Challenges Related to the Implementation and Development of Electromobility in Cities

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Abstract Transport is one of the main urban logistics issues. The discussion on the development of transport systems, expressed in consecutive EU White Papers and communications, highlights two main challenges, i.e. the need to change the modal split, including the growing role of public, rail and intermodal transport, as well as changes in energy sources. The response to the second challenge includes, inter alia, electromobility. Technological advancement turned the electric vehicle into a real alternative to the conventional car, especially in urban areas. This enabled to reduce the negative impact of transport on the environment (e.g. reduced emission and energy consumption) which did not require a major increase in the use of public transport.

The chapter describes challenges for the urban logistics as regards the large-scale implementation of electromobility. It distinguishes four main types of activities, such as the development of vehicles, adjustment of infrastructure, improvement of organizational structure and the support of integrated information systems.

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Keywords Electromobility · Transport infrastructure · Electric vehicles · ICT

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1 Introduction

The transport network is the circulatory system of the city. Movement of people and cargo necessitates relevant organizational setup and also has a negative impact on the city itself. Contemporary challenges forced the improvement of efficiency in companies through the implementation of a new approach to urban logistics. There are several definitions of urban logistics. Most of them make reference to the sustainable urban development (e.g. [1–7]). One of the definitions, which encompasses possibly the largest number of issues, has been presented in [8]. According to the definition, urban logistics is a set of processes, including the management of people, cargo and information flows in the city logistics system, aimed at meeting city development needs and goals. Those needs and goals are met with due respect to the natural environment and the fact that the city is a social organization which overriding goal is to meet users' needs. As regards urban logistics, we may distinguish three types of stakeholders, such as the local council, companies operating in their specific areas of business, and inhabitants and people permanently staying in the city. Negative impact of transport (external cost of transport [9]) can be seen primarily as emission of noxious substances, noise and congestion. From the point of view of the social dimension of a city [10], we should examine choices people make while travelling and their impact on the functioning of a given area [11]. The process can be supported by mobility plans which are introduced to promote specific transportation behaviour [12].

Recently, we have observed a significant development in the area of alternative fuels. It is the consequence of guidelines published, including guidelines for the EU member states [13–15]. According to the guidelines, decarbonization of transport is one of the main global challenges (e.g. [16, 17]). Although electricity has become an alternative to traditional fuel, the development of electromobility necessitates a number of actions and poses a challenge for contemporary cities. Undoubtedly, several social barriers need to be overcome and the same applies to thinking about electric cars. It is, however, a technical issue related to the development of vehicles and transport infrastructure [18, 19], but also information systems:

$$D_{\mathrm{EM}} = f\left(D_{\mathrm{EV}}, D_{\mathrm{TI}}, D_{\mathrm{ICT}} \right) \tag{1}$$

where: D_{EM}—electromobility development, D_{EV}—development of electric vehicles, D_{TI}—development of transport infrastructure, D_{ICT}—development of information systems.

The chapter presents issues related to the implementation of electromobility. Technical changes are combined with information technologies; the latter can substantially shape user behaviour and expedite full implementation of electromobility in urban logistics.

2 Development of Electric Vehicles

Currently, a number of countries have intensified their efforts to develop electromobility. For instance, Poland established the 2016–2025 Electromobility Development Plan [20]. We may expect that in the longer term the technology will prevail in transport, especially that we have already observed an increase in the number of new electric cars registered [21]. According to the Polish national estimates, in 2025, we expect to have one million electric vehicles. According to the EU forecast, we should have eight to nine million electric vehicles by 2020 [13], whereas the global outlook is 20 million [22]. In 2015, the number of electric vehicles (including hybrids) exceeded 1.26 million [22], and in 2016, 2 million [23]. From the point of view of users, major barriers to a wider expansion of those cars are their range and price. According to Table 1, the range of an electric vehicle is insufficient for commuting to work or school. In the case of longer distances, only the most expensive makes can meet expectations. We may compare the positioning of an electric car against other modes. Thus, considering longer distances and the use of public transport (e.g. rail, bus), a larger range does not have to be a rudimentary feature of an electric car.

Unfortunately, the price of an electric car remains the main barrier for users. Figure 1 shows that to buy an electric car one needs to spend PLN100 to PLN160 thousand. Two cheaper makes can meet the range requirement, but due to their limited size they are not able to transport the standard number of passengers.

A number of research projects have been implemented, e.g. Horizon 2020 Programme, as regards the construction of new electric vehicles and improvement in the capacity of their batteries. It should be noted that those projects cover both individual passenger cars and trucks [25]. The latter are an important link in the green supply chain [26] for the first and the last mile [4], especially when a vehicle needs to enter a city centre and due to the emission zoning other types of vehicles are banned [27]. Selected projects of 2015–2018 are listed in Table 2.

The development of electric vehicles does not apply to individual passenger cars only. The recent intensive effort led to the implementation of electric buses in public

Table 1 Electric car ranges. (Source: author's own collaboration based on car manufacturers' websites and [24])

Brand and model	Range[a] [km]	Brand and model	Range[a] [km]
Tesla S	340–540	Hyundai Ioniq Electric	200
Hyundai Kona	390	Renault Kangoo ZE	181
Jaguar I-Pace	354	Ford Focus Electric	185
Nissan Leaf	340	Kia Soul Electric	150
BYD e6	301	e.GO Life	130
Renault Zoe	268	Volkswagen e-up!	107
BMW i3	240	Renault TWIZY	100
Volkswagen e-golf	200	Smart Fortwo Electric Drive	93

[a]for selected makes, longer range corresponds with the most powerful battery

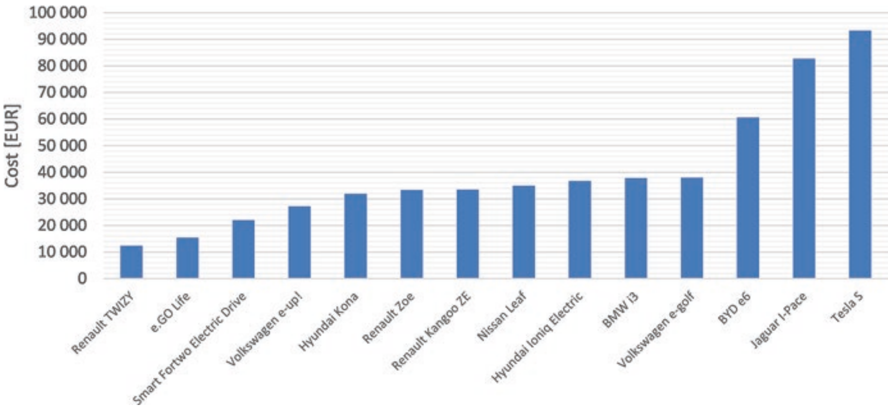

Fig. 1 Electric car prices (Source: author's own collaboration based on car manufacturers' websites and [24])

Table 2 Selected European electromobility research projects (2015–2018). (Source: author's own collaboration based on project's websites and European Commission website [28])

Project acronym	Project full title	Topics	Project's website
EU-LIVE	Efficient Urban LIght VEhicles	Concept and design electric vehicles	eu-live.eu
RESOLVE	Range of Electric SOlutions for L-category VEhicles	Concept and design of electric vehicles	www.resolve-project.eu
ESPRIT	Easily diStributed Personal RapId Transit	Concept and design electric vehicles	www.esprit-transport-system.eu
ECAIMAN	Electrolyte, Cathode and Anode Improvements for Market-near Next-generation Lithium Ion Batteries	Batteries and battery packs	www.ecaiman.eu
SPICY	Silicon and polyanionic chemistries and architectures of Li-ion cell for high energy battery	Batteries and battery packs	www.spicy-project.eu

transport. Apart from public transport advantages, i.e. reduced occupancy of urban space, the development brought a positive influence on the environment by limiting emission [29]. The implementation of electromobility in public transport necessitates a number of organizational changes pertaining to routing and timetable planning. The routing needs to guarantee that a vehicle reaches its charging stations in due time (depot or terminus) (more in: [30–34]).

Apart from public transport and individual cars, urban logistics provides a number of opportunities for organizational and conceptual changes designed to establish and operate electric car and scooter rental [10, 35]. Not only does the urban logistics aim at increasing the number of users of electric vehicles but also integrate various modes of transport. Electric car-sharing can be a good complement to the public transport chain, and incentivise people to use electric vehicles. The idea of combining electric car rental with Park & Ride systems establishes a transport chain, in which people first use their private cars, then public transport, and they cover the last stretch using an environmentally friendly car from a city car rental [36].

3 Changes of Transport Infrastructure

The development of infrastructure involves the building of charging stations. Shortage of such stations is a technical barrier for operating electric vehicles and a mental barrier for users. Locations of such stations should correspond with people's needs. While discussing the issue of electric car charging stations, we need to distinguish three parameters [23]:

- Output power,
- Type of plug,
- Mode of operation defining communication between charger and vehicle.

To promote integration and expedited implementation of electric cars attempts are made to harmonize technical specifications [13]. At the moment, several different types of plugs are used in the world, including type 1, type 2, CHAdeMO, CCS, Commando, 3-pin etc. We can also distinguish slow and fast chargers with rated power below 22 kW and above 22 kW, respectively [23]. Although recently, we witnessed a major increase, differences between specific areas still remain. The diversity in the development of electric car charging stations is presented in Fig. 2. While in certain areas, despite high industrialization (Upper Silesia Conurbation), we can still see a shortage of such transport infrastructure, some cities, e.g. Amsterdam, have become friendly to electric cars [39].

In the nearest future, we can expect a major increase in the number of charging stations. In Poland, until the end of 2020, it is planned to establish at least 1370 charging points [40]. According to the global forecast, until 2025, we expect 4 million slow chargers and 0.1 million fast chargers [23].

4 Support for Integrated Information Systems: Example of Electric Travelling Project

The expected increase in the number of electric vehicles on our roads, the development of infrastructure, and organizational changes has created an information gap regarding travelling options. Therefore, on the one hand, we should look for tools that can facilitate education of users regarding electromobility in an integrated manner, and on the other, such a tool should support local governments in the

Fig. 2 Location of charging stations in selected cities and areas in Europe: (**a**) Amsterdam, (**b**) Budapest, (**c**) London, (**d**) Oslo, (**e**) Kraków, (**f**) Gdańsk, (**g**) Warszawa, (**h**) Upper Silesia Conurbation (Source: own research based on [37, 38])

implementation of electromobility solutions. The above tool has been developed by the international research project of 'Electric travelling—platform to support the implementation of electromobility in Smart Cities based on ICT applications' (ET Project) [41] under the ERA-NET CoFund Electric Mobility Europe Programme. The analysis of information shortages has helped to identify main needs. The tool developed comprises a trip planner and development scenario simulator.

The trip planner has been designed to provide users with functionalities to choose, visualize and compare possible trips, as well as support the development of the transport network between two (or more) points within a transport chain consisting of one or more means of transport. The majority of trip planners, however, is limited to defining distance and travelling time, and only a few take into account the environment (more in: [42–45]). In the case environmental impact is included. It means user can choose between time, distance but also cost and environmental impact. In all these criteria, optimal solution will be minimum of the value of selected criteria.

Apart from the majority of means of transport in the city, including public transport, individual cars, bikes, and walking trips, the new trip planner (Fig. 3) encompasses transport chains using existing Park & Ride and Bike & Ride systems and car-sharing and bike-sharing systems. Moreover, the planner enables to plan one's trip using an individual electric car, which is particularly important for the promotion of electromobility. The tool is an extension of the route planning system developed by the Green Travelling project [46]. The optimized route is set taking into account charging stations available in the city and the user can receive information about the need to recharge batteries during their trip. This improves the image of the electric car and overcomes the mental barrier that prevents users from buying the electric car due to its limited range. The system, including the planner, can be connected to Smart Transport Systems operating in the city [47–49] and the system can set better routes that take into account congestion and availability of charging stations.

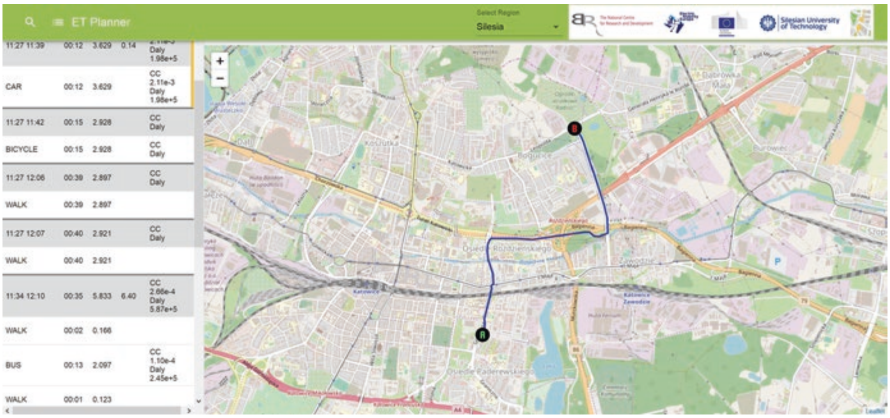

Fig. 3 ETPlanner interface (Source: own research)

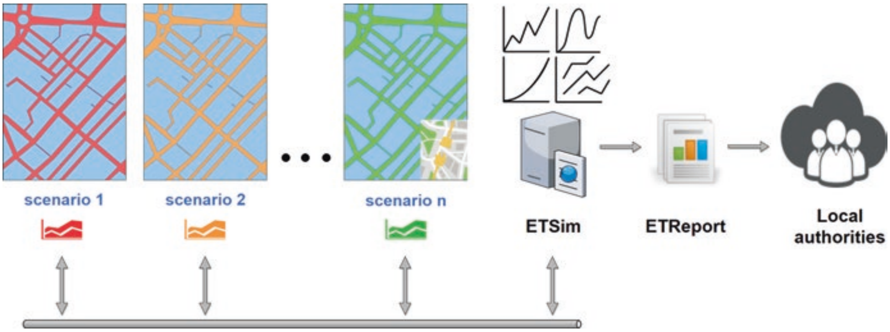

Fig. 4 Multi-agent simulator as support in decision-making process (Source: own research)

The second component of the system is the multi-agent simulator. The tool enables to simulate behaviour of travellers who use various modes of transport [50]. A system-generated report can be used as a support in decision-making [51] and selecting the most appropriate scenario for a specific area (Fig. 4).

Comparisons included in the report collate the current status, locations of new charging stations and selected incentives. The report provides suggestions for the local government to facilitate planning of electromobility and expedite the introduction of electric vehicles in the city. Since the planner is based on a heuristic approach, the local government can introduce limitations to the traffic for specific groups of users directly through a routing algorithm [52]. Real needs of travelling persons can be collected based on user queries recorded in Big Data server.

5 Summary

Environmental benefits and incentives for users make electric cars more popular in the world. However, we should remember about barriers that need to be overcome on the way to make the solution really effective. The full implementation of electromobility requires a multifaceted approach and integration with existing transport systems. Apart from the development of vehicles, batteries and charging infrastructure, users' behaviour can be changed by well-tuned and properly delivered information. As discussed in the chapter, the tool developed by the ET Project can be one of elements supporting promotion and faster implementation of electromobility in cities.

It is expected that further research will develop the tool. Moreover, it has been planned to combine the tool with the existing ITS in a specific area for testing.

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