortality. However, as large-scale data regarding absenteeism and presenteeism are scarce, indirect costs are usually estimated only by calculating the financial value of premature death.

Ding et al. used the global PAFs calculated by Lee et al., in order to estimate direct and indirect costs for health-care systems for 142 countries. Their results showed that, conservatively estimated, physical inactivity cost health-care systems 53.8 billion Int$[4] worldwide in 2013. In addition, physical inactivity related deaths contributed to 13.7 billion Int$ in productivity losses [7]. For Greece, direct health-care costs were 116.45 million Int$ and indirect costs were 30.53 million Int$ proving a total of 146.98 million Int$ cost for 2013.

2.2 The Health Economic Assessment Tool of the World Health Organization/Europe

Along the same lines, the World Health Organization/Europe (WHO) has developed the Health Economic Assessment Tool in order to assess the economic impact of

[2] See http://www.heatwalkingcycling.org.

[3] Population Attributable Fractions (PAFs) can measure the fraction of each disease that is attributable to physical activity.

[4] Int$: An international dollar has the same purchasing power as the U.S. dollar has in the United States. Costs in local currency units are converted to international dollars using purchasing power parity (PPP) exchange rates. …. An international dollar is, therefore, a hypothetical currency http://www.who.int/choice/costs/ppp/en/ [12].

cycling and walking. HEAT is designed to estimate the economic benefits based on the reduction of mortality rates due to cycling or walking for a specified period. The estimated reduction in mortality rate is quantified in monetary terms using the Value of Statistical Life (VSL) method. VSLs are derived from population surveys employing the 'willingness to pay' concept. This concept indicates how much each individual of the population would be willing to pay for a specific reduction of the population's annual risk of dying. Currently, HEAT provides country specific VSLs based on related data from the Organization for Economic Cooperation and Development. It assumes a linear dose-response relationship between physical activity and mortality. Estimations are provided for people between 20 and 64 years of age for cycling and for people between 20 and 74 years of age for walking. Therefore, HEAT is not suitable for older or younger people. Further, the developers of the Tool [9] note that HEAT "does not take into account differences in the intensity of walking and cycling" (p. 8).

HEAT can be used, among others, in two ways: (a) to estimate the reduced mortality and, based on that, the economic benefit of current levels of cycling and walking of a specific population, and (b) to estimate the economic effects of increased cycling or walking caused by interventions in the built and social environment. The former requires data from a single point of time, while the latter pre- and post-intervention data. Data required are: (a) an estimate of how many people are cycling or walking, and (b) an estimate of the average time spent or distance covered walking or cycling by the population under study.

3 Measuring the Economic Impact of Change in the Direction of Urban Active Environments: The HEAT Application in Trikala, Greece

A study of the former was undertaken in the context of the Erasmus+ program SPACE for the City of Trikala[5], a city in Central Greece of ~60,000 inhabitants, capital of a prefecture of ~130,000 (2011 Census). The modal split back in 2010 showed a 9.8% for cycling and 61% for private car use [10] [6]. In the frame of the SPACE action-based research project, the Trikala Municipality, with the assistance of the University of Thessaly and the core of the international collaborators prepared an Action Plan (AP) for developing an Active Urban Environment for cycling and walking that broadly targets adults, retired adults, and a certain group of schoolchildren. The AP includes the materialisation of interventions for non-motorised transport, which were thought to be vital for the city in the context of a town planning vision.

The general objectives of AP comprise (a) the connection of the leisure and recreation settings to the city centre by cycle lanes and pedestrian roads, (b) the creation of a sense-making network by the improvement of the connectivity of pedestrian routes and cycle lanes, (c) the promotion of walking and cycling. These are concretised in specific measures to be undertaken by the municipality.

[5] For more information on this project and on Trikala, see www.activeenvironments.eu [13].

[6] A later (2012) survey by "Public Issue" showed increased cycling usage up to 15% [11].

In order to support the prospect of the materialisation of AP, the research team organised an action in the context of the European Mobility Week 2016 in cooperation with the Municipality. The aim of the action was to assess the economic impact of the current level of cycling, as well as to make estimations of the economic impact of future increases of cycling as derived by the Municipality's stated policy. The reason for this action was to support the argumentation for the transformation of the city centre into an active urban environment for the benefit of the citizens.

Data Collection and Handling

A questionnaire covering a range of themes, such as perceptions of current state of cycle paths, preferences for expansion, perceived easiness to move by bicycle, perceived usefulness of more pedestrian roads etc. was developed by the Municipality of Trikala. The Municipality posted an electronic version of the questionnaire on its website and forwarded relevant notifications to citizens. Further on, employers of the Municipality distributed printed questionnaires to citizens individually. Three hundred and sixty printed questionnaires and 198 electronic ones were collected. Obviously, this is an opportunistic sample and its representativeness is somewhat limited. However, it can provide a rough estimation of the benefits of possible increased cycling in the city. Regarding HEAT, data collected involved days of cycling per week and distance travelled on an average day. From the 558 respondents, 255 were retained (after excluding those not between 20 and 64 years of age, those who do not have a bike, and those who use their bike less than once per month). This sample reported a mean days cycling per week 5.04 and a mean distance covered per day 1,830 m. An estimation was set for 200 days usage per year taking into account weather conditions in Greece. The most recent (2011) available data of the Greek Census Bureau provide a number of 33,349 persons living in Trikala aged between 20 and 65. A national survey of bicycle use (2012) indicated a 15% daily usage in the Region of Thessaly (compared to an overall 2.5% for Greece) [11]. Based on the above data, the number of current cyclists in Trikala was estimated to be 5,000. Further HEAT specifications were a Value of Statistical Life of 2.690,703 euros, a mortality rate for 238.55 deaths per 100,000 persons per year and a discount rate of 5%.[7], Entering these data in the HEAT Tool provided a calculation of the economic impact of current cycling. Further projections (shown in Table [1]) were calculated in line with the Municipality's goals for increasing cycling. These results are going to be used by the Municipality in order to estimate cost/benefit for developing infrastructure for the promotion of cycling.

[7] For the full set of specifications used in this case study see: http://activeenvironments.eu/media/SPAcE-Output-3-Measuring-the-Value-of-an-Urban-Active-Environment-using-HEAT.pdf [13].

Table 1. Economic benefits of current cycling and future projections for Trikala.

	Cyclists n	Days per w/y	Mean dist./day	10 years economic benefit
Current cycling	5000	5/200	1,830 m	7,480,000 €
Projection: increase cyclists from 15% to 18%	6000	5/200	1,830 m	8,970,000 €
Projection: increase mean daily distance to 2300 m	5000	5/200	2,300 m	9,400,000 €
Projection: increase cyclists to 18% and mean daily distance to 2300 m	6000	5/200	2,300 m	11,127,000 €

4 Conclusion

It has been shown in this paper that modern cities, becoming compact, have to adopt, as some of their most crucial policies, sustainable transport modes, primarily non-motorised transport. Besides the well-known technical transport advantages, this has the additional benefit of enhancing the health of the population by preventing, or even curing, a number of diseases. This can best take place in urban 'active environments' i.e. physical and social environments enhanced with all possible ways to inspire people towards physical activity. The benefits of physical activity have recently been measured by HEAT, a method devised by the World Health Organisation/Europe. This method was applied to the case of Trikala Greece, in the context of an Action Plan of the City written in the frame of the SPACE Erasmus+ European programme. The research team, applying this method by means of a widely distributed questionnaire survey measured the possible economic results of several scenarios for the adoption of more cycling. The outcome is expected to be useful to the local community in order to support and argue for more opportunities towards creating an active urban environment. As becomes evident, the adoption of non-motorised transport modes is not merely ecologically and socially sustainable (the latter because of health enhancement) but also economically sustainable in the sense that it creates net 'profits' for local communities in the medium and long run. It remains to be seen whether a more generalised adoption will be sustained in a way as to become institutionally sustainable too.

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Autonomous Vehicles and Blockchain Technology Are Shaping the Future of Transportation

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Abstract. In this paper, the possibility of using the autonomous vehicles with the contribution of Blockchain technology as part of a service is examined. As a first step a short Literature review of Autonomous Vehicles as well as Blockchain technology is provided. Blockchain is another newly established technology and its main purpose is to facilitate secure online transactions. Furthermore, through this paper it is explained that together Autonomous vehicles and Blockchain technology could provide the end user with cleaner, more economical and efficient transportation. In addition, a publicly owned system is described, where the two technologies combine, and the autonomous vehicle will provide the user the most convenient route based on real-time traffic information, while Blockchain will make the economic transaction easier since it could allow peer-to-peer carsharing and eliminate the need for banks. Moreover, in order to fully understand this system, the rising concerns regarding these technologies are mentioned. This paper aims to examine such a possible service using autonomous vehicles and Blockchain technology, since they essential could become the future of transportation.

Keywords: Autonomous · Vehicle · Blockchain · Technology
Mobility · Services

1 Introduction

Nowadays, technological advances are influencing the way we travel every day. The rising costs of transportation and the environmental damages, led to the creation of new means of transportation such as the Autonomous Vehicles. In the next few years, it is expected that owning an autonomous vehicle will be the norm for consumers, although fully autonomous vehicles are likely to be too expensive for individual ownership. Autonomous vehicles (AVs) offer a unique solution to many of the current issues in transportation, as they represent a technological leap forward that could influence how individuals view mobility [1]. Blockchain is another newly established technology and its main purpose is to facilitate secure online transactions. Together Autonomous vehicles and Blockchain technology could provide the end user with cleaner, more

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economical and efficient transportation. In this paper, the possibility of using the autonomous vehicles with the contribution of Blockchain technology as part of a service is examined.

2 Literature Review

2.1 Autonomous Vehicles

The concept of driverless vehicles was first attempted in the early 1920s and was later acknowledged in the 1980s when the automated highway systems were developed [2]. This paved the way for semiautonomous and autonomous vehicles to be connected to the highway infrastructure. The first pilots of Autonomous Vehicles were largely made in Germany and the U.S. during 1980 to 2000 [3], but it was Google's driverless car that introduced the term to the public and arose the publicity of Autonomous Vehicles.

The vehicles that can be driven without a human driver are commonly called Driverless or even Autonomous Vehicles (AVs), as it is considered the most popular term. The level of automation can vary from zero to full automation according to the international Society of Automotive Engineers (SAE) that has classified vehicle automation in six automation levels [4]. It is noted that in September 2016, the National Highway Traffic Safety Administration (NHTSA) discarded its own formal classification system released in 2013 and adopted the SAE standard. In SAE's autonomy level definitions, "driving mode" means "a type of driving scenario with characteristic dynamic driving task requirements and the automation levels are categorized as: No-Automation (Level 0), Drive Assistance (Level 1), Partial Automation (Level 2), Conditional Automation (Level 3), High Automation (Level 4), Full Automation (Level 5). The last level is describing Fully Autonomous Vehicles, where an Automated Driving System (ADS) on the vehicle can do all the driving in all circumstances, while the human occupants are just passengers and need never be involved in driving. Fully Autonomous Vehicles (Level 5) are expected to make travelling safer, cheaper as well as more comfortable and more sustainable [5]. The general use of AVs in every day travel will lead to the reduction of the generalized costs of travel and the use of AVs will open car travel to children, elderly and the disabled [5].

Even though the idea of driverless vehicles has been around for decades, the large costs have delayed large-scale production [5]. Due to the great competition among car manufacturers, the year 2020 has been slated as a horizon year to offer commercial AVs to the general market [5]. Based on the deployment and adoption of previous smart vehicle technologies, such as automatic transmission and hybrid electric drive [6] the forecast is that AVs are expected to constitute around 50% of vehicle sales, 30% of vehicles, and 40% of all vehicle travel by 2040 [7]. Thus, it is essential to understand the challenges and the opportunities that lie ahead if all those assumptions are to become true, taking as a fact that autonomous vehicles will revolutionize transportation.

2.2 Blockchain Technology and Applications

Blockchain is a shared digital ledger encompassing a list of connected blocks stored on a decentralized distributed network that is secured through cryptography. Each block contains encrypted information and hashed pointers to a previous block, thus it is difficult to retroactively alter a block without modifying the entire chain and the replicas within the peer network. New blocks are validated by peers on the network, providing credibility and preventing malicious activity and policy violations. Cryptography and membership functions provide easy data sharing between parties without privacy breach and tampering of records. All confirmed transactions are time stamped to provide full record provenance [8].

The last few years, Blockchain technology has gained widespread traction and is constantly attracting new investments. A wide range of industries, including finance, insurance, healthcare, logistics and supply chain management are starting to discuss and test Blockchain technology in a number of use cases [9]. Blockchain enables a potentially evolving and open set of parties to maintain a safe, permanent, and tamper-proof digital ledger of transactions, without a central authority. The main asset of this technology is that transactions are not recorded centrally, each party maintains a copy of the ledger and a majority of parties need to verify a new transaction before it can be recorded in the ledger. Once a transaction is approved, it is practically not possible to modify it or cancel it. Therefore, Blockchain technology can be seen as a replicated append-only transactional data store, and it can be used as a substitute for centralized registers maintained by single trusted authorities [10]. Blockchain technology is considered to be among the most disruptive technologies across several industries. One of the key advantages of blockchain is that it is much more secure than traditional IT solutions. In addition, blockchain-based applications have the potential to revolutionize several sectors.

3 Problem Statement

It is largely believed that Autonomous Vehicles will mainly attract those without current access to private transportation or those, who were previously unwilling or unable to drive a private car [3], but the main question is how these Vehicles will be obtained by the end-user. Due to the large cost of a privately owned Autonomous Vehicle, the main most likely scenario is that they will be publicly owned and they will be shared as an alternative use of transportation. The concept of Shared Autonomous Vehicles combines elements of conventional carsharing and taxi services with AVs [5]. These shared vehicles could provide inexpensive and convenient mobility-on demand services [11], which have been described as driverless taxis [5], while providing the end user the most convenient route based on real-time traffic information. But this situation raises the problem of the safe and secure payment for the services provided.

This problem could be rectified by blockchain's digital encryption and distributed consensus algorithms. This plays a key role in promoting trusted communication and cooperation among vehicles, road-side devices, and pedestrians that use smart phones in a decentralized autonomous transportation system, since there could be the risk of successfully spending the digital currency more than once. The Blockchain technology consists of a distributed data verification mechanism that guarantees a traceable blockchain ledger that can protect against the double spending without trusted central authorities in a completely decentralized fashion, thus facilitating point-to-point money transfer or digital asset exchange without intermediaries.

4 AVs and Blockchain Combination System

In this paper, in order to resolve the issues that can arise from the use of Autonomous Vehicles, we propose a system that combines blockchain technology effectively to support the communication and the transaction between the vehicle and the end user (Fig. 1). To avoid any profit making from the private sector companies, this system will be publicly owned and will be considered as an alternative form of public transportation, thus increasing the users' choices for transportation.

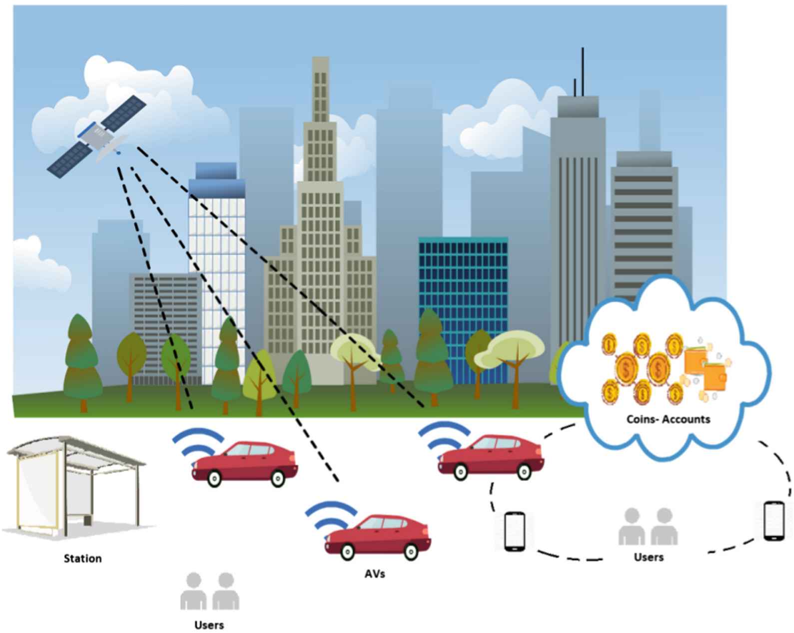

Fig. 1. AVs and blockchain combination.

It is noted that in all EU countries the number of taxis ranges from 1.3 to 2 per 1,000 inhabitants. The indicator chosen for Greece is clearly higher than the European average (2.5 taxis per 1,000 citizens for Athens, 2 taxis per 1,000 citizens for the rest of Greece). Indicatively, in Rome the ration between taxis and citizens is 2.1 taxis per 1000 citizen and in Brussels the ratio is 1.5 taxis per 1000 citizen. Based on the 2 taxis per 1,000 citizens ratio that is mainly used in Greece, we consider using the same ratio for the number of autonomous vehicles included in our system. Thus, in a city such as Patras with a population approximately 160000 citizens, an average number of 320 Autonomous Vehicles would be used. This will be a system with shared AVs, where they will be placed in their suitable designed stations throughout the city, where the user will be able to collect them.

In order for the system to work in a suitable environment, a specialized mobile application must be created. In the application the location of the stations that the AVs can be collected must be provided, as well as the location of the Vehicles themselves. The Autonomous Vehicles would be able to present all their necessary information in this mobile app, therefore making every ride safer for the end user. Furthermore, the application must be user friendly for all ages and it should be accessible to all end users. The users themselves should make a personalized account in this application and they should provide all their necessary information. Moreover, through the application they would be able to create "coin accounts" using blockchain ledgers, thus making their payment transaction easier once they finish their trip. The vehicle itself must be able to recognize "coin accounts" using blockchain ledgers and confirm the transaction. Once the trip and the payment are complete, the AV should be able to return to its allocated station or even pick up a new costumer through the application. Once the transaction between users and AVs are complete, the AV should be able to use the blockchain ledgers that it collected in order to facilitate other needs that may arise, such as paying a parking space in the city center, if there is no station available, or even charging for an electrical AV. In this system AVs and Blockchain technology could work together through the use of a Smartphone application in order to provide an alternative form of transportation.

5 Rising Concerns

Autonomous vehicles and Blockchain Technology offer a wide range of benefits, in terms of safety, efficiency, environmental impacts, and increased mobility, but they could also have diverse impacts. The use of Autonomous Vehicles while reducing or even eliminating driver errors, it does not necessarily eliminate vehicle, road or environmental factors, or other road users from contributing to crashes. Neither can we be certain that computer-based control will be sufficiently safe and reliable [12]. Moreover, another issue that may arise is the responsible "person" in case of an accident. The question that needs to be answered is in case that a driverless crashes, who will be guilty and who should compensate for the damage.

Furthermore, a particular issue created by the advanced automated vehicle control is the ethical tradeoffs, such as "The social dilemma of autonomous vehicles" [13]. For example, consider the dilemma of a driver approaching a group of pedestrians crossing the road immediately in front of him or her. The vehicle is design to opt for the utilitarian design option; namely minimizing the number of injuries. However, when people were asked if they would purchase a vehicle programmed to minimize total injuries versus a vehicle programmed to protect its occupants at all costs, they generally preferred the self-protective option. To summarize, we all want to increase overall safety, but we think that our own safety precedes all others', thus making a challenging the use of an Autonomous Vehicle with this characteristic.

In addition, when it comes to new technology such as AVs and blockchain, privacy concerns are accounted for. There is the belief that Autonomous Vehicles would function using information regarding the users' location (private home or office address) as well as their personal information, thus creating major privacy issues. There may be also some security worries in regards of hackers. Hackers may get into the vehicle's software and affect or control its operation, therefore creating a security concern. This is the reason why policymakers will need to modify or enact rules to address and influence these broad concerns, since this technology becomes more widespread, and models become available for consumer use.

6 Conclusions

In this paper, we propose the use of Blockchain technology together with Autonomous Vehicles in a publicly owned system that will be mainly used by those without current access to private transportation or those, who were previously unwilling or unable to drive a private car, such as elderly, disabled and small children. This system will be offer its end safer, cheaper, more comfortable and more sustainable travelling experience through the use of Autonomous Vehicles, while Blockchain will provide the means to a secure payment transaction by facilitating point-to-point money transfer or digital asset exchange without intermediaries.

It is clear there is significant value in the Blockchain being used to verify transactions, avoid fraud, confirm ownership and simplify purchasing processes. But it is important to note that Blockchain does not solve privacy issues, and it is an authenticity solution only. Blockchain technology is excellent for smart contracts, but it is not ideally suited for protecting data. If the data stored on the Blockchain is altered it will be noticeable, however there is no way to neither know what parts of the data have been altered nor retrieve the originals via the Blockchain. This is the reason why applying the blockchain technology to autonomous vehicles could have some value, since it could act as a ledger to validate transactions between a vehicle and a service provider.

To summarize, the combination of Autonomous Vehicles and Blockchain technology has the potential of establishing a secured, trusted a system where the autonomous vehicle will provide the end user the most convenient route based on real-time traffic information, and Blockchain will make the economic transaction easier since it could allow peer-to-peer carsharing and eliminate the need for banks.

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Transport Interchanges

Integrating Logistics and Transportation Simulation Tools for Long-Term Planning

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Abstract. The complexity that underlies in transport systems and logistics necessitate the integration of different models that are capable of overcoming potential limitations when considering tools individually. This paper focuses on the evaluation of traffic and logistics measures by integrating two simulation software (PTV VISSIM and AnyLogic). The simplicity of integrating the two software make the resulting model a suitable tool for evaluating measures at regional level.

The result of the integration is a model that is able to simulate the traffic conditions on a transport network. The integrated model is tested in the wider area of Volos Port, Greece and port's intra-logistics processes. The model is used to evaluate the feasibility of the measures in the year 2030, by comparing it with the situation in the year 2030 without the implementation of any new measure. The evaluation of the model is performed by using a set of indicators that represent environmental and transport impacts. The analysis is completed by using a multi-criteria decision making tool to generate the Logistics Sustainability Index (LSI) to summarize the information that is provided by the indicators. The study indicates that the usage of simulation models has the potential to provide a holistic impact evaluation of complex decisions and support long term planning.

Keywords: City logistics · Software integration · Evaluation · Simulation Transport interchanges · Port

1 Introduction

Urban freight transport constitutes one of the biggest problems that modern cities have to deal with today, as it can produce many adverse impacts (economic, environmental, societal and transport) and deteriorate the quality of life for citizens of urban areas. Impacts occurring from different logistics measures can be estimated by using simulation tools. Simulation provides a comprehensive way to engineers to test and explore different measures under various assumptions and conditions for long term planning by

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considering local geographic, transport and legal characteristics. A wide-range of simulation software has been developed for transport and logistics modeling based on data or agents. Although these simulation software adopt partly similar approaches, their strengths and weaknesses make them suitable for different problems. The complexity that underlies in transport systems and logistics necessitate the integration of different models that are capable of overcoming limitations in modeling and suggesting the best measure to support long term planning. Specifically, the system or the agents performing each individual task can be changed or tuned according to the requirements posed by the problem. A challenge to complete integration of two or more tools is that the interfaces of the programs vary between applications and each phase of the process requires its own amount of computational power. These are all demanding tasks which require expertise with a variety of applications, often belonging to more than one discipline. Therefore, the use of an integration platform can facilitate engineers work within the design process, especially when tackling multi-disciplinary sources.

The objective of this study is to integrate two simulation software and test the resulting model in a study at local level. As local authorities do not usually have the expertise or the capacity to operate simulation software which are based on high level architecture, the resulting model aims to provide an asset for local authorities towards evaluating measure performance. This paper focuses on the evaluation of traffic and logistics measures by integrating two simulation software (PTV VISSIM and AnyLogic). The two software are used to develop two models which are integrated; the AnyLogic model is used to control the VISSIM model via its COM interface. The study area is of high interest to the city of Volos since expected development of the port by 2030 will lead to increased traffic flows and emissions [1].

2 State-of-the-Art

Simulation modelling represents a widely-used tool for urban planning, traffic management and logistics, especially in the field of commercial ports, where a number of studies has been conducted. Analytically, Dragović et al. [2] give a comprehensive overview on port simulation modelling over the last 20 years, highlighting the growing importance and the increasing popularity of the Discrete-Event-Simulation (DES) approach. Lin et al. [3] and Hou and Geerlings [4] investigate planning alternatives in terms of economic impacts and environmental effects towards port sustainability. Chimpeanu et al. [5] use simulation not only to evaluate long-term planning but also to support port operations as maintenance scheduling. Schipper et al. [6] analyze related systems such as hinterland connections and the urban situation around the ports to cope with the various challenges of sustainable and efficient port development and operations.

In order to simulate urban traffic and transportation systems, different approaches can be found in literature. Hofmann et al. [7] presented an Open-Street-Map-based simulation tool in which transportation processes are simulated taking into account realistic distance matrices. Nevertheless, vehicle speed profiles and transport process durations are only roughly estimated, leaving room for a more detailed consideration of vehicle movements.

Systems as commercial ports consist of many interrelated sub-systems with various interdependencies. To investigate the behavior of interrelated sub-systems of different types, different simulation models and approaches can be linked [8]. This process is known as hybrid simulation or as hybrid systems modeling approach [9]. Modern simulation tools typically offer different possibilities for interfacing. Mittal and Krejci [10] showed how an agent-based model can be linked with a DES model by storing results in output-files which then become inputs to the other model. Fellendorf and Vortisch [11] explained how to control a running simulation via its COM interface for a more dynamic integration. However, when multiple tools need to be linked it can be cumbersome and error-prone to manually implement pairwise connections between all tools. The most widely used approach to enable different simulation systems to work together in a distributed environment is the High Level Architecture (HLA). Jain et al. [12] used HLA to evaluate sustainability in urban systems.

3 Methodology

The flowchart in Fig. 1 presents the methodology that is followed in this study. The connection of VISSIM and AnyLogic, which is the main objective of the study is done via the VISSIM COM interface.

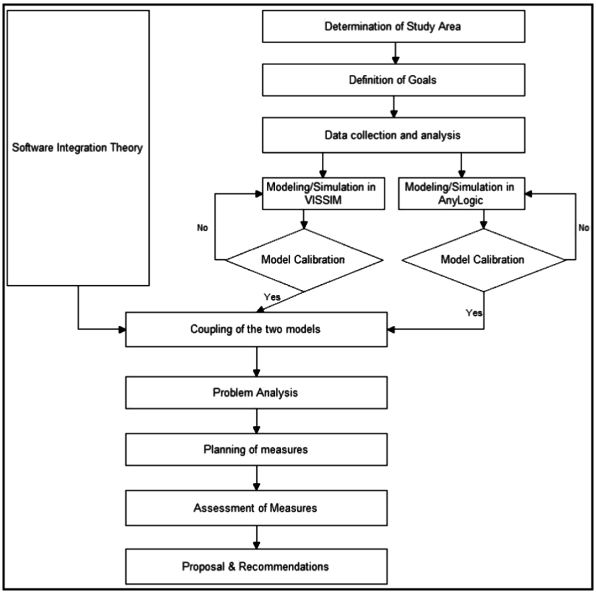


Fig. 1. Methodological approach.

AnyLogic is configured as the master application, controlling the VISSIM model via the JAva COm Bridge (JACOB) [13] and corresponding COM commands as specified in the VISSIM COM API. Analytically, the network files are loaded and the simulation is run in a synchronized manner, always running for the time until the next event in AnyLogic. Whenever a Heavy Good Vehicle (HGV) is reaching the exiting point of the port, a corresponding vehicle is inserted into the VISSIM network at the specified entry point location.

The geo-reference of the inserted vehicle is stored in AnyLogic to enable the query of status data such as location and current speed of the HGV, which then can be used to keep the GIS-map animation synchronized with the actual status in VISSIM. The GIS-map HGVs move autonomously, but their speed and location are cyclically synchronized to correct deviations regarding speed and route choice. Due to the fact that location coordinates are handled differently in VISSIM and AnyLogic (VISSIM uses Mercator coordinates and AnyLogic WGS84 coordinates), a conversion of the coordinates based on the VISSIM reference was necessary.

The resulting model is tested in the Port of Volos, Greece to perform a holistic impact assessment.

4 Application in Smart Urban Freight Measures

To ensure sustainable transport of goods and make safe proposals for the area of the commercial port of Volos in the year 2030, a traffic volume forecast has been carried out for further investigation. Based on the results of the forecast, a 144% increase of cargo shipment loads is expected by 2030 due to further development of the port which will be added to the additional induced traffic due to the growth of the city [14]. This will bring a higher number of HGVs using the network around the port which will set the adoption of new measures as an imperative necessity in order to keep the same level of traffic performance in the network.

To quantify the impacts of the future situation a base scenario named onwards as "without any measure" and a scenario "with measures" for the year 2030 were modeled and evaluated. Within the two scenarios projections of population (based on economic indexes) as well as port's development were considered.

4.1 Data

Traffic volumes and the percentage of HGVs derived from on-site measurements which were realized during a weekday in June 2017, representing a "typical" day [15]. A preliminary analysis was conducted to determine the peak hour (09:45 am–10:45 am). Traffic lights' programs were given by the Traffic Management Center of the city of Volos. The remaining operational elements of the VISSIM model were determined either from Google maps or from on-site observation.

The cargo shipment loads on a monthly basis as well as loading/unloading, storing and scheduling information were given by the Port Authorities both for containers and bulk loads [16]. Except for the loads all other information was given empirically by Port's Traffic Management Office due to the absence of official records.

4.2 Measures

The selected measures to be modeled are a combination of traffic and logistics measures, identified during the problem analysis of the model. Their selection was based on the following criteria:

- Measures directly applicable with strong positive effect towards sustainability
- Soft measures (no major structural interventions)
- Intelligent Transport Systems (ITS) oriented
- Low cost implementation.

In the following sections measures' description, implementation results and modeling efforts that differentiate the scenario "with the measures" from the scenario "without any measures", are presented.

Measure 1 – Real Time Online System for Better Monitoring
Description: This measure aims at increasing the load factor of the HGVs that carry bulk shipments. According to the authorities of Volos port, nearly half of the HGVs are used to carry such shipments (mainly corn and grain) with an average load factor of 85%. These HGVs could achieve higher load factors if there was a real-time online system that could provide information to the carriers (volume of the remaining product so as to choose the most appropriate truck type/size, information about unexpected events due to poor programming, etc.).

Implementation Result

The adoption of information systems in conjunction with better programming could end up to an average 95% load factor.
Modeling Effort:

- 5.5% reduction of HGVs entering/exiting the commercial port
- Weight distribution for 50% of HGVs has been increased (10%).

Measure 2 – Green Fleet
Description: The second measure focuses on the share of HGVs that are powered by alternative fuels. The share of CNG and Electric HGVs can be increased by 2% and 3%, respectively, (meaning −5% of Diesel HGV) according to EU projections, the percentage of local sales of alternative fuel vehicles and the expected market penetration of alternative fuel vehicles. The increase can derive from tax incentives and campaigns promoting the benefits of new technology vehicles.

Implementation Results

- Diesel HGV: 73% (from 78%)
- Compressed Natural Gas HGV: 4% (from 2%)
- Electric HGV: 23% (from 20%).

Modeling Effort:

- Change the parameters of share for "Heavy-Duty" vehicles to estimate the environmental impacts, in EnViVer software.

Measure 3 – Local Traffic Management

Description: This measure focuses on ITS adoption for control and traffic management. Specifically, the third measure improves the "green wave" for the three successive intersections on the tested corridor and based on the calibrated simulation model, a better coordination is achieved by slightly offsetting earlier the signals of the last two intersections. Green wave preconditions are fully covered [17].

Result After Implementing the Measure

- Minimization of the percentage of vehicles that drive through the intersection without stopping, allows loaded HGVs to avoid unnecessary deceleration and acceleration which results to smoother rolling with fewer emissions and noise, and lower fuel consumption.

Modeling Effort:

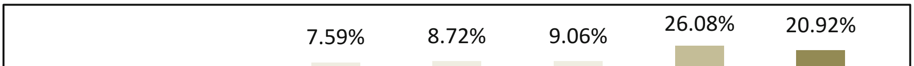
- Offset the signal programs of the last two intersections of our network, by 8 and 6 s earlier.

4.3 Evaluation

The environmental indicators (CO_2, NO_X, PM_{10}) and the indicator "Delays" which represents the sum of delays of all vehicles within the peak hour were measured for the whole network both in VISSIM and AnyLogic model. The indicators' values were then inserted to Evalog (http://evalog.civ.uth.gr/) which formulates a multi-criteria multi-stakeholder decision making process in order to produce the Logistics Sustainability Index value for each scenario [18].

5 Results and Discussion

For the computation of the LSI, all three environmental indicators were equally weighted (0.166), while for the delay indicator a weight of 0.5 was attributed in order to evaluate equally the transport and environmental impact areas. Figure 2 shows the change (%) of the indicators' average values per scenario after five simulation runs.



Indicators		CO2 (g/km)	NOx (g/km)	PM10 (mg/km)	Delays (s)	LSI values
Scenario 1	Without any measures	408804	3752	254731	207537,46	0,827
Scenario 2	With measures	377761	3425	231656	153403,63	1

Fig. 2. Before and after values for indicators and LSI.

The results show that by implementing all three measures at the same time, the traffic performance in the year 2030 is significantly improved. Due to lack of cost-related data, a cost-benefit analysis is difficult to be performed, however, it can be safely concluded that these measures, in combination with hard measures may contribute to the sustainability of the system.

The integration of the two simulation software has been performed successfully and tested in a real case scenario for the Port of Volos in Greece. The impact assessment results, although basic at this stage, show that the two well-known software can be integrated effectively. The resulting model overpasses the complexity of high level architectural systems and diminishes the need for human resources while it is able to support local long term planning. Lastly, the methodological approach that was presented in this study can serve as a guidebook for future studies willing to assess transport systems such as transport interchanges, commercial ports or urban consolidation centers, since it connects a facility's intra-processes with the nearby transport network.

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Development and Simulation of Priority Based Control Strategies of Ground Vehicles Movements on the Aerodrome

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Abstract. Performance indicators to measure delay and delay improvement within the system are the non-operation period of an aircraft, the distance and time by ground vehicles needed to get to their assigned task. Due to the rising number of passengers within the next years, the effectiveness of these indicators needs to rise. A conceptual model was built with the help of Kuhn's process chain model, which was used as a basis for the following rough calculation. The rough calculation contains time for necessary tasks at an airport as well as data about aircrafts, which departure and arrive at Riga International Airport. This paper focuses on the development and computer simulation of priority based control strategies for improving turnaround times of aircrafts at the apron of the Riga International Airport.

Keywords: Ground vehicle movement · Apron simulation
Prioritization of vehicles

1 Introduction and Problem Formulation

1.1 Introduction

In the current Eurocontrol seven year forecast from 2017 to 2023, a rise in number of passengers are prognosticated. For all of Europe a stable flight growth from 1.7% in average per year is expected. Specifically, for Latvia, the baseline growth is expected to be 3.0% as average annual growth [1]. This trend can be validated by the annual number of passengers and the annual number of flights at Riga International Airport (RIX) [2, 3]. Since 2004, the annual average number of flights has risen uninterrupted, also throughout the economic crisis of 2008. In the last 13 years, so between 2004 and 2017, the annual average number of flights rose for about 275%, compare Fig. 1.

The Passenger Traffic Forecast of Riga International Airport, approved by the board of RIX in 2015, indicates that the personnel at the RIX believes in a rise of the number of passengers for about 1.6 million passengers from 2015 to 2036 [4]. In order to be able to serve airlines and their passengers in a proper manner, the performance level should be increased at best or kept at the current level in the worst case. To be able to

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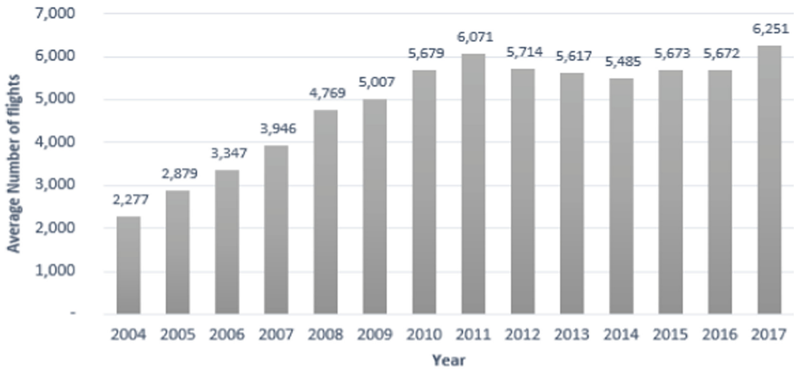

Fig. 1. Development of annual average number of flights from 2004 to 2017 for Riga International Airport (in accordance with [2]). The number of passengers is shown on the y-axis, the number of years on the x-axis.

do that, every process should be organized in a way so that its efficiency is increased. One way is to optimize the ground vehicle movement at one of the aprons closest to the gate area.

1.2 Problem Formulation

The regarded system is Apron 3 of Riga International Airport. It has a road system containing three different road types. One for aircrafts (AC), being cut off from the other two road types, and two road types for ground vehicles (GV). One for normal ground vehicles and one for prioritized ground vehicles. All roads have speed limits, some are one way, the roads for aircrafts and the ground vehicle road close to the parking positions of the aircrafts, and others are two-way. All aircrafts are prioritized before all ground vehicles. Ground vehicles driving on the prioritized lanes are above normal ground vehicles within the hierarchy. In order to measure the enhancement, but also delay, several performance indicators have been defined:

- Non-operation-period or handling time of an aircraft
- Estimated and the measured time of travel for ground vehicles
- Distance the ground vehicles have to drive
- Resource utilization, in this case relating to the ground vehicles.

Control factors can be defined for aircrafts and ground vehicles. For aircrafts, the parking position is relevant, as it effects the distance as well as the route ground vehicles need to drive. Ground vehicles can be control through several control factors. The way of prioritization, determines which vehicles are allowed to drive on the prioritized lane. The rule, which is used to determine the next task, is a second control factor for ground vehicles. This describes the choice whether metric or timely distance or ecological influence is the major parameter for the next task. With these control factors, scenarios can be built and experiments can be executed.

The aim is to fasten ground vehicle movement through the implementation of a second driving lane for said vehicles. Named performance indicators will be used to measure any happening improvement and control factors will be used to maximize the possible improvement.

2 Stand of Science and Technology

Ground operations and aircraft turnarounds are entwined with the facilities of the airport, as well as the airline itself. A key aspect in improving the efficiency of ground handling is the early detection and elimination of delay of any kind. Here, a distinction can be made between delay on the airside and on the landside. In the following, only the processes in ground handling on the airside are considered. The Riga International Airport statistical bureau collected data regarding delay at RIX in 2016. During the main season, with the highest daily number of flights, from June to August 2016, about 10% of all flights, were delayed. During 2016, average delay due to ground handling processes was about 15 min. In total, delay due to ground handling processes was 2500 h [5].

A similar simulation-based approach also use Silverino and Arias [6]. They determine the approximate optimal time buffer sizes during turnaround operations. Here, they use a mathematical approach with linear functions. The investigations are made using stochastic variables. A simulation study from Mas, Juan et al. [7] focuses on boarding processes of passengers while using a bridge. They identify the bridge as part of a time-critical path at the airport. Other processes like fueling and cleaning need to be ready for the boarding to start due to safety restrictions. Numerical experiments ensure the results. They conclude that effective boarding is critical to customer satisfaction. Liang [8] considers the aircraft maintenance routing problem. In this case, general statements about all airline activities like flight scheduling, fleet assignment (allocate a fleet to every flight of the schedule), crew pairing (part of crew scheduling) and aircraft maintenance routing (management of aircraft rotation) are given. The proximity to the subject presented here, however, reach only Norin [9] and Wu [10]. While Norin increases resource utilization by streamlining the turnaround process, Wu uses schedule buffer time in aircraft turnarounds, in order to balance aircraft utilization and schedule punctuality. Due to the high complexity, Norin places the focus on the necessary de-icing process, which takes place shortly before the start. The goal of her investigation is to better schedule the de-icing process. At Wu, stochastic functions are used for simulation. Simulation describes the output of stochastic effects on ground operations of aircraft based on mathematical models. Scheduled turnaround time consists of two elements: mean time service time and schedule buffer time. Buffer time is used to absorb the delays. Further studies describe the use of various mathematical and optimization algorithms [11, 12] These approaches largely consider staffing and coordination in the turnaround process.

3 Data Preparation and Concept Model

The route network of RIX are in total 89 destinations, some are only approached within one season [13, 14]. Thus, there are 60 destinations during winter and 79 during summer season.

The exact sequential arrangement of the processes happening differ from airport to airport, due to infrastructure, equipment as well as number and training of personnel [14, 15]. As a part of the conceptual model, the turnaround process was defined. Several references were used to compile this [13–15]. A process chain model based on Kuhn [16] was built based on common turnaround processes. This combined with the layout of apron resulted in the conceptual model. The conceptual model was shaped into figures through the rough calculation, quantifying the conceptual model and being the formal model.

All described processes happen at apron 3, compare Fig. 2. Aircrafts arrive on the runway and drive via a taxiway to their assigned stand or parking position. As soon as the aircraft is assigned to a stand, ground vehicles for unloading and deplaning, buses and tugs, are assigned to the aircraft and drive to its stand. The unloading process takes place, as passengers leave the aircraft and enter the bus and the luggage is unloaded. Meanwhile a tanker truck drives to the stand. The passengers and their luggage is transported to the Arrival area. From there the vehicles head back to their depot or are assigned a new task. In the meantime, the aircraft is being fueled. Vehicles for the loading process drive to the Departure Area. Passengers enter the bus from the Departure Area and the luggage is loaded onto the vehicles. The vehicles then drive to the aircraft. Due to security reasons, passengers are allowed to board the plane and the luggage is loaded into the plane after the fueling process is finished. After all previous processes are finished, the pilots are allowed to start the jet engine, drive towards the taxiway and leave the apron.

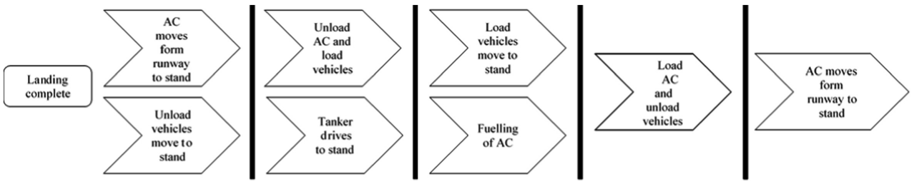

Fig. 2. Concept model as process chain model according by Kuhn for RIX.

For data preparation, the schedule of departure and arrival times were taken from RIX. There are more than 458 data sets in the summer schedule of 2017, without any repetitions. The details (volume, tonnage, fuel level, number of flight seats) to the various types of aircraft were researched from the manufacturers. The amount of luggage carried per passenger depends on the airline. Values for the deplaning and enplaning rate of an aircraft as well as the rate of fuel running into the tank of the aircraft per minute were taken from aircraft manuals, which were made for airports [14, 17]. This is supposed to ensure realistic results.

4 The Simulation Model

4.1 Modeling the Initial Situation

Based on the data preparation and its results, a rough calculation was calculated as well as a formal model was constructed. Each flight received an individual flight-ID (compare Table 1). The flight number, used aircraft, the airline executing the flight, start airport, end destination and the days at which the flight is flown were taken. The data were supplemented by the individual technical features of the aircraft, such as number of seats for each plane, fuel capacity and delay in minutes. All influences on ground handling processes could be identified and modeled.

Table 1. Exemplary extract of the built flight schedule, based on real data.

ID	Scheduled Time	Flight Number	Duration (hh:mm)	Distance (km)	Aircraft	Fuel (l)	Seats (max.)	Freight capacity (t)	Destination start	Destination end	Days flying
1	00:10:00	W62502	2:15	1.663	A320	27.200,00	180	71,50	London/Luton	Riga	- - - - 5 - 7
3	00:20:00	BT317	0:45	282	DH8D	6.423,83	73	1,60	Riga	Tallinn	1 2 3 4 5 6 -
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

The transfer into an executable simulation model is shown in Fig. 3. To illustrate the investigation, the dependencies of the existing input, influence and output factors were identified. The model was created using the simulation tool AnyLogic.

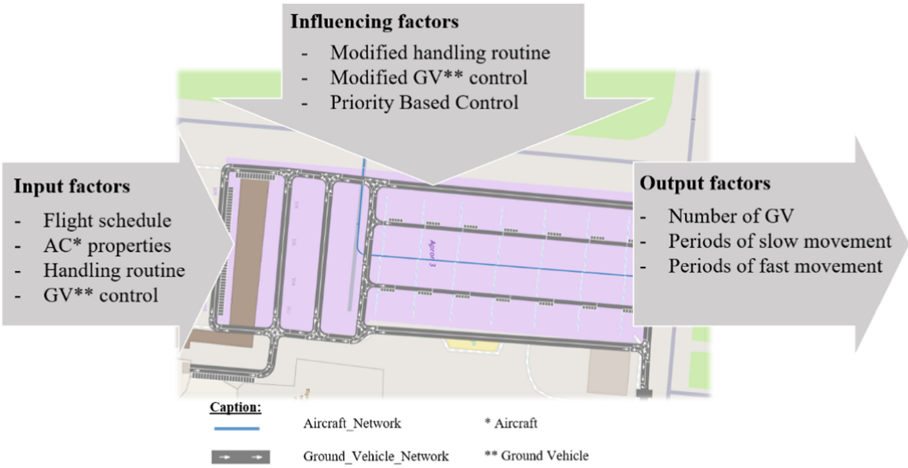

Fig. 3. Simulation model of Apron 3 created in AnyLogic.

The input factors are described as a flight plan (summer flight schedule RIX), aircraft properties (seats, tank capacity, loading volume etc.), current material and information flow (handling processes and ground vehicle control).

The target criteria as output factors are described as the number of used ground vehicles and the periods of slow and fast driving movements on the apron 3. These periods are crucial for the prioritized ground-based control. This is characterized by the addition of a further route as a priority-route. At the same time, the intersection control was adapted and improved. The influences of parameter on performance indicators can be determined and evaluated. In addition, movement speeds and transportation times can be measured. This makes a detailed assessment of the system's behavior possible. By analyzing the speed of movement of ground vehicles, possible congestions can be detected.

4.2 First Experiments and Results

First Experiments were carried out with the built model, to evaluate the maximum possible effect of the introduction of one additional, prioritized driving lane. The aim was to gain more exact handling times for aircrafts being located at the same stand or parking position. During the first set of experiments, normal traffic without prioritization was simulated. At some intersections, congestions of ground vehicles occurred. The second set of experiments simulated extraordinary scenarios, in which aircrafts only arrived at one stand, the so-called reference stand. Through this experiment, the shortest time of travel could be determined. In another experiment belonging to the second set of experiments, minimal arrival times were simulated, to gather information about the utilization of ground vehicles during periods of high workload. Figure 4 shows the average number of serviced aircrafts per hour subject to the number of available ground vehicles. The data was gained in a specific experimental setup, in which the number of available ground vehicles varied. In Fig. 4, a saturation effect can be observed at about 70 ground vehicles in use. This means that more than 70 ground vehicles has no positive effect on the system, due to traffic congestions. Fig. 5 illustrates the periods of time with faster or slower movement of ground vehicles as a function of the number of vehicles.

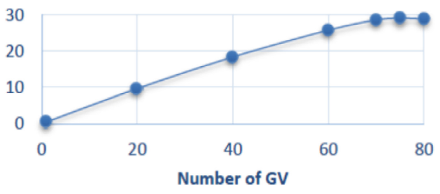

Fig. 4. Average number of serviced Aircrafts subject to the number of available GV.

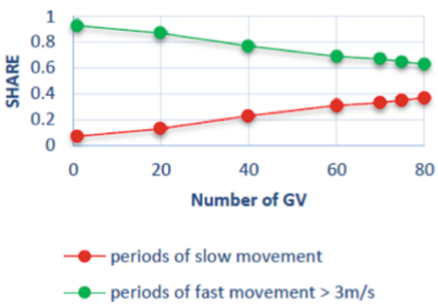

Fig. 5. Periods of time with faster or slower movement of ground vehicles as a function of the number of vehicles.

Fast movements starts at a threshold value of 3 m/s, about 10 km/h. Since normal acceleration and deceleration periods are included in the measurements, the congestion-free movement of only one vehicle already comprises slow movement periods with a share of about 7% of the overall driving time. With a growing number of moving ground vehicles the need of decelerating rises. The reasons are diverse, ranging from priorities to other vehicles parking maneuvers at the terminals and the stands. Comparing the optimal throughput number of ground vehicles with the congestion-free scenario of only one ground vehicle driving, the usually measured duration of vehicles movements improves by 32% in the congestion free scenario. It can be stated that the following positive effects were achieved by the prioritized route guidance.

- Empty runs of ground vehicles shortened
- Intersection control adapted and improved
- Flight times of the aircraft accelerated
- Efficient design of the number of ground vehicles.

5 Conclusion and Outlook

The method described above for estimating the characteristics of aircraft handling using prioritized vehicles can give only very approximate results, since even if there would be additional lanes for prioritized vehicles, they could not cross the intersection without delays. Additional time would be required to pass vehicles already at the intersection.

This time could be reduced if the aerodrome transport network management system would continuously monitor the position of each prioritized vehicle and timely blocks the movement of the remaining vehicles in the area of the respective intersection. Furthermore, the airport transport network management needs information about driving speed, planned finish time of the current task. Then a system of automated work assignment could be installed to minimize human error. Another approach is to expand the cellular structure on to all simulated roads.

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Design and Prototyping of IoD Shared Service for Small and Medium Enterprise

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Abstract. The importance to have information on delivery accurate and on-time is considered quite high in B2B (business-to-business) and B2C (business-to-consumer) segments. It is also essential for managing supply chain and delivery networks. With the aim of being fast, safe, controllable and traceable, delivery and trucking companies have developed a quite different logistics networks and systems in their logistics processes. Usually implementing of such processes requires a lot of resources from finance and IT perspective, which is not very suitable for SME (small and medium-sized enterprises). This paper presents concept, design and prototyping of the solution, which can be used and shared between delivery companies, 3PL (third-party logistics) operators and consignees to get IoD (information on delivery) accurate and on-time without implementing high costs and complicated processes and IT systems. The proposed solution is primarily based on QR (quick response) code recognition and data sharing.

Keywords: Logistics · Tracking · Information on delivery · QR code

1 Introduction

Transport deliveries in eastern European countries play a significant role in the supply chain. The majority of last mile delivery companies are the small business entities, who do not have modern ERP (enterprise resource planning) systems and still manage booking in Excel tables. At the same time market demands a high level of IT integration between shippers or 3PL (third party logistics) providers and last mile delivery companies. It is crucial to the consignee and supply chain, to have precise delivery information in time. The proposed solution will help to reach needed integration level without high investments and high running costs. The main purpose of the solution is to help small transport companies to enter the delivery market, where the demand for IoD (information on delivery) exists.

The proposed solution corresponds to the vision of the Industry 4.0 approach and force to enable smart logistics solutions to move to digital supply chain (see Fig. 1) [1, 2].

The solution will give an opportunity for small delivery enterprises and 3PL companies to be more efficient and provide better service in last mile delivery. There are several technologies, which are adapted by the business entities to provide the all involved entities by the IoD (information on delivery). Some of the authors [4, 5] propose to use RFID (radio-frequency identification) technology for IoD and tracking

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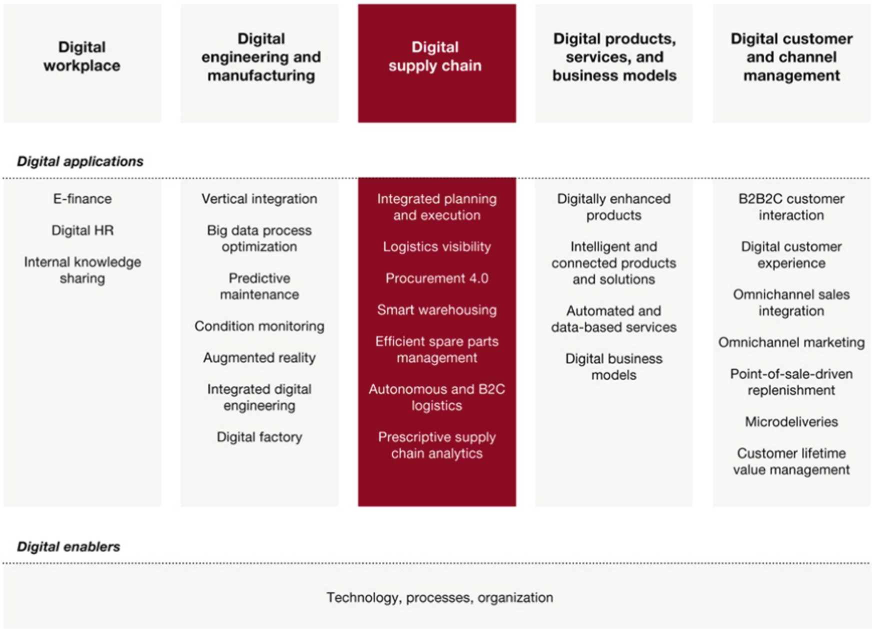

Fig. 1. The supply chain at the centre of the digital enterprise [3].

problem. They underline the benefits of the RFID based solutions, but in the same time points put on disadvantages, starting from costs, ending with technological limitations of RFID. Also, GPS (global positioning system) is treated by some of the researchers as a feasible solution for the described problem, the publications [6–8] demonstrates GPS application for delivery tracking. Both technologies are playing a significant role in forming the IoT (internet of things) concept, which also treated as a feasible solution [9]. But mentioned above solutions require high investments and high running costs. That is why, they are not feasible by the SMEs. As a feasible solution for SME the QR (quick response) code tracing solution was proposed in the paper "Requirement Analysis for the Collaborative Supply and Logistics Management of Fresh Agricultural Products" where QR code was used to trace farming operations and agricultural products [10]. The same concept could be implemented in a wider way, which is demonstrated in the paper.

2 QR Technology

QR (quick response code) is one of the coding type technologies currently used for personal and commercial purposes. QR is a two-dimensional matrix code developed in 90's by Denso Waive, a subsidiary of Toyota. It has still to mature as a full pledge commercial paradigm [11]. QR technology can encode various types of scans such as URL, text, image, mobile phone no, map location, or "Buy Now" link, with the capability of leading the user directly to a particular product or service [12]. The code typically consists of black modules arranged in a square pattern on a white background (other colours also can be used). 2D code holds up to close to 4,000 symbols of data [13] and can be used without maintaining a database (depending on the intended application).

The QR codes can be scanned and read directly from the print, projection or computer screen.

The QR Code's unique design gives it many advantages and benefits, including.

- Fast, omnidirectional scanning: Position-detection patterns in three corners of a symbol allow the QR Code to be read from any angle within 360°, eliminating the need to align the scanner with the code symbol. The position-detection patterns also eliminate any background interference, ensuring stable high-speed reading.
- High-capacity data storage: A single QR Code symbol can contain up to 7,089 numerals—over 200 times the amount of data as a traditional 1-D barcode.
- Small size: A QR Code can hold the same amount of data contained in a 1-D barcode in only one-tenth space.
- Error correction: Depending on the error-correction level chosen, a QR Code symbol can be decoded even if up to 30% of the data is dirty or damaged.
- Many types of data: The QR Code can handle numerals, alphabetic characters, symbols, Japanese, Chinese or Korean characters and binary data.
- Distortion compensation: A QR Code symbol can be read even if its image is on a curved or otherwise distorted surface.
- Linkability (Structured Append): A QR Code symbol can be divided into up to 16 smaller symbols to fit long, narrow spaces. The smaller symbols are read as a single code, regardless of the order in which they are scanned.
- Direct Marking: The QR Code's high degree of readability under low-contrast conditions allows printing, laser etching or dot-pin marking (DPM) of a symbol directly onto a part or product [3].

2.1 QR in Logistics

The QR labels can be placed on work in process goods (WIP), raw materials (RM), and finished goods products (FG) for easy identification of given SKU (stock keeping unit) in terms of part number, quantity, traceability code, etc. According to Motorola- a manufacturer specializing in the scanning devices, the QR technology grows in the popularity among progressive manufacturers [14]. Motorola company recommends the following applications:

- location codes identifying warehouse storage location. The labels are available for forklift drivers ensuring accurate inventory records. The codes should be enclosed in the plastic to prevent from wear-and-tear.
- floor code labels identifying goods to be stored in given locations. These codes are covered with tape/film to withstand harsh conditions such as forklift traffic and chemicals.
- pallet QR labels placed on the pallets or crates for identification and tracking purposes (usually printed on higher quality paper).
- shipping/receiving documentation allowing quick identification of the merchandise.

3 Solution Components and Overview

The proposed solution will have three main parts. First part – a platform for the software itself, integration logic and administration interface. This is the main and most important part of the software as the whole solution logic will be implemented there. Second part – mobile applications for drivers to upload information on delivery and for the clients to check online status of the package or shipment. The third part will be designed for the shippers or 3PL to be able to upload package information.

Figure 2 shows IoD shared service solution use-case from shipper, driver, delivery company and consignee perspective.

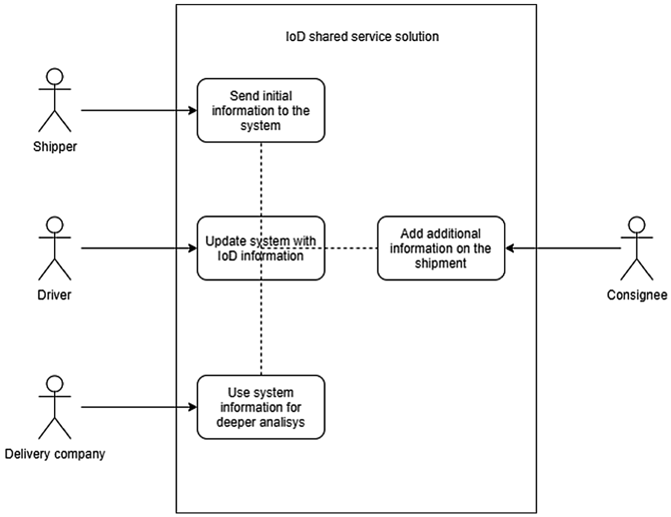

Fig. 2. IoD shared service solution use-case.

Every label printed by shipper should have QR code (see Fig. 3) with an encoded link to the solution web platform with including order number and client ID.

Fig. 3. Delivery label example with QR code.

When trying to read barcode it will look like https://ourcompany.lv/Delivery.php?contid=010000000000037585&client=tri, where contid is a shipping container number (could be GS1 SSCC code) and the client is the shipper or 3PL company code in the solution platform.

3.1 Actions on Delivery

Arriving at delivery address driver can scan the code directly to the browser and confirms delivery. Delivery can be confirmed with several options, statuses and comments. Sign-on glass technology can be used to identify consignee. In case, if on delivery place the internet connection not available, driver will be able to use the application on mobile phone or tablet to store the data. As soon as phone or tablet goes online data will be transferred to the system automatically (see Fig. 4).

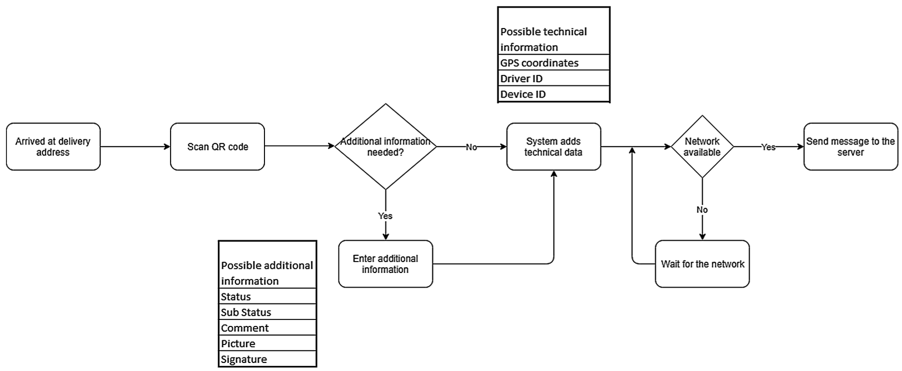

Fig. 4. Driver actions at the delivery address.

After system received delivery data, it stored in the database and could be accessible by the clients as IoD information. System going to save following information:

- Parcel ID
- Delivery time
- Status
- Sub Status
- Comment
- Picture
- Signature
- Actual GPS position
- Driver ID (from phone application)
- Device ID
- Comment if any.

When system got information on IoD one of the predefined client workflows is triggered. Different workflows available for the client dependent on the integration level and client needs. Most simple one is to send notification e-mail that shipment delivered.

3.2 Shipper Actions

To be able to use the system and get most of it, shipper needs to send data to the system. Minimum data required is a parcel number. Sending only parcel number to the system shipper can expect back only notification of delivery and nothing more. To get most out of the system shipper should send full information on the planned delivery including following:

- Parcel ID
- Consignee name
- Delivery address.

As shippers have different IT levels and knowledge level, it will be possible to send information electronically using web service or enter it manually for each parcel using system's website. Also, it would be possible to generate parcel ID's and print out delivery labels.

Such approach will give the possibility of using the system by companies with different IT levels.

3.3 The Action Flows on Delivery

It will be possible to have different action flows on delivery. There are defined two main flows and each flow can be adapted to the exact client.

Action Flow 1
This is the flow which provides only information on delivery time and comment if any. The delivery message can be delivered to the shipper by e-mail or electronically, if integration in place (see Fig. 5).

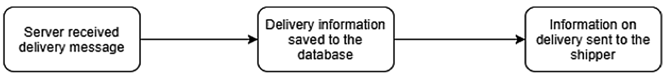

Fig. 5. System actions on flow 1.

Action Flow 2
In action flow two, it is supposed to receive more information from driver's device. In addition to the information from flow one system will get GPS position and picture if it was taken. GPS position will be used to compare it with delivery address position and ensure that delivery was made to correct place.

Picture sent together with IoD information, it can be used in different ways. For example, to proof and show the shipment damage. It could be useful when corrections were made to the delivery documents and driver would like to inform shipper immediately. Document picture can be sent together with information on delivery.

Figure 6 shows the possible action flow in case if additional information sent by driver's application.

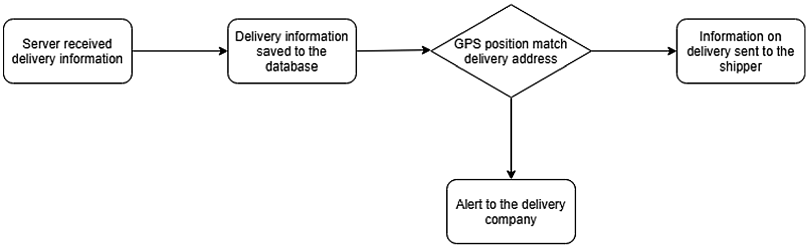

Fig. 6. System actions on flow 2.

4 Conclusion

Implementation of the described system will give a change for the small last mile delivery companies enter the market without high investments in the technology for solving the IoD problem. Shipper or 3PL will receive the possibility to make deliveries with any transport company they want, not taking into consideration, if transport company can provide IoD information or not. The delivery company will get a chance to provide IoD information without investing in technology and will be able to enter previously closed to them markets. The client will receive transparent service and online information about their shipments and packages.

Use of proposed system gives not only advantages of having IoD information. It will be able to provide delivery accuracy indicators and user-useful reports. For example, comparing the time between driver sends information on the delivery system can calculate driver's performance.

In addition to limited visibility at each point in the fulfilment and delivery process, customers want to track temperature sensitive items.

Many clients are putting different probes and monitoring devices in the packages themselves. This way the pharmaceutical company, frozen foods or spirits manufacturer will know the probe temperature and possibly the humidity level at every step. It's becoming an industry standard. Adding such sensors as a part of the system will give more global solution for all 3PL's on the market without the need to invest in their own solutions.

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Comparing the Customer Use and Satisfaction in Two Latvian Transport Interchanges

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Abstract. Transport services usability refers to the conditions of the infrastructure: reliability, safety, comfort and ease of access to various modes, travel time, and affordability. However, the transport services market does not distribute equitably in urban and rural areas. The scope of research is to analyze equity in user satisfaction in two transport interchanges: Bus Stations in capital city Riga and in small town Jelgava. Data were collected through a questionnaire survey in August 2017. The questionnaire included the users' opinion about service usability and quality of services. The analysis of differences between provided services and quality level for interchange in the capital city and small town was conducted.

Keywords: Transport interchange · Quality of services · Survey
User satisfaction

1 Introduction

Sustainable transport and mobility are basic to progress in implementing the Sustainable Development Goals (SDG) [1], and the concept of universal access features directly in the next SDG targets that addresses the need: in (9.1) to develop quality, reliable, sustainable, and resilient infrastructure, and focuses on affordable and equitable access for all groups of population; and in (11.2) for access to safe, affordable, accessible, and sustainable transport systems for all, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities, and older persons.

Public transport (PT) is vital to the life-sustaining activity and dwelling of residents and commuters, who rely on public transportation to provide cheap, efficient, and convenient methods of travel for their daily use. However, Kim et al. [2] suggested that the high reliance on PT also means that, when expectations are not met, it can be subject to the complaints and distrust from passengers and potential reduction in demand.

Transport services in East European countries in urban and rural areas often differ substantially. In rural areas, it is difficult for conventional PT to meet different accessibility needs of different user groups [3]. The objectives of rural area planning should be to improve the access to the facilities, goods and services for rural communities to live a socially and economically productive and decent life. However, a

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number of different authorities are responsible for the administration, procurement and planning of various passenger transport services; and it is a real problem on the way of integration in rendering services which support multimodality; MaaS etc. Moreover, the PT operators face not only the challenge to provide cheap and efficient service from the passenger's point of view but also to maximize operational efficiency. In the case of the public transport system (PTS) in rural area, as its extensive coverage depends on strategic position of terminal that connect, the operational efficiency of the system depends heavily on the safe, comfortable, and quick transfer of its passengers at these transport interchanges. Interchanges between transport modes often are significant pain points in regional transport system.

The concept of a sustainable transport system as stated in Latvian Transport Development Guidelines for 2014–2020 [4] is a high-quality transport infrastructure, high level of traffic safety, transport and logistics services, which create pre-conditions for the development of other sectors, provide jobs and the affordable public transport within the reach of the entire territory of Latvia. Mobility is one of the key elements that promotes social equity, and with ageing society and dramatically decreasing population in Latvia and especially in small cities and rural areas it is becoming essential for the local authority to monitor the running of the service with a view to adjusting the offer as closely as possible to users' needs. Necessity of researching the problems of role and place of the Coach and Bus Terminals in the PTS, formation of the multimodal passenger hubs on their basis, actuality and importance of the theoretical and practical questions of the transport service quality for the population as a required condition for the integration into the multimodal system determined the choice of this paper research aim.

The structure of the paper is following: in Sect. 2, basic concepts are presented, including a brief description of the Riga International Coach Terminal and Jelgava Bus Station, and an overview of interchange quality of services monitoring. The methodology of the interchange quality comparison is given in Sect. 3. The results and discussion are presented in Sect. 4 and the last Section provides conclusions.

2 Basic Concepts

Nowadays, an interchange is more than just a simple node in a network and a good interchange will generally be to improve the quality of public transport services and support seamless door-to-door travel [5]. Public transport customers expect the same kind of lifestyle services and connectivity from stations as they already have in their own environment [6]. And the way which the provision of public transport services can be integrated into the surrounding economy and economic activity can significantly increase the utilization of public transport services and a comfort factor for the passengers [5]. Moreover, the similar conditions should be in all towns notwithstanding their size.

Giannis et al. defined in [7] transport interchanges from the view of passengers as "transportation nodal points that enable seamless mobility, increase travelling efficiency, achieve user satisfaction and ensure system performance for door-to-door journey by making optimal use of combinations of modes in a sustainable way" [7]. In [5] mentioned that users have two totally interconnected views of the interchange: as a transport node and as a place. As the node of the multimodal transport system the interchange is a part of a passenger 'logistic' chain and its reliability, safety and other properties influence the properties of the whole chain (travel).

Two Latvian Passenger Transport Interchanges in Riga city and Jelgava city were considered. Riga International Coach Terminal (RICT) is one of the most important transportation hubs in Latvia [8]; the node of regional and international transportation networks, which generates a number of routes. Jelgava Bus Station (JBS) is situated in Jelgava City which is the 4th largest city in Latvia and just 42 km away from Riga with the total area is 60.3 km^2. Jelgava city is the hub of 6 main motorways and 5 railway lines that gives the basis for transferring JBS to Multimodal Terminal. Key attributes of Terminals are shown in Table 1. These terminals were chosen because they have one operator and both Terminals are included in Strategic plans of reconstruction and be integrated in multimodal hubs with rail station.

Table 1. Key characteristics of two Latvian transport interchanges.

	RICT (Riga)	JBS (Jelgava)
Interchange size	13193 m^2	186.5 m^2
Bus platforms	24	6
Routes in 2017, including:	156865	605959
Transit routes	3320	21648
International routes	24843	498
Tickets sold (passengers)	1661529	166722

Both terminals are long distance terminals within the city center, connected with city transport network and attract various activities to its surrounding area. In connection with the necessity to provide the accessibility of PT, the interchanges can be considered as a part of the transport system, which transforms the demand flows into a product – a set of the required services offered to passengers. As a public space RICT and JBS should take care of the passengers and should manage all the public space existing risks.

Taking into account that the services of a passenger terminal are integrated into the whole chain of passenger transportations and are accepted by the user as a single service of the chain, development of a complex approach to the analysis of the terminal service quality is quite actual. The system of complex monitoring of these terminals' services quality includes three types of surveys [8]. Each year in accordance with the quality management system procedure "Passenger Satisfaction Measurement", passenger survey was carried out in the RICT and JBS.

3 Comparison Methodology

The surveys for data collection described above, were conducted in long distance terminals in Riga and Jelgava in August 2017. Data were collected by SIA Factum Interactive through the questionnaire survey conducted both face-to-face with customers (passengers; terminal services users) and online.

The questionnaire included the users' opinion about service usability and quality of services and included 22 questions. The survey was divided into three parts. In the first part of the survey, socio-economic characteristics of the respondents such as gender, age and place of residence were recorded. In the second part, referring to the travel habits of the users, information was collected about the trip frequency and regularity, trip purpose, the information source, for ticketing: type and place of selling etc.

And the main - last part – is aimed at understanding users' views on various aspects of service quality provided by RICT and JSB. Respondents were asked to evaluate the following indicators on the (1–5) Likert scale, where 1 represented the lowest satisfaction with the respective service or station feature and 5 - the highest:

(1) *Safety and security* is a key factor for interchange attractiveness.
It is closely related to emergency situation handling, and a holistic approach to risk assessment and prevention is integral part of the service provided to passengers.
(2) *Cleanliness* – the important element for comfort feeling.
Attractive terminal design is important element for a successful interchange and it provides easy access for all users, including disabled passengers, that's why the next attributes were included:
(3) *Easiness of boarding and disembarking procedures.*
(4) *Bus location.*
(5) *Waiting room location.*
(6) As indicator of customer care - *attitude of the personnel* was included.
The crucial support for interchange is accurate information about trip and interchange, that can help travelers use their time more efficiently, give a general sense of the interchange's facilities, can influence on users' choice of transport modes, etc. therefore the following factor was included:
(7) *Information availability.*

The role of the information services and easiness of ticketing are significant that is why additional questions about the source of timetables, place and form of payment for tickets and satisfaction of these services were included in the questionnaire.

For our research the answers on questions in the last part were analyzed in detail. For the primary data analysis, descriptive statistics was applied: a number of the sample characteristics, such as size, age and gender and other were analyzed, by estimating the frequency distribution per gender and age, as well as the mean values and standard deviations for 7 indicator of quality. For two terminal services quality indicators comparing inferential statistics (non-parametric tests) were used. Mann-Whitney two-sample U-test was performed to assess differences among and between the samples in characteristics measured on the 5-point scale.

4 Analysis and Results

In total, 405 respondents (1^{st} Sample) were interviewed in Riga and 102 (2^{nd} Sample) - in Jelgava. 98 respondents answered online. But using U-test, the homogeneity of answers tested and for almost all indicators have very significant difference between respondents that answered face-to-face and online (p-value < 0.001). So, these on-line responses were excluded from analysis about perceived quality of services.

The samples are almost equally spread between females and males (for RICT: 58%–42%; for JBS: 62%–38%); but age structures of respondents are different.

For both cases most of the respondents are aged between 19 and 29: for RICT: 33% and for JCT: 24%. But than for RICT 18% of respondents were aged between 30 and 45, the same percent for respondents were aged older than 65 and 15% - between 46 and 59 and the same – for respondents aged less than 18. But for JBS the distribution of age's intervals have no significant differences: 14% - for respondents aged less than 18; 20% - between 30 and 45; 22% - between 46 and 59; and 21% of respondents were aged older than 65. It can be explained by the fact that Jelgava is a regional hub and a lot of people between 30 and 59 from surrounding region use buses for trip to job. 16% of terminal visitors use services mainly on weekends, the rest - mostly on business days, or equally frequently, on weekdays and weekends. On weekends, older people use the terminal more rarely, but more often school-age young people do.

Figure 1 presents the distribution of respondents' answers about perceived quality aspects for RICT and JBS between levels: 1st – 'poor' and 'very poor'; 2nd – 'satisfactory'; 3rd – 'good'; 4th – 'excellent'.

Table 2 presents an overview of the average rating and standard deviation of the seven indicators of quality. In terms of attractive design: easiness of boarding and disembarkation procedures and waiting room location the JBS was rated a little lower compared to the RICT. Also, personal attitude was evaluated higher in the RICT. But in aspects of safety in security and cleanness the JBS was rated higher (of course, it

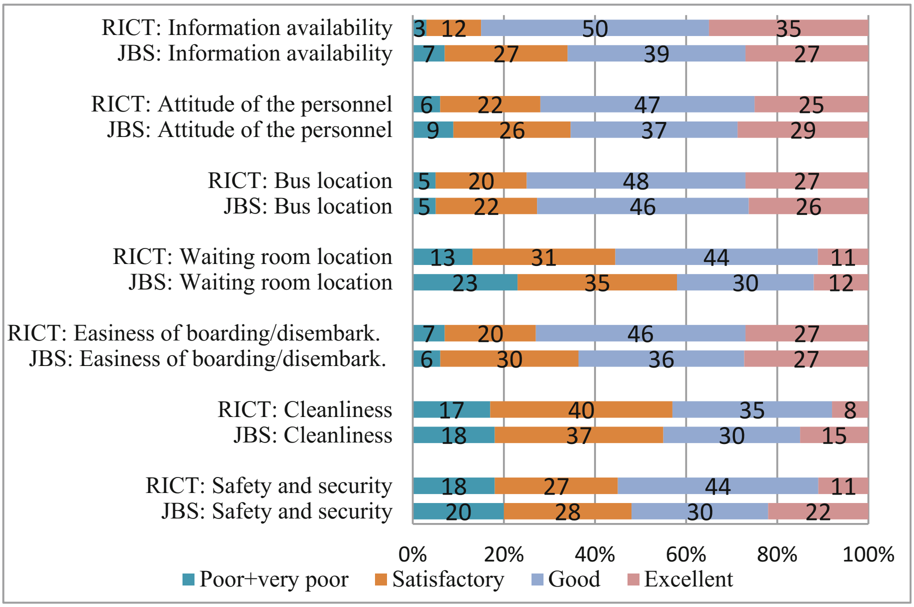

Fig. 1. Satisfaction level with indicators of perceived quality of the interchanges.

may be due to the small area). But the statistically significant differences for services quality in terminals that was tested on the basis of the Mann-Whitney test were met only in the indicator ‘information availability’ (Z-test = −2.756; p-value = 0.0057). All other differences were non-significant (p-value > 0.05)).

Table 2. Indicators of perceived quality of the RICT and JBS: average and standard deviations.

Indicators	Average rating		Standard deviation	
	RICT	JBS	RICT	JBS
Safety and security	3.46	3.52	0.062	0.124
Cleanliness	3.31	3.35	0.059	0.116
Easiness of boarding and disembarking procedures	3.98	3.83	0.054	0.106
Waiting room location	3.54	3.34	0.056	0.111
Bus location	3.99	3.98	0.047	0.094
Attitude of the personnel	3.92	3.80	0.055	0.109
Information availability	**4.20**	**3.87**	0.049	0.096

Considering ‘information availability’ in detail, respondents in the RICT most frequently mentioned that the source of information is still the telephone information service (49%) and then the most commonly used sources are the website (26%), timetable and Infocenter available at the RICT (21%), while other sources are of relatively small significance (see Fig. 2). Respondents on the JBS most frequently cited the information in station as the source of information on bus services, such as: the timetable and Infocenter (38%), telephone information service (32%) and website (28%). Other sources are used relatively less.

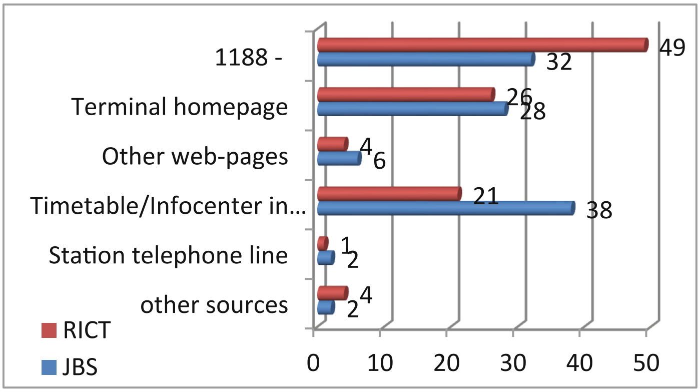

Fig. 2. Source of information on bus services of the interchanges (in %).

30% of RICT respondents have used the opportunity to purchase online bus tickets or mobile applications over the past year. The most popular type of remote payment is still a payment via the Internet bank; however, the number of users of mobile applications is also increasing (see on Fig. 3).

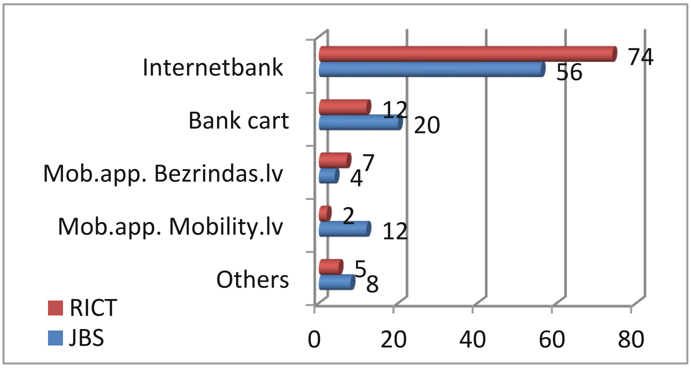

Fig. 3. Preferable payment method if users pay for services on the Internet (in %).

Finally, the comparison between the RICT and the JBS shows similarities, leads to the conclusion that users are satisfied with the services. The three most valued services are luggage storage, ticket reservations and ticket sales.

The users in Jelgava are less satisfied with services based on the station's design and information provision compared to the RICT, as well as information provided by the station's staff. On the other hand, the users seem to be more satisfied in the cleanness and safety and security in the Jelgava Bus Station compared to the RICT.

Considering the easy access to city networks, travelers reach or move from the Jelgava station mainly by walking (37%) or using other modes of public transport (43%). In the RICT more than 65% travelled from/to the RICT by public transport and 23% by walking. In both cases no significant percent of travelers used train for access and entrance to terminals. And the reasons of it are: (1) the absence of schedule and ticketing integration and (2) infrastructure integration (as was discussed in [6]).

5 Conclusions

Common European Market and integration of Latvia in the EU has presented new demands to passenger transport – high mobility, inter-modality, comfort observing of passengers' rights, as well as new requirements to the interaction of transport [9]. Interchange infrastructures and services should support smart and seamless inter-modality and equitable access for all groups of travelers.

The aim of this paper was to compare the quality of services that were provided by two different interchanges in Latvia: one – in capital and one regional. Data collection was in the framework of surveys taking place in the above-mentioned stations. Overall results based on descriptive analysis show similarities between the RICT and the JBS users' opinions: users are satisfied in the services. Most important conclusions that there are no significant differences between average ratings for indicators. Only aspects of 'information availability' are critical from the point of view of the multifaceted access. This is due to the different structure of population in the region surrounding the JBS and other level of life in comparison with the capital.

In the future, it is necessary to analyze the differences in detail, more taking into account the socio-economic aspects of respondents. This is particularly important in the area of planned serious reconstruction and integration with the railways, both in the regional station (JBS) and in the capital (RICT). It is impossible to fully consider all users' requirements without a systematic approach to the formation and management of the passengers' services market, taking into account public transport at the level of the country, region and cities and to the activation of business potential around terminals for achieving customer oriented and liveable neighborhoods.

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Investigating the Accessibility Level in Riga's International Coach Terminal: A Comparative Analysis with European Interchanges

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Abstract. This paper investigates the accessibility level of the International Coach Terminal in Riga, Latvia, determining crucial parameters, such as needs, elements and policies that can reform existing transportation hubs into fully accessible ones for all citizens. In order to receive users' feedback on the existing conditions of the terminal and gather their expectations for future interventions, a questionnaire survey was conducted by the Transport and Telecommunication Institute in cooperation with the terminal administration. Achieving a response rate of 95%, 239 users provided useful information about their travel habits, preferences and level of satisfaction, by rating thirty indicators. The results of this survey were also compared, through a meta-analysis approach, with relevant findings of similar surveys realized in five European transport interchanges.

Keywords: Interchange · Accessibility · Intermodality · Transport Hub Meta-analysis

1 Introduction

Although urban transport terminals are vital mobility city cells, they still lack an adequate level of accessibility, both infrastructure and information related. Busasi et al. (2015) described the concept of transport sustainability, as defined by the European Council of Ministers of Transport [1]:

- from the social side, a sustainable transport system provides basic accessibility of individuals, companies and society, and connects present and future generations
- from economic side, it enhances competitiveness and regional development through affordable and efficient operation, and lastly
- from environmental side, it promotes the use of renewable resources and the limit of emissions and waste in terms of planet's absorption ability, and moreover, through these features future, negative impacts can be prevented.

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The present paper aims at investigating the accessibility level of the Riga International Coach Terminal (RICT) in Latvia. The terminal, cooperating with 30 passenger transportation companies (16 of which ensure domestic transportation, 18 international transportation, and 12 of them are foreign companies) is one of the most important transport interchanges in Latvia. On average, the terminal maintains 420 routes daily, 350 of which are domestic and 70 are international routes, serving more than 2 million passengers [2].

In order to identify all needs, elements and policies that can reform existing transportation hubs into fully accessible ones for all citizens, a state of the art review of best practices, policies and legislation was conducted and key issues for accessible transportation hubs were determined [3–5].

In addition, applying a meta-analysis approach, research results were compared with relevant findings from similar surveys in European interchanges and pointed out the level of accessibility in the terminal. For the meta-analysis, five interchanges were studied: Moncloa Interchange in Madrid, Spain, Kamppi Interchange in Helsinki, Finland, Ilford Railway Station in London, United Kingdom, New Railway Station in Thessaloniki, Greece and Kobanya-Kispest Station in Budapest, Hungary.

The rest of the paper is structured as follows: the methodology of the paper is given in Sect. 2, followed by the presentation of results in Sect. 3. Section 4 provides conclusions and reflections about possible implications for the future research.

2 Methodology

2.1 Survey Design and Data Collection

Data were collected through a questionnaire survey conducted both online and face-to-face. The survey was separated into three parts. The first part aimed at understanding travelers' views and preferences on various aspects and elements of an urban transport interchange, and the respective level of their satisfaction. In the second part, referring to the travel habits of the users, information was collected about the trip purpose, the selected transportation mode, from origin to the interchange, and from the interchange to the destination, the respective time to/from/inside the interchange and the ticket type of public transport. In the last part of the survey, socio-economic characteristics of the respondents were recorded, including gender, age, education level, employment status, etc.

For the evaluation of the terminal accessibility level, four main criteria, formulated by eleven indicators were selected, based on the relevance of the certain survey questions with the concept of accessibility. Respondents were asked to evaluate these indicators on a (1–5) Likert scale, where 1-the lowest satisfaction with the respective service or station feature and 5-the highest. The selected criteria and indicators are presented in Table 1.

Table 1. List of evaluation criteria and indicators.

Criteria	Indicators	Average rating (M)	Standard deviation (SD)
Wayfinding information	Signposting to different facilities and services	3.62	1.05
	Signposting to transfer between transport modes	3.31	1.12
	Information and assistance provided by staff	3.59	1.08
Time and movement	Distances between different transport operators or transport services	3.77	0.97
	Coordination between different transport operators or transport services	3.43	1.03
	Use of time at the interchange	3.52	1.06
	Distance between the facilities and services	3.93	1.0
	Ease of movement due to number of people inside the interchange	3.64	1.06
Access	Ease of access to the interchange	3.97	0.94
	Ease of access from the interchange	4.02	0.93
Overall satisfaction	Level of services provided by the interchange	3.50	0.79

2.2 Data Analysis

Data were analyzed through descriptive and inferential statistics. In the first case, a number of the sample characteristics, such as size, age and gender were addressed by estimating the frequency distribution per characteristic, as well as the mean values and standard deviations. In the second case, the statistical analysis of the responses was carried out using non-parametric tests. Specifically, in order to estimate whether there were any differences in the average rating of respondents, hypothesis testing was used: the null hypothesis H_0 was that the median difference between the pairs is zero, and the alternative hypothesis H_1 was that the median difference is not zero. Kruskal-Wallis testing and Mann-Whitney two-sample U-testing were performed to assess differences among and between the samples in characteristics measured on the 5-point scale, respectively [6], and the alpha test was used to build combinations of the measures parameters [7]. A confidence level of 95% and confidence interval of 5% were assumed. In addition, in order to investigate the inter-relationships among the four main criteria (questions), bivariate correlations were conducted.

3 Results

3.1 Sample Characteristics

Achieving a response rate of 95%, the final sample size was defined by 239 users, of which the 62% are women and the rest 38% men. Regarding age, the 35% of the respondents are between 18–25 years old, the 30% of them between 41–65, the 28% between 26–40, and the 3% of them younger than 17, the 3% older than 66 years old, and the rest 1% preferred not to answer this question. In addition, most of the users (55%) are highly educated, the 24% have received a secondary level of education, the 15% hold a secondary professional level diploma, and the rest 6% are primarily educated. Focusing on the employment status of respondents, it was observed that the 64% of them are employed, the 24% are students, the 3% are unemployed and the rest 9% respondents stated a different status.

3.2 Evaluation of Terminal Accessibility Level

Results showed that users were mostly highly or moderately satisfied with the majority of the features and services related to the terminal's accessibility level (Table 1). "Access" was the highest rated criterion (average rating M = 4.00), followed by "time and movement" (M = 3.70), "wayfinding information" (M = 3.50) and "overall satisfaction" (M = 3.50). Focusing on the eleven indicators, the three higher rated were: ease of access from the interchange (M = 4.02, standard deviation SD = 0.93), ease of access to the interchange (M = 3.97, SD = 0.94) and distance between the facilities and services (M = 3.93, SD = 1.0).

In addition, the sample was grouped according to parameters such as gender, age, education level, employment status, trip purpose, frequency of using the station and number of transfers, and the eleven indicators were statistically analyzed based on this grouping. The most representative results are discussed in the following paragraphs.

Regarding gender, it was observed that women rated higher than men the seven out of eleven indicators, however, these differences were not statistically significant (p-value >0.05). In terms of the different age groups, statistically significant differences were indicated in the average rating of the overall satisfaction of users (p-value = 0.004). More specifically, results showed that the youngest and oldest users were more satisfied by the terminals' services and facilities, however, it has to be mentioned that these two age groups represent the lowest proportion of the sample, 6% in total. When testing the eleven indicators according to the education level of users, statistically significant differences were met in two indicators: signposting to transfer between transport modes (p-value = 0.003) and overall satisfaction (p-value = 0.009). In the first case, respondents holding a secondary professional level diploma gave the highest rating (M = 3.81, SD = 1.01), while on the other hand, the primarily educated were the most satisfied users of the terminal (M = 3.79, SD = 0.80). Focusing on the four different cases of employment status, results showed statistically significant differences in the indicators "ease of access from the interchange" (p-value = 0.046) and "overall satisfaction" (p-value = 0.008). The ease of access from the interchange was rated higher from students (M = 4.23, SD = 0.914) and users with any other employment status (M = 4.23, SD = 1.02). In addition, it was observed that the overall satisfaction of users traveling for work was higher (M = 3.6, SD = 0.79), compared to the rating of users traveling for "education" (M = 3.5, SD = 0.8) or "leisure/meeting with friends and relatives" (M = 3.4, SD = 0.79). However, these differences were not statistically significant (p-value >0.05). Also, users that do not make any transfers at the terminal were (significantly) more satisfied (M = 3.6, SD = 0.79) than those that make at least one transfer (M = 3.3, SD = 0.79) (p-value <0.05). Lastly, when grouping sample into commuters (frequent use of the station) and non-commuters, and testing the overall satisfaction, it was indicated that commuters are more satisfied (M = 3.6, SD = 0.8) than non-commuters (M = 3.4, SD = 0.79), but this difference was not statistically significant (p-value >0.05).

The correlation degree among the individual criteria and their relationships with the criterion addressing the overall satisfaction level was also tested (Table 2). Results showed that the criteria, which mostly affect positively the overall satisfaction of users seem to be wayfinding information (β = 0.707, p-value <0.05), then access (β = 0.615, p-value <0.05) and lastly time and movement (β = 0.615, p-value <0.05).

Table 2. Bivariate correlations of the individual criteria and their relationship with the criterion addressing the overall satisfaction level.

Criteria	1.	2.	3.	4.
1. Overall satisfaction	-			
2. Wayfinding information	0.707*	-		
3. Time and movement	0.548*	0.590*	-	
4. Access	0.615*	0.627*	0.487*	-

**p-value <0.05*

3.3 Meta-analysis

The Moncloa interchange was built in 1995, and an expansion took place in 2008. It is situated at an entrance point to the city of Madrid, which is also a location with high historical value, as there is a number of monuments in the station's vicinity. It accommodates 56 metropolitan bus lines, three urban bus lines and two metro lines, which serve 59,989, 96,789 and 109,321 passengers per day, respectively. Some facts that are worth noticing are that the interchange does not offer car parking services and its bicycle parking space is very limited (10 spots), but at the same time, it has entrances on all sides, which during its renovation in 2008 were made safer and more easily accessible. Another interesting feature of the interchange is the existence of dedicated bus tunnels offering easy and fast access to the interchange for bus passengers. Finally, the station is designed in such a way as to help people with disabilities move and orient themselves inside the facilities [8].

The Kamppi station started its operation in 2005 and a shopping centre was established in 2006. It is located in the central area of Helsinki, 500 meters from the Kamppi interchange. It is an important interchange, mainly at local and regional level, at the same time accommodating some national routes and an international bus route to

St. Petersburg. About 57,060 passengers use the station daily (19,360 through its 21 local bus lines, 8,500 through the 40 offered regional bus lines, 7,500 through its 15 interurban bus lines and 8,500 through its metro line). The station also offers two tram lines, as well as five more in close vicinity. Finally, it provides passengers with bicycle centers offering parking, repairing and renting services and with car parking and taxi service [8].

The Illford Railway Station was built in 1839 and was rebuilt in 1980. It is located in the central area of the suburban town of London Borough of Redbridge. It is of local and regional significance and is considered as an important transport interchange. It offers train services to the centre of the London city, while at the same time being a hub of bus services, providing bus routes to the city and its suburbs. Through its offered railway routes, it serves 21,000 passengers per day. The means of transport that the station can accommodate are rail, bus, car (for drop off purposes or for leaving it at the provided parking area), bicycle (with provided bicycle parking facilities, for which however concerns regarding its security were voiced during a passenger survey) and taxi. In order to enhance its accessibility, the station formulated a plan to improve the pedestrian environment, to make accessing it on foot easier [8].

The New Railway Station of Thessaloniki was built in 1961 and has seen no changes in infrastructure ever since, with the exception of the construction of a shopping centre. The station is located close to the centre of the city and is near the city's port. It is an interchange mainly of local and regional but of national importance and serves 6,000 passengers by regional rail, 130,000 by urban bus and 22,500 by suburban bus per day. The station also offers a direct bus line to the airport, taxi service, kiss- and park-and-ride facilities and facilities that help passengers access the station by bicycle. In that regard, it is also worth noting that there is a cycle path leading from the city centre to the station. There is also a metro line under construction, which is expected start operating in the following years [8].

The Kobanya-Kispest station was constructed in the years between 1978 and 1980. In 2008, it was expanded to accommodate a metro and a bus terminal and park-and-ride facilities, while a shopping mall was also created. In 2011, the interchange was renovated for the first time with the exception of the railway station, which causes some problems to its accessibility, as its old design might prove problematic, especially to people with disabilities. The interchange is located in the Budapest city and provides local, regional, national and international routes. The railway serves 9,886 passengers on a daily basis, while 67,967, 74,650 and 3,141 make use of its metro, local bus and suburban bus services, respectively. The interchange also offers a direct bus line to the airport, as well as bicycle and park-and-ride facilities [8].

Based on the acquired information, Riga International Coach Terminal (RICT) is of high regional importance, as it provides on average 350 regional bus routes per day. It also offers 70 international bus routes per day, which makes it an interchange of international importance. To this end, the station can be compared in terms of role, with Kamppi interchange and Kobanya-Kispest, which accommodate international lines. However, the number of offered routes reveals that RICT is much more oriented towards international transport than Kamppi and Kobanya-Kispest. The number of passengers that use the station yearly amounts to approximately 2 million per year, which is translated into 5,480 passengers per day. This number puts RICT much lower in terms of passengers served than all of the other interchanges. In terms of services offered and facilities, the station provides assistance and guidance to people with disabilities through specialized staff, while also providing a lift and two parking lots. This shows that the station tries to keep up with good practices, even though through a different method compared to Moncloa, which adopts a more conventional approach. Taking into account this information, RICT seems to be more similar to Kamppi and Kobanya-Kispest in terms of role and size (with a much lower number of passengers served per day) however, it can also be compared to Moncloa in relation to the accessibility measures for people with disabilities.

Compared to the results of the surveys taking place in the above-mentioned stations, RICT shows an overall satisfaction rate with a mean of 3.50, which is higher than Thessaloniki (3.13) and Illford (3.16), but lower than Kamppi (3.94), Kobanya-Kispest (3.61) and Moncloa (3.92).

By combining the indicators for the distance between transport means and facilities, ease of movement and time in the interchange, a mean value can be calculated that expresses the satisfaction of the passengers with time they spent in the station and their movement inside it. This mean was found to be 3.70, which is higher than the relevant indicators calculated in all other five stations.

Using the same method, the combination of the indicators measuring the satisfaction levels of cooperation between transport modes and ease of access to and from the interchange can give a general idea of how easily accessible the interchange is. The mean value of this indicator is 3.81, which is higher than the respective values of Illford (3.33) and Thessaloniki (3.73) and lower than Moncloa (4.19), Kobanya-Kispest (4.31) and Kamppi (4.29).

Finally, the grouping method was used for the indicators measuring the passenger satisfaction with the signposting (of both facilities and transport modes) and the provided information by the station's staff. The mean that was calculated was equal to 3.50, which is again higher than Thessaloniki and Illford (both at 3.26), lower than Moncloa (3.81) and Kobanya-Kispest (3.70) and at the same level with Kamppi.

The comparison between the station and the interchanges with which it shows similarities, leads to the conclusion that passengers are less satisfied with the station's accessibility compared to Kamppi and Kobanya-Kispest. On the other hand, passengers seem to be more satisfied in the area of time spent and information provided in the station compared both to Kobanya-Kispest (3.52) and to Kamppi (3.69). In terms of ease of access, and taking into account the accessibility measures adopted for helping people with disabilities, the station was rated lower compared to Moncloa.

4 Conclusions

In recent decades, accessibility as a key factor for sustainable transport, has gradually gained importance. A user-friendly public transport system should take into consideration this feature, when designing and operating public transport interchanges and provide seamless connectivity for multimodal trips. Interchange accessibility is also a crucial element to consider in decision-making involving any action that may influence the performance and attractiveness of the transport system in total.

The findings of this paper are especially important in the context of future tasks of Riga Municipality to develop the Central Multi-Modal Public Transport Hub that integrates the Riga Central Railway Station and RICT.

Whatever the local situation regarding the organization of transport in the Riga city is, moving towards both modal integration that includes soft modes and functional integration appear to be essential in order for transport policies to play a role in interchange "time penalty" reduction. Another critical point is the quality of the process in RICT, which is still compromised by gaps in the information chain, meaning that integration between information providers is necessary. Nevertheless, the complex workflows in RICT can be effectively improved through state-of-the-art technology: ticket validation systems, based on rechargeable and contactless e-cards, real-time information system for all modes of transport, either in panels at RICT, or via smart phone applications. The main point to solve is to be more integrated with the help of the same technological platforms and it depends on a public policy to foster integration of all stakeholders.

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Impact of Critical Variables on Economic Viability of Converted Diesel City Bus into Electric Bus

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Abstract. Through the European Strategy for low-emission MOBILITY of 2016, the European Commission is working to strengthen the economy by promoting sustainable urban mobility and increased use of clean and energy efficient vehicles and looking into how to accelerate this process. Cities are crucial for the delivery of this strategy, and electrification of buses is a step towards reducing the fossil fuel dependency of the transportation sector as well as creation of a healthier urban environment.

At the same time electric buses are still a challenge for public transport operators due to high acquisition costs of a new vehicle and lack of charging infrastructure. Therefore, conversion of diesel city bus into electric bus is one of the alternatives considered. Economic viability of converted diesel bus into electric bus can be parameterized using an economic model that allows to estimate an impact of critical variables on the total cost of ownership.

In this paper, a specific case of operating converted diesel bus into electric bus in a city of Latvia is analyzed. With the help of economic model, critical variables are determined as well as their switching values, which make the use of converted diesel engine bus into an electric vehicle economically viable. It can be used to support decision-making process of public transport stakeholders in the context of the deployment of environmentally friendly public transport.

Keywords: Low-emission · Electric bus · Converted diesel bus Economic analysis · Total cost of ownership · Sensitivity analysis

1 Introduction

A European Strategy for Low-Emission Mobility [1] states that Europe needs to accelerate the transition towards low- and zero-emission vehicles like some plug-in hybrids, full electric cars and fuel cell (i.e. hydrogen-powered) vehicles. Transition to a low-carbon economy is supported in all EU countries, including Latvia. Through the Strategy, the European Commission is working to strengthen the economy by promoting sustainable urban mobility and increased use of clean and energy efficient vehicles, and looking into how to accelerate this process. One of the EU transport sector goals stated in the White Book [2] is to reduce CO_2 emissions by 60% until 2030. Transport, in particular urban transport, uses a great share of energy resources.

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Urban public transport (PT) is in the process of transformation driven by technological developments and demand for environmentally friendly, energy-efficient, cost-effective, and smart mobility. Cities are crucial for the delivery of European Strategy for low-emission, and electrification of buses is a step towards reducing the fossil fuel dependency of the transportation sector as well as creation of a healthier urban environment and reducing the impact on climate change.

At the same time electric buses are still a challenge for PT operators due to high acquisition costs of a new vehicle and lack of charging infrastructure. The development of local economy along with the technological opportunities are important factors to be considered in the decision-making regarding the use of electric buses in a city. A new electric bus is a costly investment for a company providing PT services in small and mid-size cities with a population of 20 000 up to 200 000 (according to the definition of a medium-sized town in [3]). Therefore, solutions have been sought to look for less expensive alternatives that meet the goals of a low-carbon economy and sustainable urban mobility.

Innovative technologies increasingly oriented towards electrification of vehicle propulsion systems are expected to lead to: (i) a reduction of harmful emissions, (ii) an increased efficiency of vehicles, (iii) improved performances, (iv) a reduction of fuel consumption, (v) a reduction of noise, and (vi) potentially lower maintenance costs [4]. Conversion of a used diesel bus into an electric bus allows to substitute electricity for diesel with minimal changes to existing fleet.

This study focuses on mid-size city diesel buses that are used in the urban environment. As a bus ages, operating and maintaining (O&M) costs tend to increase. At this point the strategic decision has to be made – to renew the fleet or to modernize the existing fleet. The research aim is to assess economic viability of the proposed solution: converting a diesel city bus into the environmentally friendly electric bus.

The structure of the paper is the following: the methodology of estimation an impact of critical variables on the total cost of ownership is described in Sect. 2; in Sect. 3, the results and discussion of a specific case of operating converted diesel bus into electric bus in a city of Latvia are presented; and the last part offers conclusions.

2 Methodology

Total Cost of Ownership (TCO) model is utilized in this research to determine economic viability of a diesel bus conversion into an electric bus, and sensitivity analysis is used to assess the impact of critical variables on the TCO. Life cycle costs for buses with different types of engine (diesel and electric) are compared to evaluate cost-effectiveness of the conversion process.

The analysis focuses on the mid-size buses up to 12 m long with the capacity of 80 passengers used in the urban environment, which is affecting the operational phase related impacts, as well as investment costs. The average annual distance is assumed to be 60 000 km. Diesel bus used for PT services in the city has a lifecycle of 10 years. There are major costs cycles that repeat throughout the bus life and the cost peak is reached at roughly 6 to 7 years [5]. Thus it is assumed to be optimal timing to convert the diesel bus into the electric bus.

2.1 Total Cost of Ownership Model

TCO analysis is a method to assess life-cycle costs that include all costs of purchasing, operating, and maintaining the vehicle. The economic analysis model is prepared with the objective function to calculate TCO for the diesel bus (DB) and the converted electric bus (EB). The comparison of the results allows to assess economic viability of the DB replacement with the EB for PT services in the urban environment.

In case of EB, availability of charging infrastructure has to be considered. If the infrastructure is not in place for charging electric buses, then the investment costs of charging infrastructure as well as costs of grid connection are also included in the TCO calculation.

TCO include the vehicle costs, the charging infrastructure costs, and external costs:

$$TCO = CInv\,(bus) + CInv\,(charger) + CInv\,(grid) + C(O\&M) + I * C(ext) \quad (1)$$

where CInv (bus) - investment costs of a bus; CInv (charger) - investment costs of a charger; *CInv (grid)* - investment costs of a grid connection; *C(O&M)* - operating and maintenance costs for the vehicle and the charger; *C(ext)* - external (environmental) costs; and indicator *I,* that equal to 1 for DB, and to 0 for EB.

External (environmental) costs *C(ext)* are considered in this analysis because these costs relate to the damage of human health and ecosystems associated with air pollution and emissions of greenhouse gases (GHG), and are calculated as follows:

$$C(ext) = C(CO_2) + C(NO_X) + C(PM) \quad (2)$$

where $C(CO_2)$ - costs of CO_2 emissions; $C(NO_X)$ - costs of air pollution (Nitrogen oxides (NO_X)); and *C(PM)* - cost of particulates (PM).

The damage of human health and ecosystems are mainly caused by the vehicles with internal combustion engines. Electric vehicles do not create GHG emissions but they may increase CO_2 emissions generated in electricity production. Since the main energy source (70%) is water power in Latvia (the rest being renewable energy 3.5% and fossil fuel 26.5%, out of which coal is 2% only), the CO_2 emissions generated in electricity production are not included in the analysis [6].

Costs of CO_2 emissions are calculated for the DB using the following formula:

$$CO_2 = CO_2\,\text{emissions (g/km)} * \text{cost (EUR/g } CO_2) * \text{annual mileage (km)} \quad (3)$$

$C(NO_X)$ - costs of air pollution and *C(PM)* are calculated on the same basis.

For the comparison purposes TCO is expressed in Equivalent Annual Cost (EAC), which includes cost of owning, operating and maintaining an asset. The present value of capital investment costs is expressed in equal annual payments using Capital Recovery Factor, at a discount rate of 4% [7]. EAC shows the net present value of an investment through annuity factors and therefore allows to do a comparison relative to time. The total cost of ownership is expressed as cost per kilometer (€/km), and is calculated dividing EAC by the number of annual operation kilometres. All prices are given net of VAT.

2.2 TCO Model Assumptions and Parameterization

Economic analysis includes both mathematical and expert estimations regarding model development, e.g. some cost items are included on constant bases whereas others require expert evaluation based on specific location, situation, and mostly on availability of necessary infrastructure for the use of EB.

Variables used in the TCO model and their values are given in the Table 1. The variables are identified as the main indicators of cost-effectiveness, which is the measure of outcome.

Table 1. TCO model variables and their values.

Asset	Variable	Value (DB)	Value (EB)
Vehicle	Investment cost	200 000 €	196 700 €
	Useful life	10 years	7 years
	Energy consumption	10.4 MJ/km (29 l/100 km)	1.2 kWh/km
	Energy price	1.00 €/liter	0.11215 €/kWh
	Urea, oil	0.011 €/km	n/a
	Maintenance and repair	0.15 €/km	0.10 €/km
	Transport operating tax	0.002 €/km	n/a
Charging infrastructure	Investment cost of charging infrastructure	n/a	150 000 €
	Charging infrastructure maintenance	n/a	1 000 €/year
Grid connection	Investment cost of grid connection	n/a	30 000 €
	Transmission power maintenance	n/a	19.56 €/kW/year
	Electricity transmission tariff	n/a	0.02129 €/kWh

The price of the converted EB is estimated taking the remaining value of the 7-year old diesel bus, subtracting the re-sell value of diesel engine and transmission system, and adding the cost of battery, electric drive and other supplementary materials, as well as labor costs. Battery is the most expensive component of the electric bus. According to the historical trend of battery price, the cost of batteries is expected to decrease in the future. Department of Energy of the United States predicts that with new material chemistries and lower-cost manufacturing, cost parity with internal combustion engines could be reached in the next ten years [8].

It is assumed that mid-size urban PT buses travel around 200 km a day without returning to the depot. Fast charging infrastructure, also known as opportunity charging, with pantograph is selected in this analysis because it allows to use comparatively small batteries which can be easily integrated into the vehicle [9]. Smaller battery means less initial investment cost, less weight, and more room inside the bus for passengers. Charging infrastructure includes the following elements:

- a static conductive fast charging station;
- pantograph coming down from an overhead charging mast;
- contact rails to be placed on the roof of the vehicle;
- Wi-Fi protocol for communication between vehicle and charging mast.

The charging infrastructure can be used by several buses on the line therefore investment costs are calculated proportionally to the number of buses using the charger. In the analyzed scenario, the quick charger can be used up to 6 vehicles per hour assuming charging time 9 min per vehicle. The realistic scenario of 5 vehicles is used in calculations. Fast charging infrastructure requires very little maintenance, just periodic inspection with estimated annual costs of 1000 EUR.

It is assumed that the charging infrastructure is owned by the bus company therefore the grid connection costs have to be considered as well, if a new connection to the power grid is required. With the estimated charger power of 150–300 kW, a connection to the low-voltage 6–20 kV line is sufficient. In this case, annual energy transmission service costs have to be considered for the owner of the charging infrastructure.

The energy consumption of electric bus is estimated at 1.2 kWh/km in the conditions typical for the average medium-sized city in a relatively flat area using the mathematical model which was created within the study to evaluate the effectiveness of the electric bus. The maintenance costs of electric drive system are expected to be 30% less compared to combustion power transmission system because it requires less frequent service maintenance. Electric drivetrains have less subsystems - no transmission, no oil tank, no catalytic converter. Also, electric vehicles can be exempt from transport operating tax (as it is in Latvia).

Refueling infrastructure for DB is not included in the TCO calculations assuming that this infrastructure has been in place already for 7 years and does not require additional investments for the bus operator.

2.3 Sensitivity Analysis

Sensitivity analysis method is used to identify the critical variables and to assess their impact on the model results. It allows establishing the financial sustainability level of the project given by the potential changes of the influence factors and serves, at the same time, to measure the project risk in order to justify decisions [10].

Let consider the ***critical variables*** as variables whose variations (positive or negative) have the largest impact on the TCO. The analysis is carried out by varying one variable at a time and determining the effect of that change on the TCO model results. In this research, variables are to be considered ‘critical’ for which a variation of $\pm 1\%$ of the value adopted in the base case gives rise to a variation of more than 0.2% in the value of the TCO results. The cost-effectiveness of the conversion process depends heavily on those variables whose value changing up to 20% results in a disadvantage of the use of EB. It is assumed that the tested variables are independent.

On the next step ***switching values*** are calculated. It is the value that the analysed variable would have to take in order for the TCO of the EB become equal to the TCO of DB, or more generally, for the outcome of the bus conversion project to fall below the minimum level of acceptability from the economic point of view. The use of switching values in sensitivity analysis allows making some judgements on the risk of the project and the opportunity of undertaking risk preventing actions [4].

3 Results and Discussion

The main results of TCO analysis are shown in Fig. 1. The calculated TCO of the diesel bus is 1.44 €/km, including environmental costs 0.05 €/km. It should be noted that in some studies, in which the comparison of the buses is performed [11], labour costs, insurance costs and vehicle tax are not included in the TCO calculation, whereas in this study all costs related to owning, operation and maintenance of the bus are considered in the TCO. For the diesel bus, investment costs form 28% of total TCO. The price of the 7-years old diesel bus converted into the electric bus is similar to the new diesel bus, but because of shorter remaining lifetime (7 years), the investment costs comprise a bigger share in the TCO (39%). The total TCO of the electric bus is 1.40 €/km, which include costs of charging infrastructure (0.07 €/km) and grid connection costs (0.03 €/km).

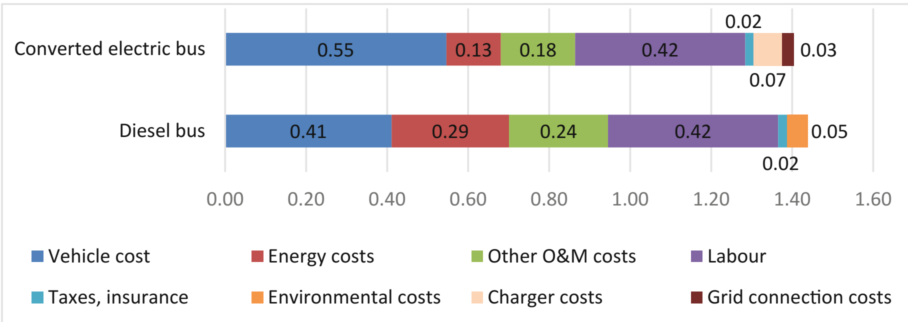

Fig. 1. TCO analysis results of diesel city buses in comparison with converted diesel bus into electric bus (EUR).

If the comparison is made for bus costs only (excluding infrastructure and external costs), the total TCO of the EB is 6% less than that of the DB. Significant part of converted bus price is the cost of the battery (36%). Battery is the most expensive component of an electric vehicle, and therefore is tested in the sensitivity analysis.

Significant benefit of DB conversion into EB is the reduction of energy costs. In the first case, the fuel costs are 20% of TCO, whereas after the conversion, the energy costs reduce 2.2 times due to significant reduction in energy consumption. O&M costs also decrease for the electric vehicle (by 20% in total) because there is no need for liquids such as engine oil and urea, and less frequent service maintenance required.

Based on the TCO results, investment costs and O&M costs are found to be critical for the sensitivity of economic justification (see Table 2). An increase in energy consumption or in electricity tariff is not a threat to the economic benefit of a bus conversion. It may be assumed that due to technological development, the price of the battery has a decreasing trend over time.

Table 2. Elasticity of equivalent annual TCO.

Variables	DB TCO change	EB TCO change
Vehicle parameters		
Investment costs	0.29%	0.39%
O&M costs	0.68%	0.54%
Cost of electricity	-	0.10%
Battery cost	-	0.17%
Energy consumption	0.20%	0.10%
Charging infrastructure parameters		
Charger infrastructure costs	-	0.04%
Number of buses using charger	-	0.07%

Using the TCO model, the switching values of critical variables are determined in order to have the conversion of the DB into the EB economically viable (see Table 3). The switching values of critical variables are those values at which the equivalent economic annual costs of DB and EB become equal. If the cost of conversion of DB into EB will be 6% higher than estimated in this study then the conversion will not be economically viable. If the total O&M costs of DB will reduce by 3% or O&M costs of

Table 3. Switching values of variables.

Variables	Benchmark value	Switching value	
		DB	EB
Vehicle parameters			
Investment costs (DB)	200 000 EUR	−8%	-
Investment costs (EB)	196 700 EUR	-	6%
O&M costs per year (DB)	58 578 EUR	−3%	-
O&M costs per year (EB)	45 475 EUR	-	4%
Cost of electricity	0.11215 EUR/kWh	-	25%
Battery cost	70 000 EUR	-	14%
Energy consumption (EB)	1.2 kWh/km	-	25%
Energy consumption (DB)	29 l/100 km	−12%	-
Charging infrastructure parameters			
Charger infrastructure costs	150 000 EUR	-	54%
Number of buses using charger	5 buses	-	−25%

EB will increase by 4% then there will be no economic benefit of using converted DB into EB. At least 4 electric buses are needed in operation in order to justify the investment of the charging infrastructure (excluding the grid connection costs).

4 Conclusion

The comparison of economic performance of the two bus alternatives – diesel bus and converted electric bus has been made using developed TCO model and similar TCO results for both alternatives are achieved. Nevertheless, the overall results of economic analysis are in favour of converted electric bus which apart from lower O&M costs provides additional benefits to the environment and extends the life of the used diesel bus. The conversion process is cost-effective as it reduces total TCO of the vehicle by 6% if infrastructure costs and external costs are not taken into the account.

The presented TCO results are satisfactory to justify the DB conversion into the EB; though variations of certain input parameters for O&M costs and investment costs of conversion have significant influence on the TCO results. Charging infrastructure investment costs do not have significant impact on economic viability of the diesel bus conversion to electric bus due to the fact that the charging infrastructure can be used by number of vehicles over its lifetime thus significantly reducing the cost burden per vehicle.

Methodology offered in this research can be used as a framework for local authorities and transport operators, on the bases of which it is possible to concretize TCO model and to assess the impact of critical variables on the life cycle cost of the bus.

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Shopping Malls Accessibility Evaluation Based on Microscopic Traffic Flow Simulation

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Abstract. The task of shopping mall accessibility evaluation is a vivid problem from a business perspective and in the same time from the public sector and urban development. Business entities are interested to have higher accessibility level to increase the profit in the same time the public sector is interested in sustainable development of the urban areas. Current paper presents the approach to evaluate accessibility of the shopping malls by the visitors based on microscopic traffic flow simulation. The proposed approach in based on idea, that the "last mile" challenge in logistics is also actual in case of the shopping malls. The main factors influencing "last mile" in this case are: usually location of the shopping malls is planned to have maximum of passing flows, it means that a network around shopping mall could be congested much and it is quit problematic to get into shopping mall; usually the number of parking lots are limited and in case of shopping mall popularity visitors are spending significant amount of time to find the free lots; also, a very important issue is related with leaving the shopping mall parking area, as it could be the situation that it is easier to get in when to get out from parking. To evaluate the influence of the mentioned above factors to the accessibility it is proposed to utilize microscopic traffic flow simulation. The paper formulates the methodology for evaluation of accessibility of the shopping malls and demonstrates its applicability based on case study.

Keywords: Shopping mall · Accessibility · Traffic simulation
Last mile

1 Introduction

There are many research papers dealing with the problem of the shopping mall accessibility measurement. The International Council of Shopping Centers (ICSC) defines shopping center as "a group of retail and other commercial establishments that is planned, developed, owned and managed as a single property, typically with on-site parking provided" [1]. There are several factors influencing the selection of the shopping mall geographical location, the review of the attributes is well presented in [2]. The main factors are the density of population in the area; distance between rest shopping malls and in [3] is mentioned that it is preferable to have main roads near. The availability of the main roads with high intensity of the traffic in the potential area of the shopping mall gives additional value as this significantly increase the rate of

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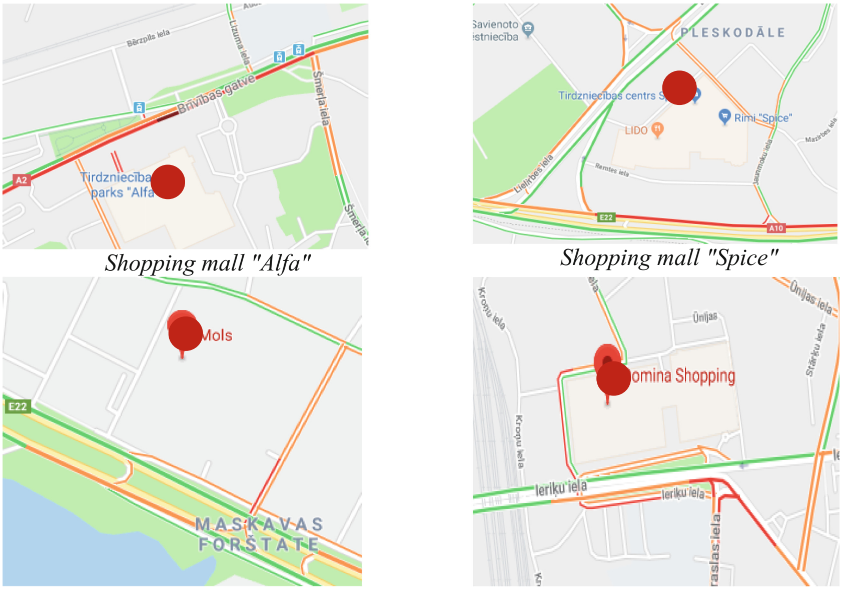
attraction of so called by-pass trips. The selection of the shopping mall location based on the mentioned above factors usually leads to the situation, that access to shopping mall area is difficult, because of the traffic congestion. Figure 1 demonstrates the examples of traffic congestions around shopping malls in Riga.



Shopping mall "Alfa" *Shopping mall "Spice"*

Shopping mall "Mols" *Shopping mall "Domina Shopping"*

Fig. 1. Examples of traffic congestions in the area of shopping malls (data from Google Maps).

In all examples could be seen, that the shopping malls are located near the main roads and it leads to the already mentioned problems. That is why it is important to measure not only general accessibility of the shopping malls as presented in [4], which is based on distance between shopping mall and residential areas, but also to measure the accessibility in detail, considering the transport infrastructure around shopping mall. By the analogues to supply chain management known problem “last mile problem”, here could be introduced the same term “last mile problem” in accessing the shopping mall by visitors. The idea behind, is the following: it could be quite easy to reach the geographical location of shopping mall using main roads of the city, but it could be quite complicated and time consuming to get into parking area of the shopping mall, as well to get out from the shopping mall area. The current paper goal is to demonstrate the usage of the traffic microscopic simulation to measure the accessibility of the shopping mall.

Accessibility means the ability to reach a particular place or area [5]. Key factors affecting accessibility of active center are: mobility, transport options, land use, and affordability [5]. Geurs and Ritsman van Eck [6] consider difference components of the accessibility such as transportation, land-use, temporal and individual components.

They also distinguish several types of accessibility measures: infrastructure-based (journey times, congestion, operating speed on the road network), activity-based (distance measures, contour measures, potential measures, measures based on balancing factors of spatial interaction models, measures derived from time-space geography), utility-based accessibility measures (interrupt accessibility as the outcome of a set of transport choice). Scheurer and Curtis [7] cite the following accessibility measures: spatial separation measures [8]; contour measures [6]; gravity measures [8]; competition measures [6]; time-space measures [6, 8]; utility measures [6, 8] and network measures [9, 10]. There are some works connected with accessibility measure for shopping activity and food stores location [11–13]. Several papers are devoted shopping mall accessibility estimation [14, 15]. Coehlo and Wilson [16] determines the most convenient location for supermarkets, Widener et al. [17] provides a novel analysis on access to supermarkets via transit using the cumulative opportunity accessibility measure; Pashkevich and Puławska [4] the location-based measures used to assess the accessibility of shopping malls as traffic generations in the city of Krakow. The used two kinds of accessibility measures: distance measures based on the straight line (Euclidean distance) and real distances and potential accessibility measures also based on the same distances and, additionally, weighted by characteristics of shopping malls and transport districts.

2 Methodology for Evaluation of Accessibility Based on Microscopic Traffic Flow Simulation

The methodology for evaluation of accessibility based on microscopic traffic flow simulation could be presented as a sequence of steps, which should be completed to get the results, usable for decision making. The proposed methodology consists of the following steps:

1. Development, validation and calibration of the microscopic traffic flow model for the area affected by the shopping mall. The demand part of the model should be presented as a set of OD matrices (regular traffic) and trip chain file, which describes the visitors of the shopping mall.
2. Simulation of the traffic flows based on the developed model, with recording in file or database the tracking data (trajectory data of the individual vehicle). The trajectory data should contain the information about specific vehicle ID, origin and destination transport zone, time in network and delay time.
3. Next, the analysis of the tracking data should be performed, by: selecting the data about specific vehicles (those vehicle ID defined in trip chain file); aggregating the data about delay time by each vehicle (to get the total delay time); aggregation of data by origin and destination transport zones.
4. Last stage consists of the statistical processing of the aggregated data, by calculating descriptive statistics measures and construction of histogram and cumulative distribution of the delay time (in general the selection of the measures is up to analyst).

To demonstrate the ability of the proposed methodology in current case-study the traffic simulation model developed in VISSIM simulation software was used. VISSIM was selected as this software provides necessary functionality for execution of the stages described above. VISSIM can record the vehicles trajectory data into database, able to provide the required information about origin and destination zone, delay time; able to mix OD matrices and trip chain file in one model to produce the demand part of the model.

3 Case-Study Description

The study object is a fragment of the Riga transport network located in the eastern part of the city on the right side of the Daugava River. The study object includes a number of signalised and not signalised crossroads and three-two level flyovers.

The territory is a part of Riga transport system, which connects several residential districts of Riga city: Purvciems, Kengarags, Centre and the left riverside. Additionally, the study area includes parts of the following main streets: Krasta, Maskavas, Lubanas, Katlakalna, Krustpils, Darzciema, Piedrujas, Ilukstes and A. Saharova street. Maskavas and Krasta streets are highly used by the traffic from the city centre to neighbouring cities. The study object is represented in Fig. 2. By the red circle is market the location of new shopping mall.

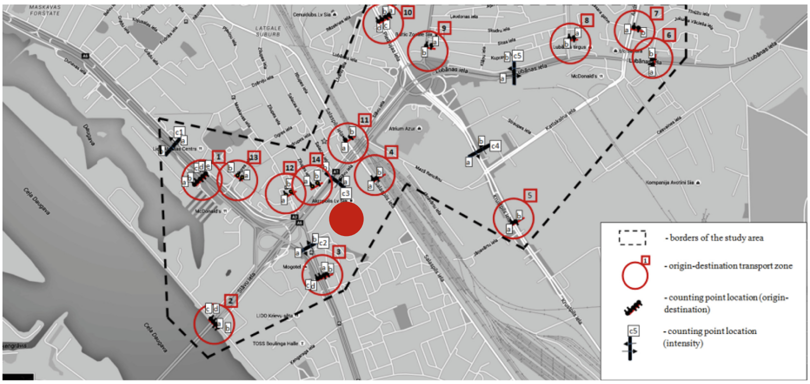


Fig. 2. Study object (background from Google Maps).

The study area is congested in morning (7:30–9:00) and evening peak hours (17:00–18:30). Moreover, this area of the transport network is complex and treated as one of the “black spots” in Riga (high number of traffic accidents). The congestion level in the evening is much higher compared to morning peak hours, so it was decided to simulate only the evening peak hours in this research. Another reason is, that by the evening time the shopping mall should attract more visitors, compare the morning time.

To complete the simulation of the study object, it is necessary to have the preliminary data for the model construction. The following data are required for the microscopic traffic simulation: Geometrical data; Controlling devices and signs data; Demand data; Validation data.

- **Geometrical data.** To implement the transport network, the images from Google Maps application were used as background.
- **Controlling devices and signs data.** The data for defining the traffic light operation were obtained from Riga City Traffic Department. In total, there are 19 signalling control points in the transport network and up to 38 none-signalized intersections.
- **Demand data.** The demand was obtained as OD matrix, which includes the travel patterns for 14 zones indicated in the study area plus additional zone, which represents the shopping mall. The OD matrix was obtained based on a license plate survey described in [18].
- **Validation data.** The data for validation were obtained during the traffic counting, described in [18] and consist of traffic volume data for 5 counting points.

The coded network in VISSIM is presented in Fig. 3 with marking the entering and leaving points to shopping mall. As could be seen the shopping mall infrastructure is integrated in common model and the parking lots are defined in the abstract mode. For each abstract parking place, the capacity was defined based on the Shopping mall master plan data.

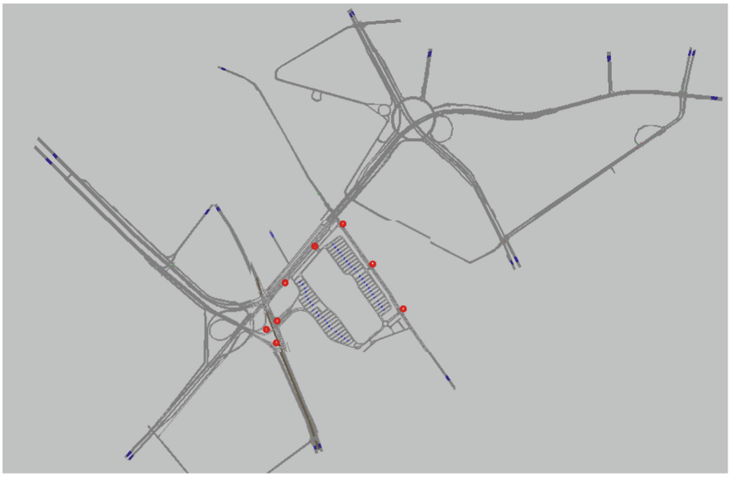


Fig. 3. Coded network of the shopping mall.

4 Analysis and Results

The individual trajectory data were obtained from the developed model to the MS SQL database. The data represents the trajectory data for 1 h of model functioning, the final size of the database is around 3 GB, this should be considered, as standard analysis tools as Excel or Access are not able to work with such volumes of data. The results were processed and descriptive statistics regarding Delay Time is presented in Table 1.

While the histogram and cumulative distribution of the Delay Time (s) is presented in Figs. 4 and 5. As could be seen, the delay time in average is equal to 253.79 s, while

Table 1. Descriptive statistics.

Measure	Mean	Conf. limits for means (95%)	Std. Dev.	Median	Min.	Max.
Value, s	253.79	(243.26; 264.32)	167.6627	204.68	0.055	807.42

the maximum value reaches 807.42 s. The median value insures, that a half of the visitors will lose around 204 s to reach the shopping mall parking and leave it out. Meanwhile, according to the Fig. 5 could be seen that 95% of the visitors will reach and get out from shopping mall in maximum of 570 s.

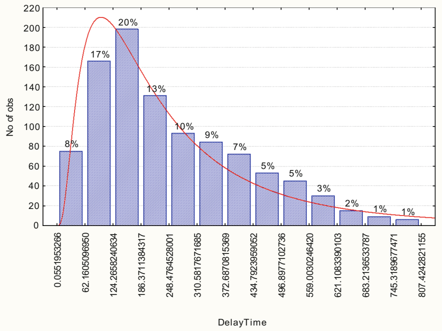


Fig. 4. Histogram of the Delay Time, s.

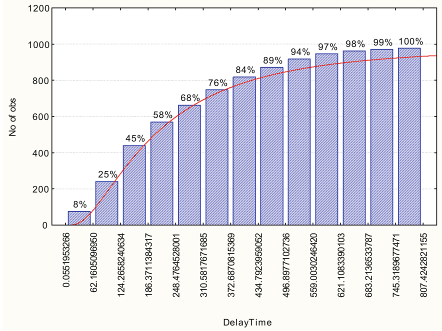


Fig. 5. Cumulative distribution of the Delay Time, s.

Table 2 shows the average Delay Time (s) of reaching the Shopping mall area from each transport zone defined in the model, to make the delay time comparable the Average Delay Time per km is calculated, this allows to understand, from each origin

Table 2. Average delay time per 1 km (from each zone to Shopping mall).

From zone	1	2	3	4	5	6	7	8	9	10	11	12	13	14
To shopping mall	*Average Delay Time (rounded values), s*													
	58	56	81	25	180	160	290	380	127	211	99	-	68	-
	Distance (rounded values), km													
	1.6	2.1	0.54	0.29	3.57	3.00	3.89	3.8	2.9	3.4	1.6	4.8	4.7	1.8
	Average Delay time per 1 km (rounded values), s													
	36	27	150	86	50	53	75	100	44	62	62	-	14	-

most of the delay expected. As could be seen the most delay producing zones 3 and 8.

Table 3 shows the average Delay Time (s) of reaching each transport zone from the Shopping mall area.

First should be pointed out, that the delay times are much higher compare to the Table 2. This could indicate that leaving the Shopping mall area could be difficult.

Table 3. Average delay time per 1 km (from Shopping mall to each zone).

To zone	1	2	3	4	5	6	7	8	9	10	11	12	13	14
From shopping mall	*Average Delay Time (rounded values), s*													
	207	368	345	27	330	282	457	234	387	227	169	-	165	-
	Distance (rounded values), km													
	1.6	2.1	0.54	0.29	3.57	3.00	3.89	3.8	2.9	3.4	1.6	4.8	4.7	1.8
	Average Delay time per 1 km (rounded values), s													
	129	175	638	93	92	94	117	62	133	67	106	-	35	-

The following zones are having high value of average Delay Time (s) 1, 2, 3, 7, 9 and 11. Planning the changes in the transport infrastructure, the obtained data should be used to produce the problem-solving solutions.

5 Conclusions

The paper demonstrates the case-study of applying microscopic traffic flow simulation to evaluate the shopping mall accessibility, by calculating the delay time (lost time) to reach and get out from the shopping mall. The proposed approach is based on idea, that shopping malls usually are in places, which are congested much by the traffic, therefor evaluation of shopping mall area accessibility is the important the critical issues for developers and transport planners. The paper introduces the idea of the “last mile” for the visitors of the shopping mall with analogue of last mile delivery in logistics. Combining the proposed approach with the existing accessibility models, which considers, the travel time from residential areas to shopping mall, could give a positive result. As a disadvantage of the proposed approach, the following points could be mentioned: the simulation model of the study area should be developed, calibrated and validated, this require additional affords; the simulation software should be able to produce trajectory data to external data store, with the mentioned in the methodology data; the DBMS (data base management systems) should be used to store the significant amount of the collected data (in this case the database size was more than 3 GB). Opposite, the disadvantages could be mentioned, that usually by planning new attraction point in the urban area, the developers are pushed to do the simulation; modern traffic simulation software is able to produce the individual vehicle trajectory data.

To conclude, the proposed approach could be adopted and used in practice to evaluate accessibility of any attraction point (not only shopping mall), if it is requested.

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