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Preface

The increase in freight volume of goods and people in recent years related to the growth of the economy and mobility of people is a major cause of increasing congestion of the transport infrastructure and increased energy consumption, as well as a source of environmental and social problems. The answer to this problem cannot be limited to the expansion of existing infrastructures. The solution lies on the side of innovation, including the introduction of transport telematics systems.

Transport telematics systems means systems in which information technologies are used in the field of transport, including infrastructure, vehicles, and users. Intelligent transport systems are advanced applications whose goal is to provide innovative services for the various modes of transport and traffic management, and enable users to be better informed and make safer, more coordinated and "smarter" use of transport networks. Telematic services integrate telecommunications, electronics, and information technology in transport engineering in order to plan, design, operate, maintain, and manage transport systems.

Implementation and use of telematics applications and traffic and travel information services requires the processing and use of data on traffic and travel. For the realization of ITS applications innovative technologies are needed. Major stakeholders such as service providers, users, operators, industry representatives, social partners, researchers, professional organizations, and local authorities should be able to advise on technical and commercial aspects of ITS deployment.

This publication is intended primarily to serve this purpose. The book constitutes a collection of selected papers presented at the 11th transport telematics conference, TST 2011. Here I would like, on behalf of my colleagues from the Scientific Committee, to greatly thank the authors for the major contribution they have made in spreading knowledge on intelligent transport systems.

October 2011 Jerzy Mikulski

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Wireless Systems of Threats Monitoring

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Abstract. The concept of wireless system of threats monitoring with self-organizing network of multipurpose data transfer nodes is presented. Two practical applications of this system are also presented. The first of these is the Global Wireless Monitoring System for Containers, and the second is the Mobile Monitoring System for Gas Air Pollution Measurements. Presented practical applications of the wireless threats monitoring system are a part of a wider security subject matter, which currently has a high priority, both in Poland and in the world.

Keywords: threats monitoring, ad-hoc networks, monitoring systems.

1 Introduction

Threats monitoring has numerous applications in many aspects of human life in the 21st century. Various types of data are subject to acquisition and control. This data is related to the transport (both land and marine), parameters of industrial processes, as well as to the degree of atmospheric pollution. It is also important to use monitoring systems in minimizing the risks of terror acts or even on a modern battlefield. In connection with foregoing, there is a need for new solutions of data monitoring network. Applying a concept of self-organizing nodes network allows to increase the efficiency and reliability of monitoring systems.

This issue became a subject of research at the Department of Radiocommunication Systems and Networks at the Gdańsk University of Technology, where the Group of Self-Organizing Ad-Hoc Wireless Sensor Networks was founded. This Group developed the original concept of a data monitoring system with self-organizing sensors network intended for cargo containers monitoring and a mobile monitoring system for gaseous air pollution measurements.

2 Data Monitoring System with Self-organizing Network of Multipurpose Data Transfer Nodes

The self-organizing network of multipurpose data transfer nodes (MDTN) is a basic part of the monitoring system (Fig.1.). Each of these nodes can be equipped with

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various wireless interfaces, depending on particular solution. For wireless communication with a radio access core network the following radio interfaces can be used: GSM, UMTS, LTE, TETRA, WiMAX or Inmarsat. Multipurpose data transfer nodes are communicating with each other via short-range wireless interfaces, such as Bluetooth, ZigBee or WiFi.

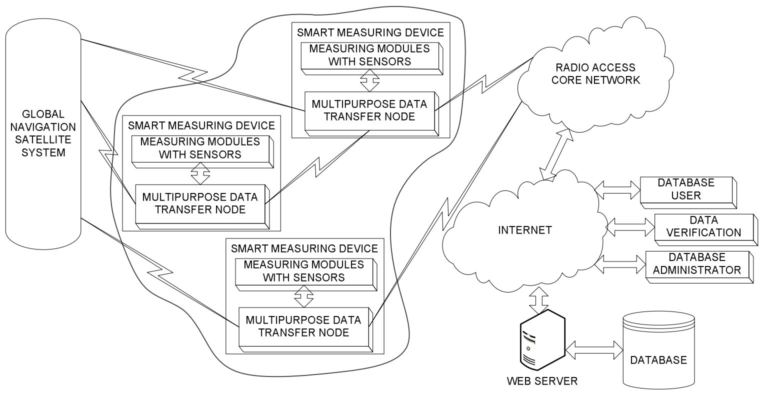

Fig. 1. Data monitoring system with self-organizing network of smart measuring devices

A separate issue is the GNSS (Global Navigation Satellite System) receiver, whose presence in MDTN depends on whether the system requires localization of measurement or not. It may be a GPS or a GLONASS receiver or another satellite navigation system. MDTN may also be equipped with a number of wire interfaces (USB, RS232, RS485, Ethernet), e.g. enabling connectivity with measuring modules, change configuration of MDTN, etc. Each MDTN is connected to measurement modules, creating a smart monitoring device (SMD) that is responsible for receiving, collecting and sending the data from sensors and GNSS receiver. The set of monitored parameters closely depends on the particular application of monitoring system and there is a large flexibility in configuration of a sensor network. It is limited only by the availability of sensors for particular parameters. Sensors can be tasked with periodical reporting of measured values. These reports often can be triggered by a detected even. The reporting period is application dependent [1]. Apart from direct communication with the radio network, the SMD is able to connect to that network in an indirect way, by organizing with other SMD modules at ad-hoc network. In this way, the reliability and efficiency of monitoring system are increased.

The measurement data is sent to the database located on a web server through the radio access core network, further through the Internet. In order to avoid incorrect entries or false alarms, the measurement data is verified before writing to the database. Data access is possible via the Internet, both for users and for administrators.

The rest of the paper will present practical implementations of wireless threats monitoring systems: the Global Wireless Monitoring System for Containers [2] and the Mobile Monitoring System for Gas Air Pollution Measurements [3].

3 Global Wireless Monitoring System for Containers

The proposed new solution of a monitoring system for containers has a layer-modular structure (Fig.2). The basic layer is the Smart Container Module (SCM), intended for installation on containers. The next layer is the Ship/Port Subsystem with self-organizing container monitoring network, based on the WiFi, working on container ships or in container terminals and sea ports. A typical container ship can carry up to a dozen thousand containers, so there is a need to locate a special database on the ship. In container terminals and sea ports there is the Port Administration Data Base, equipped with wireless access points located at entrances to ports and wireless radio networks covering the container depot. The data about monitored cargo is regularly sent to the ship/port network controller. Information can also be sent on request. All Port Subsystems located inside the country send all data to the Land Subsystem - The State Administration Data Base, which is the third layer of the monitoring system.

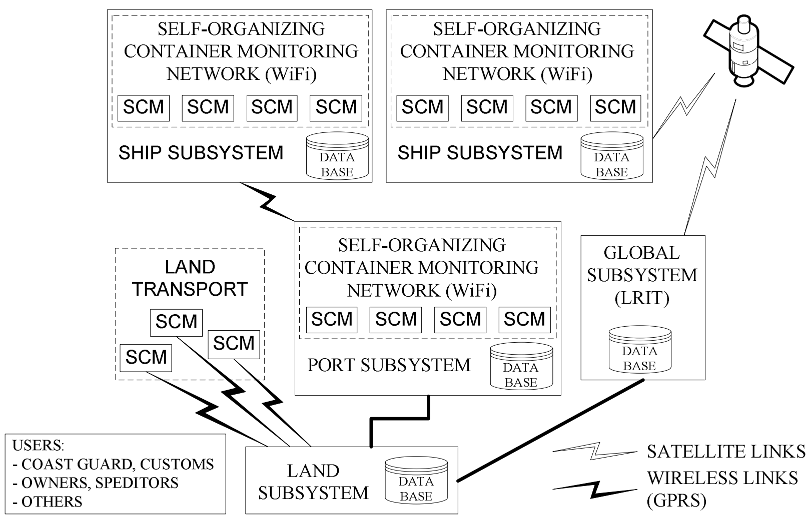

Fig. 2. Architecture of the global wireless monitoring system for containers

The information between each part of the system is transmitted in accordance with certain rules, using an appropriate transmission medium.

In the case of a container ship, the period of reporting depends on its position, i.e. on the distance from the mainland, home port and/or destination port. The frequency of sending relevant data increases with approaching to the mainland.

The Global Subsystem is the highest layer of the monitoring system that can use a database of a new LRIT (Long Range Identification and Tracking) system for long-range ship monitoring. The data is transferred to the global database via a satellite system (e.g. Inmarsat), while the vessel is on the open sea. When approaching the mainland and entering the harbour, the information is sent to the Port Subsystem. The transmission of this information is carried on using the GPRS system. The data exchange between local and global databases, and also the co-operation between databases inside the country is also necessary. It is realized by fixed lines, e.g. optical fibre.

In the case of land transport the data on cargo monitoring is sent via GPRS to State Administration Database. The SCM modules are mounted on containers carried on container lorries and there is no need to organize SCM modules in an ad-hoc network.

The users form a separate layer of the system. We can distinguish two classes of users: services responsible for cargo security and carriers. The first group is formed by the relevant services, such as the Coast Guard, Customs and Police. Owners and shipping companies belong to the second group of users. Their access to the system is carried out by authorized employees.

The Smart Container Module is one of the most important elements of the monitoring system. Fig. 3 depicts its functional diagram.

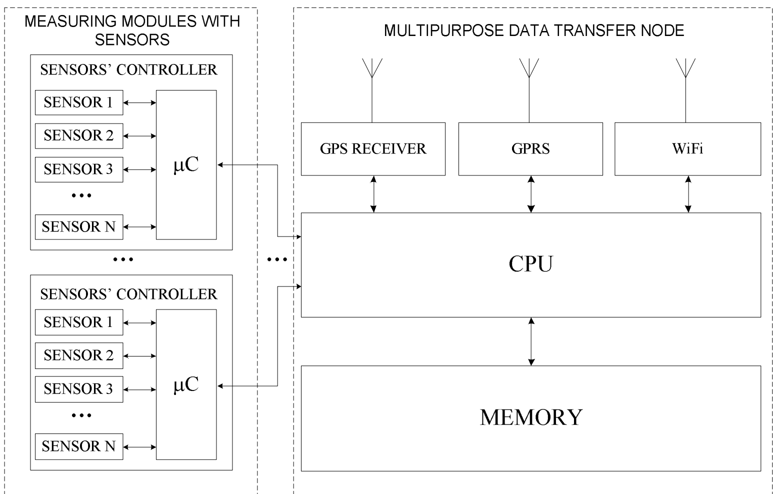

Fig. 3. Functional diagram of the Smart Container Module

The SCM is equipped with various sensors placed inside the container. An important aspect is also the location of container, so each SCM is equipped with a GPS receiver. The GPRS module and the WiFi module enable communication with a port database (GPRS) or a local wireless network working on the container ship (WiFi). The measured data is stored in SCM's memory. The data is sent to an appropriate database, whenever necessary. In the case of a lack of connection with a radio network, the data is sent shortly after the SCM gets within a network range.

The Sensors' Controllers have been designed to enable free deployment of sensors inside containers. Sensors, that the Sensors' Controller can be connected with, include sabotage, door switch, motion, smoke, temperature, humidity, acceleration, and any other sensors with electrical outputs. Sensors' Controllers allow connecting simultaneously many sensors to the SCM. Additionally, they allow unrestricted changes sensor types of and their deployment inside the container.

Because of the vertical way of containers storage on container ships, there is a problem of access to on-board wireless network for Smart Container Modules mounted on containers at the lowest level of a container stack. Additionally, GPS satellites are beyond the sight of view of a GPS receiver, installed in the adversely located SCM modules, thus it is impossible to read the geographical position. In order to solve this problem SCM modules have been programmed in a manner that allows them to organize in an ad-hoc network [4].

During the research a new algorithm for data transmission control over a multi-hop ad-hoc network (assuming slow-moving nodes) has been developed. By dint of this solution it is possible to transfer the cargo data to the Ship Subsystem database, even from the Smart Container Module installed on the lowest container. The cargo data is transferred to adjacent modules by a WiFi radio link. If a module is connected to the on-board wireless network, it will forward the data to the database. If this module is beyond the reach of the on-board wireless network, it will forward the data to the next SCM, etc. Additionally, the self-organizing ad-hoc network enables SCM modules, which are beyond the reach of a GPS system, to read and save the geographical position based on the data from modules at the top of containers' stack. The ability to self-organize modules in the ad-hoc network can also be useful in harbours or container terminals, where direct access to the Port Subsystem's wireless network or receiving signals from GPS satellites could be impossible. This ad-hoc network has been tested and results proved the ability of tested network to self-organize in real time.

In the course of research, a user interface including a database storing all data about the system has been created. Depending on granted access privileges, users can get the following information: state of the system, defined types of containers, registered containers (with the assigned sensor network), ongoing and completed shipments and communication history. In addition, users can manage only, if they have administrator privileges. Each transport can be remotely monitored. The cargo information is available in three forms: a table, graphs and a map. The interface use is intuitive, user-friendly and greatly facilitates access to the system at any point on the world with access to the Internet [5].

4 Mobile Monitoring System for Gaseous Air Pollution Measurements

The urban traffic has become the most important cause for the air pollution in big cities, but the measurement of air pollution along transport lines is still very rare. It is caused by the fact, that the equipment used in fixed air quality monitoring stations (which gives very accurate and reliable results) is voluminous and heavy and it cannot be used for measurements in motion. The proposed monitoring system consists of mobile monitoring units, which are small and light enough to be put on public transport vehicles (buses, trams) and even cars. They can be used to measure, record and transmit to central database the concentration of various air pollutants, together with weather conditions such as temperature, relative humidity and geographic coordinates from a GPS receiver. These units can provide support for fixed stations by taking measurements in places selected for additional control or by measurements in motion.

The road traffic is the largest source of noise and local air pollution, and a considerable contributor to global emissions of greenhouse gases [6]. The air pollution from the road traffic consists of a number of harmful substances. Some of them should be periodically measured, because of their impact on human health and state of the environment. These substances are: benzene (C_6H_6), nitrogen oxides (NO and NO_2), ozone (O_3), carbon monoxide (CO) and carbon dioxide (CO_2) [7]. Measured concentrations of gas pollutants in the air are recorded and sent via GSM/GPRS and Internet to a central database for further processing.

The block diagram of Mobile Monitoring Unit (MMU) is presented in Fig. 4. The most important component of MMU is a set of gas sensors. They react to change in gas concentration by changing some electric value on their output. The first version of MMU was equipped with factory-made module with sensors, A/D converters and a microcontroller to convert sensors' electric response to gas concentrations.

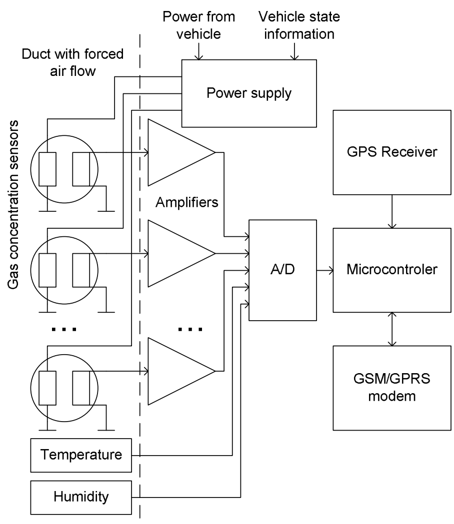

Fig. 4. Block diagram of Mobile Monitoring Unit

This module was connected to the communication unit which aggregated measurement results with geographic coordinates from GPS and sent this data to the server using GSM/GPRS link.

Positive test results and the usefulness of proposed device confirmed in practice encouraged authors to build the next generation of a monitoring station with additional functionalities: more sensors to measure the concentration of different gases in the air, a mechanical design of the casing including a special tunnel with forced constant flow of air to increase the repeatability of measurements, a universal power supply unit which allows to power the device from 12V or 24V and containing additional battery back-up to ensure the continuity of measurements, adaptation to work in temperatures below zero degrees Celsius by separating the gas concentration sensors from electronic circuits, which require a positive temperature.

The proposed monitoring unit can be described as maintenance-free. A properly configured and set-up monitoring station can operate for several months without intervention. The information about the state of operation and about possible errors in the functioning of electronic components or problems with the data collection is transmitted to respective persons via short messages (SMS). The results of the measurements sent to the server are verified in terms of reliability and made available to authorized users via the web site as tables, graphs and maps. Any additional data processing is made after the results are recorded in data base.

In accordance with article 25 paragraph 2 of the "Environmental protection law" [8], the most important source of information about the state of environment is "state environmental monitoring", which includes a system of measurements, assessments and forecasts of the environment and the collection, processing and dissemination of environmental information. The objective of this monitoring is to support efforts to protect the environment by informing the administration and public about the current state of the environment. For the air protection it is recommended to measure the concentration of different pollutants (gases) using the so-called "reference methods". These reference methods of measurement in most cases are suitable only for stationary measurements, to create a permanent monitoring station. This paper presents a mobile monitoring system, measuring the concentration of pollutants using semiconductor sensors which are not included in the reference methods. However, measurements made by devices not using reference methods can be taken into account provided the equivalence between proposed and reference method is proved.

In order to verify the equivalence of the proposed method, results obtained by the mobile monitoring units were compared with results obtained from fixed measurement stations owned by the ARMAAG foundation (Agency of Regional Air Quality Monitoring in Gdańsk metropolitan area).

On the basis of tests in laboratory and in real conditions it can be concluded, that semiconductor sensors used in mobile monitoring units, built at the Gdańsk University of Technology, ensure the equivalency of measurement results with reference methods, recommended by the European Union to monitor the air pollution [9]. The main measurements that were carried out using the designed mobile monitoring system, related to substances emitted from vehicles which run along the Tri-City communication system and the surrounding area. For example the level of pollution was examined within the major crossroads in various states of utilisation, and within selected districts of city near main streets of Gdańsk agglomeration [10].

Mobile monitoring stations were also used to determine the concentration levels of industrial pollution in places distant from the city centre and to measure the traffic pollution in Warsaw.

5 Conclusion

The described concept of wireless data monitoring system, especially self-organizing monitoring network consisting of smart measuring devices has a universally useful form, which can be used in a wide range of practical applications. Presented practical applications of the wireless threats monitoring system is a part of a wider security subject matter, which currently has a high priority, both in Poland and in the world.

Acknowledgments. The described new solutions of the data monitoring system are funded by the Polish Ministry of Science and Higher Education and by the Regional Fund for Environmental Protection as a part of research and development projects: No. R02 012 01 [7], No. 3 T09D 100 29 [8] and No. WFOŚ/D/201/210/2007. The authors express their sincere thanks for funds allocated for this purpose.

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Monitoring of Live Traffic Information in the Czech Republic

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Abstract. Project Monitor is aiming to monitor quality of Traffic Information service and in first stage is focusing on evaluation of data provided by RDS-TMC and in structured XML. We propose technical, editorial and end user quality measurements. This paper gives examples of all 3 types of quality measurements. However, technical quality must be assured before we can start with others, therefore we formulate a system for autonomous evaluation of technical parameters of RDS-TMC service and web site to have some aspects of monitored service publicly available. This paper summarizes our approach to monitoring of selected services, presents key issues and finally reveals some important facts about the service.

Keywords: RDS-TMC, traffic information, monitoring, quality, distribution, transmission.

1 Introduction

This paper presents some results achieved in the R&D project of the Ministry of Transport of the Czech Republic called Monitor, aimed on finding out the quality of traffic information that is being provided for free by the government agencies and its subsidiaries. This approach could be applied to technical as well as editorial and factual quality of traffic information provided in structural way through new media [4], first outputs are however limited just to RDS-TMC.

1.1 Why to Monitor Quality of Traffic Information Service?

Problem is, that set of standards for RDS-TMC does not specify in detail how to handle and interpret traffic information received over the RDS-TMC. Direct consequence of this is that every navigation system vendor invests a lot of money into "tuning" their device to handle received messages in "best" way, as a black box [5]. The result of this tuning and customization is often not as good as it could be, sometimes vendor even overlook some crucial facts, because of limited understanding and almost no possibility of real testing. Organizations responsible for generation of

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traffic information start to realize this problem and to mitigate it, for example Austria started in 2010 to give conformity statements to navigation devices that properly interpret traffic information [2]. Also other providers started to look at this problem, started testing behavior of navigation devices under specified conditions more extensively [1], [7] and some published their results.

2 What Is RDS-TMC?

RDS-TMC is the actual system for getting traffic information into navigation devices, where RDS is the delivery system and TMC defines structure of traffic messages.

2.1 Radio Data System

RDS or Radio Data System allows transmission of digital information over analog (VHF FM) channel [6]. RDS enables traffic reports to be received more easily, and provides many facilities including enabling the radio station name to be displayed on the radio display. Other facilities include type of programme, indication of traffic news, frequencies on which it is being broadcast etc., and also to carry free format applications, one of them being TMC. RDS services are carried over by so called RDS groups. Standard defines 32 possible group types, TMC service is conveyed by 2 group types, 3A (TMC service information) and 8A (actual traffic messages).

2.2 Traffic Message Channel

TMC or Traffic Message Channel allows silent delivery of live traffic information suitable for processing by a navigation system, which then offers the driver the proposal for alternative routes to avoid traffic incidents [3]. TMC defines structure traffic information. It introduces set of rules and tables that are used together to encode and to decode traffic information at traffic center and navigation device. Each traffic incident encoded as a TMC message consists of an event code and a location code in addition to expected incident duration, affected extent and other details.

Event codes table contains a list of up to 2048 event phrases. Some phrases describe individual situations such as a crash, while others cover combinations of events such as a crash causing long delays. Location codes table represents simplification of road network, assigns numerical codes to locations (typically major junctions) on the road. Location tables are then integrated in the maps provided by in-vehicle navigation system. Event code and location code tables, which allow real interpretation of TMC message, are never broadcast over RDS. It is always delivered into device by other means.

2.3 Benefits and Drawbacks of RDS-TMC

As RDS provides very limited capacity for amount of data, TMC must be very space efficient. Just 4 bytes are enough to describe the simplest traffic situation. Because it uses tables of events and of locations for encoding and decoding messages and these tables can be translated into different languages it is said that one of its main advantages is language independence. Limiting factor is that tables must get somehow to navigation device, this poses a distribution problem. Another problem is, that table of locations must be predefined and has limits for number of locations. As a result, only small part of road network can be included in a table, messages outside this set cannot be described and new locations require distribution of updates to receivers.

3 Overall Quality of a Service

There are many ways how to measure quality of a service. We chosen quite simple approach and defined so called editorial quality that is represented by having precise traffic information right at the time and corresponding to real traffic situation. And we defined technical quality which we see as proper use of technical means in order to get effective service. There is also a TMC interpretation quality and it takes place in navigation devices and evaluates if handling of messages and presentation to the user meets requirements expected by users and service providers.

3.1 Editorial Quality

By comparing services together and thus learning some information about timelines and content of same information distributed via different services (channels) we can find out if messages are delivered in the same time (no time delay), have same (or similar) content and though are describing situation in the same way, and are cancelled (deleted) in the same time. All comparison information have much higher value if paired messages does not come from same providers and channels, however even comparison between different services of one provider can bring invaluable information about internal handling of the messages in whole distribution chain.

Basic Quality of Service. In the Czech Republic we have 3 RDS-TMC providers. One of them is providing information on local level (Prague) others are nation-wide. They are:

- Municipality of Prague (DIC PRAHA),
- National traffic information center (NDIC) and
- Commercial provider company Teleasist

NDIC integrates also information from DIC PRAHA so it shall have all its information available for distribution via data distribution interface (DDR) in structured XML, via RDS-TMC and RSS feed. NDIC also and shows information on a map. Commercial service, Teleasist, gets information from NDIC and integrates it with his information sources to get new service.

Comparison of Services. Further analysis has shown that there is a possibility of direct comparison between RDS-TMC and structured DDR XMLs. This is enabled by having same markers in both RDS-TMC and DDR. Comparison can be done also utilizing markers from other distribution forms (text, voice, www), like:

- textual parts of structured messages, concerning problem description, direction, location, district, or
- voice recognized parts of spoken messages in radios.

This is however quite a challenge to comparison algorithms and can possibly lead to false positive paired messages. Therefore we decided for a start to just to compare messages in such distribution forms that have exactly same markers. To prove if our comparison method is working we initially compared services from just one provider the NDIC. We called this part of the project as a “first stage” which is focusing on evaluation of data provided by national traffic information centre (NDIC) in XML form as well as monitoring its broadcast by means of RDS-TMC.

If this comparison proves to be feasible, then we can proceed to broaden the portfolio of monitored services. In near future we plan to start monitoring remaining RDS-TMC services.

3.2 Technical Quality

Technical quality of RDS encoded information, i.e. parameters of RDS transmission and coding of messages are important due to their direct influence on their processing and interpretation in navigation devices. Later in this text we also use instead of parameters term quality indicators. In the project we established about 33 quality indicators that can be measured on RDS-TMC service. Following sub-chapters gives a flavor of the indicators are and in few examples describes what they mean.

Indicators of RDS Related Technical Quality. Indicators of overall quality of the service describe TMC service as a whole. They are mainly inferred from parameters mentioned in related technical standards and handbooks. These indicators influence all other quality indicators. They are:

- RDS group error rate,
- TMC service availability indicated in RDS groups,
- number of immediate repetition of RDS groups,
- service parameters decoded from RDS groups,
- gap between RDS groups with TMC messages,
- optimal use of RDS channel by TMC service,

Above mentioned indicators are just examples of what can be measured. In some cases these indicators just represent a quantity that is yet to be interpreted (i.e. error rate), in other cases there are expectations how shall measured indicators look like.

Example of a service quality indicator
For example, what means optimal use of RDS channel by TMC service? European standard CEN 14819-1 defines allowed gaps between 2 consecutive RDS groups containing TMC messages (group type = 8A), groups that are conveying information about TMC service (3A) does not count. Minimal gap is 3 other RDS groups.

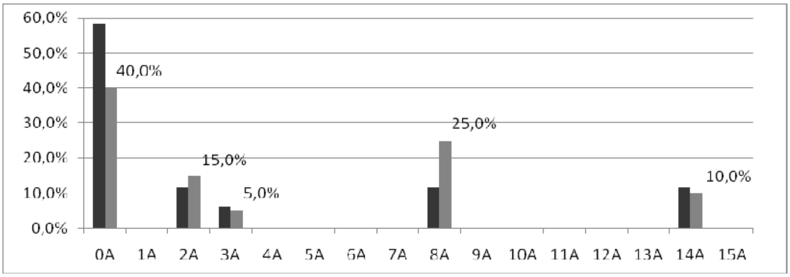

Fig. 1. Recommended rates for typical RDS groups (grey) and measured rates (black)

Any value higher than this breaches the standard and could cause troubles while handling decoding of messages in navigation device. Also lower values means that RDS channel is not used efficiently. Only viable explanation is presence of other vital services that prevents higher rate of TMC groups (8A). Lower rate of TMC groups also means lower throughput of RDS channel for traffic information and slower response times. Service provider shall try to maintain 8A groups at 25% rate.

Indicators of TMC Message Quality. Indicators of TMC message quality are also inferred from European standards and handbooks and best practices documents. They are also based on common sense of using the RDS channel efficiently and on getting maximum of actionable information, i.e. such information one can take an action upon. They are:

- number of live TMC messages,
- utilization of RDS channel by TMC messages:
  - rate of different sizes of TMC messages,
  - rate of different classes of TMC messages,
  - rate of cancel messages,
- analysis of individual TMC messages:
  - life cycle (repetition, count and cancelation),
  - invalid content (used in wrong way),
  - use of superfluous information in a message,
  - use of too many information (only effect is really necessary),
  - use of long message where exist shorter with exactly same meaning,
  - use of too vague TMC messages.

These individual message quality indicators do not have do not have exactly set limits for meeting the requirements and some of them can be defined in several ways, but all of them show parameters important for the final customer, the driver and his perception of the quality of service.

Example of a TMC quality indicator

For example, what means too vague TMC messages? Definitely, someone shall define which messages are useful and which are not. In this particular case we have selected from all event phrases such phrases which are by our understanding without any value to the driver or to navigation device (they are not actionable):

- traffic problem, event code = 1,
- restrictions, event code = 493,
- major event, event code = 1501,
- several major events, event code = 1590,
- security alert, event code = 1515.

Upon reception of such TMC messages are drivers likely to ask themselves, what does it mean to me? What is the purpose of transmitting this message and it devaluates perceived quality of the TMC service.

3.3 TMC Interpretation Quality

If the service has good evaluation in technical quality measurements concerning distribution part, we can start to pursue also higher standard of interpretation of TMC messages in navigation devices. Navigation system vendors are faced with difficult situation,

- TMC standard allows many possible interpretation
- they do not have qualified experts in TMC, it is just an extra feature,
- they often to don't have possibility to test their TMC implementation in development
- TMC implementation is different in every country
- they try to simplify driver's task regarding handling with TMC messages.

This situation leads to a fact that each navigation device handles TMC service in different way. While service providers expect that all navigation systems will behave in the same way upon reception of same message. Navigation devices therefore shall be tested if they respond in same manner to typical TMC situation like:

- tuning of TMC service,
- decoding TMC information containing typical events and locations and presenting them to driver,
- acting on reception of certain types of traffic information (like ghost driver),
- filtering of received TMC information,

Example of a TMC interpretation quality
In the project we did test of 6 navigation devices in order to find out how they are able to handle TMC. Test comprised of two separate sections. One was user friendliness in overall TMC functionality of tested navigation device. The other part was focused on handling of individual TMC messages in such a way that it does not degrade or even misinterpret them, starting with real simple messages and ending with quite complex messages consisting of several event phrases control codes and quantifiers. Test results were partially used to set up TMC message quality indicators, because it is important to disseminate only such types of traffic messages that can be handled in most of navigation devices properly. Paramount indicator for service provider is to use simple TMC messages.

4 Setting up a Test Bed

In order to evaluate technical quality indicators and to compare messages in RDS-TMC and DDR we had to process stored RDS data stream, TMC snapshot and also DDR snapshot. For every quality indicator we designed unit test with formalized output so it can be easily used by other applications or processes in streamlined publication system. Basic RDS quality test were written in Python programming language, while for more complex TMC quality test was used combination of BaseX [10], XQuery [9] and of scheduling agent. Real life test requires to test and store huge amount of data and therefore it is useful to process them in order to take up less space on storage media [11].

4.1 Intermediate Evaluation of Quality

Defined quality indicators led to 33 unit test, form which proved to be really important. Showing full length of test results is not in possibilities of this paper. We can point out most problematic parts of monitored service. They were:

- not efficient use of RDS channel (see figure 1),
- use of too many complex TMC messages,
- misuse of message quantifier (used in wrong way),
- overuse of quantifier (used when not necessary),
- overuse of additional phrases when joint one existed,
- use of vague event phrases, etc.

Our test revealed many problems and strange facts about existing data, provided by NDIC, some of them were already taken into consideration and improved.

5 Conclusion

Ad hoc test are not enough for improving quality of a service, it needs to be continuously monitored, evaluated and results of this evaluation made publicly available on the Internet. Only then there is a chance to gradually improve the service.

Proposed solution is able to collect RDS data from any place. Data can be visualized on web and using SIMILE Gadgets technology [8], any user with common web browser can evaluate current data in time and location context with possibility to do many kinds of data filtering on-line. This is currently work in progress and can be seen at http://live.rds-tmc.cz.

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Managing Uncertainty in Maritime Applications

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Abstract. The theory of evidence is widely used to model uncertainty in many applications. Representation of relationship between evidence and hypothesis space are not obvious and is to be explored in many practical cases. Evidential mappings as relationship models are sort of belief assignments. The assignments engage binary and fuzzy sets with crisp, interval and fuzzy valued masses. In all cases reasoning mechanism available in Dempster-Shafer theory is used to depict relation between the mentioned spaces. In the paper interval valued masses with binary and fuzzy evidence representations are presented. The concept is exploited in order to solve floating objects detection.

Keywords: evidence representation, Dempster-Shafer theory of evidence, floating objects detection.

1 Introduction

Mathematical Theory of Evidence (MTE) also called as Dempster-Shafer (D-S for short) theory is able to handle uncertainty and ignorance. The theory offers embedded inference engine. It is also suitable to model intervals as well as fuzziness. Uncertainty and erroneous evidence prevail in maritime applications. Possibility of detection of a floating object by a monitoring station can be considered in terms of uncertain evidence expressed by an interval value. Thanks to the theory conclusions can be drawn based on association of several independent belief assignments obtained from different sources. Detection problem may also engage fuzziness. In order to include imprecise evidence into a calculation scheme one has to engage fuzzy sets. Extended Mathematical Theory of Evidence can be used to operate on such sets.

First interval valued representation of evidence will be considered. Numerical examples regarding detection problem are included to illustrate the presentation. Second part is devoted to fuzzy representation of available evidence. Specificity of detection problem as reasoning on limited hypothesis space is presented. In another author's paper [7] problems encounter in maritime applications were also considered. In the publication main stress was put on exploiting MTE in position fixing in terrestrial navigation. Discussion was concentrated on crisp mass functions. Herein imprecise interval limits are allowed and fuzzy approach towards detection problem introduced.

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2 Evidence Interval Representation

Arithmetic operations applied to interval valued arguments are carried out on appropriate limits values. For variables X and Y being intervals: $[x^-, x^+]$ and $[y^-, y^+]$ addition, subtraction and multiplication operations are as specified by Formula 1.

$$
\begin{aligned}
X + Y &= [x^- + y^-, x^+ + y^+],\\
X - Y &= [x^- - y^+, x^+ - y^-],\\
X \cdot Y &= [\min\{x^- \cdot y^-, x^- \cdot y^+, x^+ \cdot y^-, x^+ \cdot y^+\}, \max\{x^- \cdot y^-, x^- \cdot y^+, x^+ \cdot y^-, x^+ \cdot y^+\}].
\end{aligned} \tag{1}
$$

Mathematical Theory of Evidence operates on evidential mappings, mass functions and exploits belief with plausibility measures. Evidential mapping represents relations among elements of two universes or frames of discernment Ω_E and Ω_H, it can be seen as a function $m: e_i \in \Omega_E \rightarrow 2^{\Omega_H}$. For each element e_i within evidence space Ω_E there exists a set of subset-mass pairs denoted by $m(e_i)$. The set is described by Formula 2 [9], [10].

$$m(e_i) = \{(H_1, f(e_i \rightarrow H_1)), \cdots, (H_n, f(e_i \rightarrow H_n))\}. \tag{2}$$

In Formula 2 constraints 3 are to be satisfied. Mapping for which these constraints are observed is called as belief structure.

$$
\begin{aligned}
&1.\ \Omega_H = \bigcup_{j=1}^{n} H_j\\
&2.\ H_j \neq \varnothing\\
&3.\ [m_{ij}^-, m_{ij}^+] = [f^-(e_i \rightarrow H_j), f^+(e_i \rightarrow H_j)]\\
&4.\ \sum_{j=1}^{n} f(e_i \rightarrow H_j) = 1
\end{aligned} \tag{3}
$$

Evidential mapping can be presented as matrix, example is shown in Table 1. Each row is devoted to a single piece of evidence. Contents of cells are interval valued masses expressing credibility $m_{ij} = [m_{ij}^-, m_{ij}^+]$ attributed to each of the subsets.

Table 1. Evidential mapping matrix

	H_1	H_2	…	H_n
e_1	$[m^-_{11}, m^+_{11}]$	$[m^-_{12}, m^+_{12}]$		$[m^-_{1n}, m^+_{1n}]$
e_2	$[m^-_{21}, m^+_{21}]$	$[m^-_{22}, m^+_{22}]$		$[m^-_{2n}, m^+_{2n}]$
…				
e_l	$[m^-_{l1}, m^+_{l1}]$	$[m^-_{l1}, m^+_{l1}]$		$[m^-_{ln}, m^+_{ln}]$

The matrix dimension is $l \times n$, where l refers to the number of items within frame Ω_E and n reflects count of subsets inside power set of Ω_H. Subsets for which masses are all zeroes are excluded from the matrix.

Two assignments presented in the same table refer to the same frame can be combined in order to increase their informative context. Combination of two mappings described by Formula 4 yields result structure that simplified version presents Formula 5.

$$\begin{aligned} m_1(e_1) &= \{(H_{11},[m_{11}^-,m_{11}^+]),\cdots,(H_{1m},[m_{1m}^-,m_{1m}^+])\} \\ m_2(e_2) &= \{(H_{21},[m_{21}^-,m_{21}^+]),\cdots,(H_{2n},[m_{2n}^-,m_{2n}^+])\} \end{aligned} . \quad (4)$$

$$m_c(e_c) = \{(H_{c1},[m_{c1}^-,m_{c1}^+]),\cdots,(H_{cl},[m_{cl}^-,m_{cl}^+])\} . \quad (5)$$

Within result structure elements m_{ci} are specified by Formula 6. Applying *min* and *max* operations results in implementation of a concept of tightest lower and upper bounds stipulated by constraints 7 [1]. Evidential mappings with crisp valued masses require their sum to be equal to one. Interval valued masses involve interactivity caused by stipulation that there exist total equal to one for any point within established ranges. Quite often their limits might be such that they cannot be bound for given set of data. Therefore tighten bounds are to be established.

$$\begin{aligned} m_{ci}^- &= \min \sum_{H_{1j}\cap H_{2k}=H_{ci}} m_{1j}^- m_{2k}^- \\ m_{ci}^+ &= \max \sum_{H_{1j}\cap H_{2k}=H_{ci}} m_{1j}^+ m_{2k}^+ \end{aligned} . \quad (6)$$

$$\begin{aligned} & m_{ci}^- \le m_{ci} \le m_{ci}^+ \quad i \in \{1,\ldots,l\} \\ & \sum_{i=1}^{l} m_{ci} = 1 \end{aligned} . \quad (7)$$

The tightest bounds for combined interval masses 6 under constraints 7 can be calculated based on specifications 8. As it is seen from presented specifications tightening bounds engages iterative procedure encountered while simple linear programming problem is being solved. Formula 8 were obtained thanks to results achieved by Dubois and Prade [2].

It should be noted that result of combination 6 does not exclude null sets. Mass assigned to empty set should be considered in order to obtain normalized final assignment.

$$\begin{aligned} m_{ci}^- &= \max\left[m_{ci}^-, 1-\sum_{j\neq i} m_{ci}^+ \right] \\ m_{ci}^+ &= \min\left[m_{ci}^+, 1-\sum_{j\neq i} m_{ci}^- \right] \end{aligned} . \quad (8)$$

Like in case of crisp valued mass functions association of two subsets $H_{1j} \cap H_{2k}$ can result in null set whenever null-generating operator is applied. Therefore greater than zero mass is assigned to empty set what means occurrence of conflicting information also called as inconsistency. Inconsistency violates constraints 3. Therefore the combination result is a pseudo belief structure and should be converted to its normal state by applying normalization procedure. Several approaches to normalization of pseudo structures have been suggested. One of them was proposed by Dempster, the idea of the approach is included into Formula 9. In this approach masses assigned to not null sets are increased by a factor calculated based on the sum of inconsistencies.

$$m_{ci}^{D-} = \frac{m_{ci}^{-}}{1 - \max\left[m_{\varnothing}^{-}, \left(1 - \sum_{\substack{H_{cj} \neq H_{ci} \\ H_{cj} \neq \varnothing}} m_{cj}^{+} - m_{ci}^{-} \right) \right]}$$
$$m_{ci}^{D+} = \frac{m_{ci}^{+}}{1 - \min\left[m_{\varnothing}^{+}, \left(1 - \sum_{\substack{H_{cj} \neq H_{ci} \\ H_{cj} \neq \varnothing}} m_{cj}^{-} - m_{ci}^{+} \right) \right]} \quad (9)$$

Interval valued belief and plausibility measures can be calculated given a belief structure [1]. Formulas 10 & 11 deliver calculation details. To calculate belief for given set one has to add interval valued masses assigned to all subsets of the set. Limits of the final value are to be tightened. Calculation of plausibility engages all sets that intersection with the considered set is not empty. It was proved that plausibility is not less than belief measure if calculation involved belief structure. The statement might not be true when calculations engage pseudo belief structure [12].

$$bel^{-}(H_i) = \max\left[\sum_{H_{cj} \subseteq H_i} m_{cj}^{-}, 1 - \sum_{H_{cj} \subseteq H_i} m_{cj}^{+} \right]$$
$$bel^{+}(H_i) = \min\left[\sum_{H_{cj} \subseteq H_i} m_{cj}^{+}, 1 - \sum_{H_{cj} \subseteq H_i} m_{cj}^{-} \right] \quad (10)$$

$$pl^{-}(H_i) = \max\left[\sum_{H_{cj} \cap H_i \neq \varnothing} m_{cj}^{-}, 1 - \sum_{H_{cj} \cap H_i \neq \varnothing} m_{cj}^{+} \right]$$
$$pl^{+}(H_i) = \min\left[\sum_{H_{cj} \cap H_i \neq \varnothing} m_{cj}^{+}, 1 - \sum_{H_{cj} \cap H_i \neq \varnothing} m_{cj}^{-} \right] \quad (11)$$

2.1 Inference Patterns

In the simplest case imprecision can be represented by intervals. Uncertain fact can be characterized by [*a, b*] range, for which $a \leq b$ is satisfied. The lower bound of the interval represents belief, the upper bound expresses plausibility of the corresponding fact. To state more is quite often that interval bounds are imprecise. Thus the characteristic takes the form: $[[a^-, a^+], [b^-, b^+]]$ range, for which at least condition $a^- \leq b^+$ is satisfied. Evidence mapping associated with uncertain fact P considered in $\{P, \neg P\}$ universe is in the form of pairs set as shows Formula 12.

$$m(e) = \{(P, [a^-, a^+]), (\neg P, [1 - b^+, 1 - b^-]), (\Omega, [\max(0, b^- - a^+), b^+ - a^-])\}. \quad (12)$$

Uncertain rule usually takes form of proposition: if event E is true then H is also observed. In case when imprecision is involved shortened form of the statement can be expressed: *if E then H* with imprecise bounds: $[[c^-, c^+], [d^-, d^+]]$. The rule is interpreted as relation between two universes. Thus it can be modeled by probability assignment. Modus ponens inference procedure enables inferring on consequent Q from known antecedent P and a rule $P \rightarrow Q$. The rule is conditional claim, which states that P implies Q.

Schematically the modus ponens inference procedure can be presented as [11]:

uncertainty of the rule *if … then …*:		$[[c^-, c^+], [d^-, d^+]]$
uncertainty of the antecedent P	:	$[[a^-, a^+], [b^-, b^+]]$
uncertainty of the consequent Q	:	$[[x^-, x^+], [y^-, y^+]]$

The inference scheme engages two premises. The first premise is the rule that is proved to be true inside certain interval. The second premise is the antecedent of the rule that appeared to be true within given range. From these two premises range inside which the consequent of the conditional claim is true should be logically concluded belief and plausibility of Q are specified by Formula 13 [8].

$$bel(Q) = [[a^-, a^+][c^-, c^+], pl(Q) = 1 - [a^-, a^+] (1 - [d^-, d^+]). \quad (13)$$

2.2 Detection Problem

Coastal waters are monitored by radar stations in order to enforce traffic regulations. Monitoring is also helpful during rescue operations. Allocation of radar stations should assure floating objects continuous detection at predefined level all over the area. Credibility that even smallest crafts can be spotted also during bad weather conditions should be greater than stipulated value. To meet mentioned requirements detection and coverage optimization problem is formulated [3].

Within specified area set of points are considered. For each of them ability of detection of floating objects are obtained based on locations and characteristics of all the stations that cover given position. It is assumed that the stations operate autonomously and each of them is a source of independent evidence. Fig. 1 presents locations of three monitoring stations. Ranges for which probability of detection is about zero are marked with wide rings. The figure also shows a grid of points covering area where ability of detection of small crafts is rather impaired due to distance from the radar stations locations. Overall quality of the monitoring scheme depends on continues coverage of the whole area including more distant regions. Therefore cumulated ability of detection is to be calculated for example set of points. Let us consider point number 9. Characteristic of detection covers three items {*detected*, *¬detected*, *uncertainty*}. The items are constituents of appropriate universe or a frame of discernment. Respective data for this point, with reference to the three stations, are gathered in Table 2.

Table 2. Set of detection characteristics

	detected	*¬detected*	*uncertainty*
station 1	[0, 0.1]	[0.2, 0.4]	[0.6, 0.7]
station 2	[0.1, 0.3]	[0.4, 0.6]	[0.3, 0.3]
station 3	[0.25, 0.35]	[0.3, 0.5]	[0.25, 0.35]

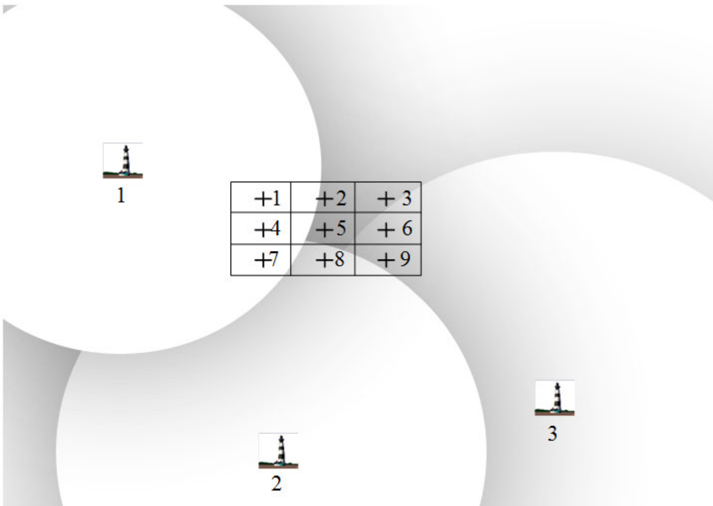

Fig. 1. Example monitoring stations locations

Joint detection characteristic can be obtained using D-S scheme of combination. Result detection ability for point 9 is shown in Table 3. The table contains result interval valued masses included in column *ivm*. Presented masses were obtained after three steps of combination involving pieces of evidence delivered by each of the considered radar stations. Column *cvm* embraces data achieved for assignments involving crisp masses obtained as means of appropriate intervals limits.

Table 3. Joint characteristic of detection ability for point 9

	ivm	*cvm*
detected	[0.09, 0.48]	0.22
¬detected	[0.42, 0.86]	0.69
uncertainty	[0.05, 0.16]	0.09

3 Fuzzy Evidence

Uncertain evidence involves fuzzy sets that consist of grades expressing possibility of consecutive hypothesis items belonging to an evidence set. Each of the fuzzy sets has assigned mass of credibility. Therefore fuzzy evidence mapping consist of fuzzy set-mass pairs. Fuzzy sets are represented by membership functions that reflect relations between two universes called hypothesis and evidence frames of discernment.

Membership function converts the hypothesis space into power set of [0, 1] interval: $\mu : \{x_k\} = \Omega_H \rightarrow 2^{[0,1]}$. Each piece of evidence is linked to certain set, therefore membership functions reflects relation between elements belonging to hypothesis space and sets attributed to elements of the evidence. Membership functions for nautical applications are discussed in previous author's papers [4], [6]. Evidence fuzzy representation stipulates normality of the sets. Normal fuzzy set should include highest grade equal to one. Belief structure with fuzzy sets should include all normal sets and total sum of their masses is to be one. In case of interval valued masses interactive values must give required sum.

Two fuzzy assignments can be combined in order to increase their informative context. Association of two fuzzy mappings can be carried out using combination matrix as presented in previous chapter.

3.1 Detection Problem and Fuzzy Sets

Fig. 1 presents example constellation of three monitoring stations. Grid of points situated at the outskirts of detection ranges should be explored in order to evaluate location instance. Smallest ability value is a primary factor in overall location assessment. Method proposed in the previous chapter can be exploited to obtain required values for each of the points. In this chapter yet another approach is proposed. In suggested solution all considered points are processed simultaneously. The proposal is based on fuzzy evidence representation and reasoning.

Different approach can be based on family of detection curves available for each of the stations (see Fig. 2). The approach takes into account ambiguity in available detection characteristics. Usually at disposal remain various diagrams although assumed for the same declared and subjectively assessed sea condition and magnitude of objects. Thus one should consider probability of detection as fuzzy value. Available bunch of characteristics can be used for specification of a membership function.

Fig. 2 shows detection probability characteristics as a function of distance from radar station. Presented curves are valid for given class of floating objects, sea condition and type of the radar station. Upper pair of curves shows optimistic maximum expected levels of detection. Lower curves indicate most pessimistic assessments. Diagram enables obtaining detection interval with imprecise bounds: $[[a^-, a^+], [b^-, b^+]]$. The interval shows uncertain probability limits related to range valued spotting ability. Given such value one can plot approximate membership function as presented in Fig. 3. The function gives answer to question of amount of possibility of detection within given range of probability. Given function $f(x)$ and n selected probability ranges grades of membership can be calculated using Formula 14. Probability assignment for example possibility grades and five selected probability ranges is presented in Table 4.

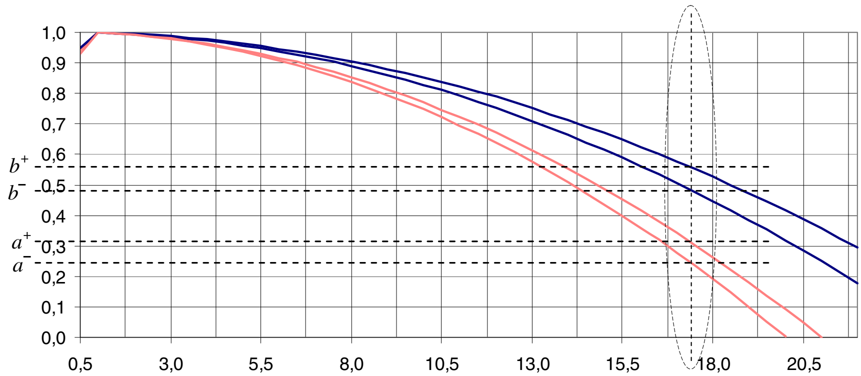

Fig. 2. Example detection characteristics of a monitoring station

$$\mu(p_i) = \frac{\int_{p_i-\delta}^{p_i+\delta} f(x)}{2\cdot\delta}. \tag{14}$$

where $\delta = \dfrac{1}{2\cdot n}$

Table 4. Detection possibilities to probability intervals mapping

	grade	interval valued probability (*ivm*)
$\mu(p_1)$	0	[0, 0.2)
$\mu(p_2)$	0.7	[0.2, 0.4)
$\mu(p_3)$	0.7	[0.4, 0.6)
$\mu(p_4)$	0	[0.6, 0.8)
$\mu(p_5)$	0	[0.8, 1]

Data gathered in Table 5 refers to the situation presented in Fig. 1. Example assignment of interval valued probability to fuzzy possibility vectors are shown in the table. The assignment embraces six rows and is related to the first station. Columns within assignment contain mappings of detection possibilities to defined probability intervals with reference to each point of considered set of discernment. Each mapping occupies five rows since the same number of probability intervals was adopted. The sixths row is all one vector that expresses uncertainty. Second last column provide interval valued masses of evidence. Last item in this column emphasizes doubtfulness of the assignment. Complement of the value shows credibility attributed to the quality of characteristics of given radar station. In below presented example each station characteristics were diversified with the credibility factor. The highest trust was attributed to station number one.

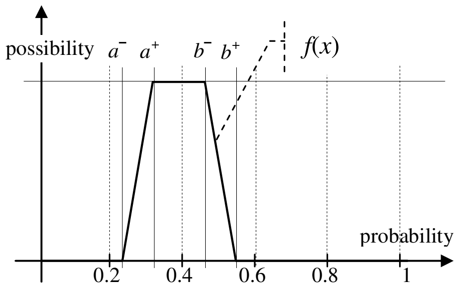

Fig. 3. Diagram of possibility of floating object detection

Mapping provided in Table 5 is not a belief structure for three reasons. First refers to assignments to null vectors. Attributing empty set with positive mass is a source of conflicting information and is called inconsistent assignment. Second is related to abnormality of fuzzy sets, there are vectors with highest grade smaller than one. The last reason that presented assignments are not belief structures is linked to masses values. It is stipulated that for interval valued masses there exist set of figures, belonging to appropriate intervals, which sum is equal to one. It is easy to notice that such set does not exist in provided assignment. Thus presented masses are to be proportionally reduced in order to fulfill the requirement. For the sake of simplicity intervals were transformed to crisp values obtained as limits means. Proportionally decreased crisp masses are presented in last column. Converted masses enable normalization process that eliminates abnormal vectors and inconsistent assignments. Transformation of probability assignments into belief structures were carried out in a manner consistent with the Dempster procedure. For normalization procedures refer to the paper by Yager [12]. After normalization crisp belief structures were obtained enabling engagement of association mechanism available in Dempster-Shafer theory.

Table 5. Assignments of interval probabilities to fuzzy possibilities of detection by station 1

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	***ivm***	***cvm***
$\mu_1(p_1)$	1	0.3	0	1	0	0	0.7	0	0	[0, 0.2)	0.036
$\mu_1(p_2)$	0	0	0	0	0	0	0	0	0	[0.2, 0.4)	0.108
$\mu_1(p_3)$	0	0	0	0	0	0	0	0	0	[0.4, 0.6)	0.180
$\mu_1(p_4)$	0	0	0	0	0	0	0	0	0	[0.6, 0.8)	0.252
$\mu_1(p_5)$	0	0	0	0	0	0	0	0	0	[0.8, 1]	0.324
$\mu_1(u)$	1	1	1	1	1	1	1	1	1	[0.1, 0,1]	0.100

Final results of combination normalized with Yager smooth method are presented in Table 6. Last rows of the table provide final plausibility regarding detection ability. For discussion on using belief and plausibility measures in maritime applications involving fuzzy sets see previous author's paper [5].

Point 2 receives smallest plausibility that can be perceived as upper probability of detection. It is a bit greater than 14% (5%*2.78). Scaling factor 2.78 was used for proportional reduction of original probability in order to convert an assignment into belief structure. Final probability is rather low therefore constellation of monitoring stations most likely will not be accepted.

Table 6. Result belief structure

	1	2	3	4	5	6	7	8	9	*cvm*
	0	1	0	0	0	0	0	0	0	0.00
	0.1	0.1	0	1	0	0	0.1	0	0	0.03
	0	0	0	0	0	0	1	0	0	0.06
	0	1	0	0	0	0	0	0	0	0.00
	1	0.3	0	1	0	0	0.7	0	0	0.10
	0	0.13	0	0	0.63	0.13	0	1	0.63	0.02
$\{\mu_c^D(x_i)\}$	0	0	0	0	0	0.1	0	0	1	0.03
	0.1	0.1	0	1	0.9	0.1	0.1	0.8	1	0.08
	0	0	0	0	0	0	0	1	0	0.01
	0	0	0	0	0	0	1	0.22	0	0.22
	0	0.1	1	0	0.5	0.9	0	1	0.5	0.07
	0	0	0	0	0	0.2	0	0	1	0.10
	1	1	1	1	1	1	1	1	1	0.29
$bel(x_i)$	0.00	0.00	0.00	0.03	0.00	0.00	0.23	0.02	0.10	
$pl(x_i)$	0.12	0.05	0.07	0.22	0.12	0.09	0.36	0.21	0.25	

4 Conclusion

Two approaches towards ability of floating objects detection were proposed in the paper. First is based on traditional uncertain facts and rule representation. The representation engages interval $[x, y]$ where x means probability that the fact is true and y means credibility for the contrary statement. In case of imprecision both values should be seen as intervals. Principles of interval valued arithmetic enable adopting known mechanisms and methods to conclude on final results. Representing imprecise elements of considered frame of discernment one can use D-S scheme of combination in order to obtain detection ability of objects being within area covered by a few radar stations. Each station provides independent evidence regarding floating objects spotting ability. Stations constellation might be approved or rejected base on joint ability of detection. Considering several constellations lead to solution of so called coverage problem. In every point within monitored area lowest probability of detection is to be above required value. It should be noted that obtained data are valid for certain class of vessels and specified sea conditions. In order to extrapolate the results to different circumstances modus ponens inference pattern can be used.

Second approach engages fuzzy sets. Possible range of probability values were split into five intervals. Ability of detection within each interval are established based on varies characteristics of the same station and supposedly for the same conditions. Variety of detection ability results from different testing methods, ways of calculations particular parameter and natural limitations. Therefore one can introduce highest and lowest probability of detection. In between these values a membership function can be used to indicate required possibility. Trapezoid function was shown as an example, although different shapes should be considered depending on available characteristics. Returned by the membership function values are grades of fuzzy sets. Before processing unity vector was added to this sets in order to introduce uncertainty. All fuzzy sets were assigned interval valued credibility masses, as a result evidence mapping were obtained. The mapping should be further converted into believe structure. Therefore masses were modified in order to fulfill summation to one requirement inside a single structure. As a consequence of this modification results generated by the two approaches are not directly comparable. It is worth to stress that proper probability can be recovered provided scaling factor is recorded. Nevertheless one is to bear in mind that ways of transformation are different in both cases thus the same results could not be expected. In order to achieve belief structures subnormal fuzzy sets were converted to their normal states and null sets assignments eliminated. Transformation corrupts not null sets assigned masses, what is inherited feature of the Dempster normalization procedure. Final result embraces belief and plausibility of object detection in each point constituent of the search space universe. Belief and plausibility can be treated as lower and upper limits of detection probability provided scaling factor is applied.

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Safety Driving Assessment Based on Video Image Sequence Analysis

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Abstract. In this paper, a driving assessment mechanism based on video image sequence analysis techniques, such as traffic signs and road markings detection, and inter-vehicular distance estimation, is proposed. A smart device connected to 3G wireless networks is used to collect and send sensory information. These data are analyzed in a cloud computing infrastructure to evaluate personal driving assessment. The traffic signs detection realized by utilizing SIFT feature descriptor and the inter-vehicular distance estimation technique based on simple geometric constraints, are shown in detail.

Keywords: driving assessment, image analysis, in-vehicle camera.

1 Introduction

Safety driving management is achieved by a cyclic process consists of collecting sensory information, safety driving assessment and improving driving through its results.

In this paper, a driving assessment mechanism based on video image sequence analysis techniques, such as traffic signs and road markings detection, and inter-vehicular distance estimation, is proposed. A smart device connected to 3G wireless networks is used to collect and send sensory information such as video image sequences, acceleration and GPS data.

These data are analyzed in a cloud computing infrastructure to evaluate personal driving assessment. The traffic signs detection realized by utilizing SIFT feature descriptor and the inter-vehicular distance estimation technique based on simple geometric constraints.

The experimental evaluation of the proposed method, as reported here, show an accuracy of over 90% in traffic sign recognition using the SIFT feature and an error of less than 10% in inter-vehicle distance estimation, which indicates that driving assessment can be effectively performed using their recognition and estimation results.

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2 A Safety Driving Management Utilized Smart Devices and Cloud Computing Infrastructure

2.1 Gathering Sensory Information via Smart Devices and 3G Wireless Networks – The Infrastructure

Currently, there are some safety driving management systems in our environment. Though, these systems have some problems described below.

- Gathering sensory data via data communication network is realized, but gathered data is closed into business operator (e.g. Taxi operator).
- A dedicated device is used for gathering sensory data, but production cost of these devices is very expensive.
- An assessment for safety driving is not automatically, made by human's hand.

To increase use of a safety driving management system to society as a whole, all of person can gather and utilize sensory data, inexpensive device for gathering sensory data, an automatically assessment for safety driving, are needed. To satisfy these demands, gathering sensory information via smart devices (iOS devices), communicating via 3G wireless networks, storing and assessment data in cloud computing infrastructure is proposed [1]. This system is still developed as an actual environment (CLOUD DRIVE, Fig.1).

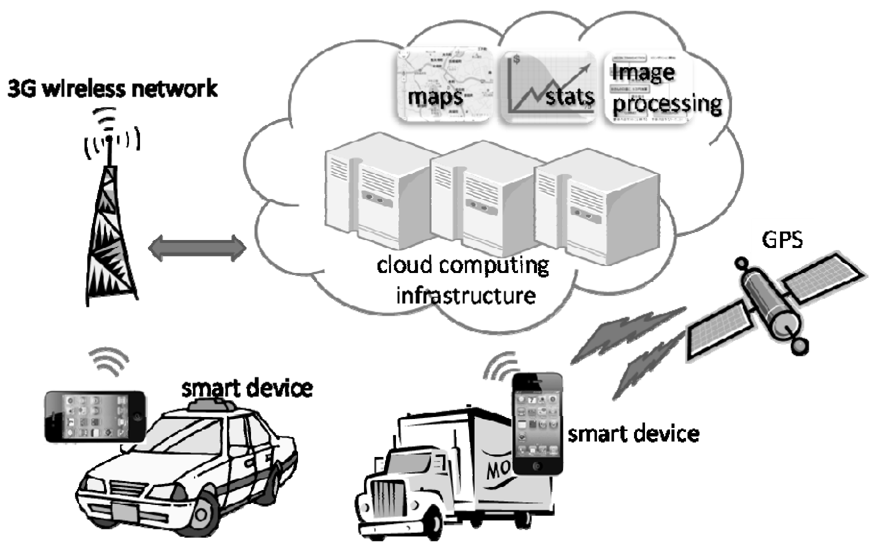

Fig. 1. A safety driving management system (CLOUD DRIVE)

2.2 Gathering Sensory Information via Smart Devices and 3G Wireless Networks – Gathered Data

In the CLOUD DRIVE, a data gathering system worked on a smart device records sensory data described below when a system detects a hard deceleration.

- Recorded image sequence on detected a hard deceleration (-10 sec to 5 sec, 450 frames of image)
- Time series data of accelerometer
- Time series data of coordinates detected by GPS

These data are sent to a cloud computing infrastructure. 3G wireless networks is used for communicating to a cloud system.

3 A Safety Driving Assessment Based on Video Image Sequence Analysis

As described in this paper, we use image processing to generate information with the goal of supporting safe driving. This information consists of the recognition (based on using the SIFT feature amounts) of traffic signs in scenes recorded by a vehicle-mounted camera and the estimation of inter-vehicle distance from the leading vehicle.

3.1 A Traffic Sign Detection Utilized SIFT Descriptor

If effective recognition of traffic signs and pavement markings within the driving environment can be recognized, then it is possible to alert drivers to things they have overlooked. With simple template matching, however, effective recognition is difficult (and requires excessively long processing times) because of the great variety in the size and orientation of traffic signs and markings acquired by the mounted camera. In the field of object recognition, for this and other reasons, interest has grown in the use of SIFT feature, which does not depend on the size or orientation of images. In this paper, we propose Color-SIFT, an extension of SIFT, and consider its application to traffic sign recognition.

Description of Image Features Using Color-SIFT. SIFT feature amounts do not change under zooming or rotation, but the feature points are difficult to detect if luminance is low. Using Color-SIFT feature, on the other hand, the gradient of each color component, rather than the luminance gradient, is described as a feature. In the "no parking" example shown in Fig. 2, the variation in value is small in the luminance image, but clearly visible in both the r image and the b image, as the two sign types are composed of colors centering on red and blue. With the use of the color information in the Color-SIFT feature amount, it is thus possible to determine the feature points even in images in which the value variation in the luminance image is small and the determination of the feature points is therefore difficult, so long as gradient variation is present in the color components. The process flow of the Color-SIFT feature amount extraction is shown in Fig. 3. In the rgb creation in this figure, the input image (the color image) is separated into images of the individual color components. The images used in this paper are normalized RGB and luminance images (I images) (1).

$$r = \frac{C_R}{C_S}, g = \frac{C_G}{C_S}, b = \frac{C_B}{C_S} \;;\; (C_S = C_R + C_G + C_B) \tag{1}$$

The use of normalized RGB enables ambient light reduction, and normalized RGB in the input image from the vehicle-mounted camera, which is influenced by ambient light, is assumed to be effective.

Fig. 2. Vehicle-mounted camera image

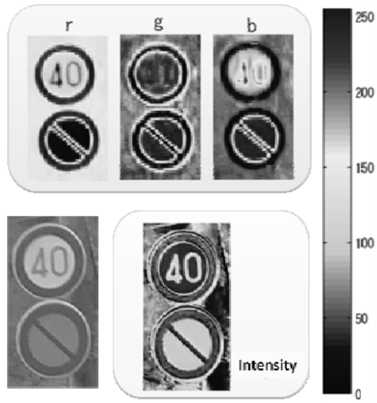

Fig. 3. Comparison of I, r, g, and b images

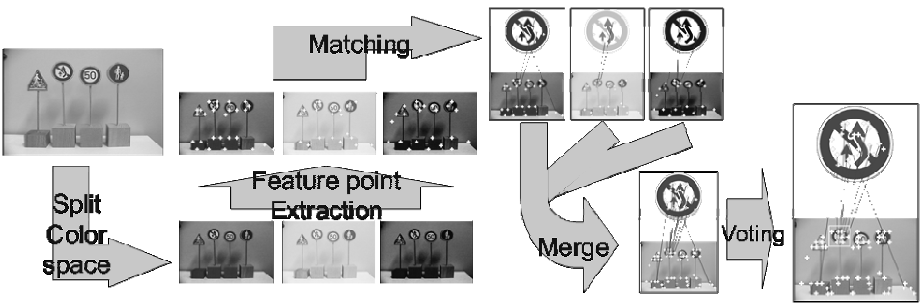

Fig. 4. Process flow of Color-SIFT feature extraction and sign detection

Detection Using Color-SIFT Feature. The method of target object detection using Color-SIFT feature amount is essentially as follows. Likelihood is calculated for each input image feature point, based on the feature points and feature amounts of a template, and voting is performed if the likelihood equals or exceeds a threshold value for the center of the detection target, as inferred from the correspondence between the template center and the matching feature point. This voting operation is executed for all feature points of the input image, and the point where votes are most concentrated is taken as the detection result. Color separation is performed, and by integration of the voting points for the individual colors, detection is possible even in cases where the voting points do not converge with the use of the luminance image alone.

3.2 An Inter Vehicle Distance Estimation Utilized Structure from Motion

We propose the semiautomatic method estimating a following distance so as to aid operators analyzing a fender bender. Our method bases on simple camera model geometry and projective image points of the leading vehicle. A focal length and a mounting height of DVR is easy to measure with an accuracy of plus or minus a few percent, though it is difficult to measure a depression angle of DVR. At the first, our proposal method realizes the estimation of the depressing angle based on a DVR's motion estimation utilizing an Eight-Point algorithm [5]. At the next, a projective image points of leading vehicle in an arbitrary frame is extracted by operator, whole remaining image frames are then extracted automatically by a particle-filter algorithm [6].

Estimating Depression Angle of DVR. In our method, estimating a depression angle consists of two phases. The first phase is the motion estimation of DVR based upon an Eight-Point Algorithm. The DVR motion is represented by a shift vector T = (Tx, Ty, Tz)> (where > is a transposition operator) and rotation vector θ = (θx, θy, θz).

Essential matrix E, as follow as,

$$E = T_{\times} R \tag{2}$$

is calculated by the Eight-Point algorithm and camera parameters.

Where T £ is a skew-symetric matrix which gives the cross product of T,

$$T_{\times} = \begin{pmatrix} 0 & -T_z & T_y \\ T_z & 0 & -T_x \\ -T_y & T_x & 0 \end{pmatrix} \tag{3}$$

And, where R is the rotation matrix.

$$R = \begin{pmatrix} C_y C_z & C_y S_z & -S_y \\ S_x S_y C_z - C_x S_z & C_x C_z - S_x S_y C_z & S_x C_y \\ S_x S_z - C_x S_y C_z & C_x S_y S_z - S_x C_z & C_x C_y \end{pmatrix} \tag{4}$$

where si and ci are sin(θi), cos(θi), respectively.

The other one is the depressing angle of DVR based on the time series of the DVR motion. In this phase, it is assumed that a vehicle body and DVR move horizontally to a road plane.

This assumption seems to be effected without incidents for a moment such as 30 [msec.]. Thus, the vertical element of T is ascribable to the depression angle of DVR.

A Eight-Point Algorithm. Is a frequently cited method for computing the fundamental matrix from a set of 8 or more point matches. A fundamental matrix F is,

$$F = A'^{T} E A \tag{5}$$

where the matrix A is an intrinsic matrix. The accuracy of the Eight-Point algorithm is affected by noise. Thus, our method adopts Hartley's normalized method [5] to overcome above.

In our method, the fundamental matrix is estimated by Kanatani's renormalized method [7] which is the one of high accuracy estimation method. Additionally, DVR's intrinsic matrix A is given because DVR has a single-focus camera. In our method, a matching between corresponding points is acquired by utilizing a KLT-Tracker algorithm. To realize a robust matching (tracking), it is necessary to extract good feature points to track. The feature points extraction is realized based on Harris-corner-detector [4].

Elimination Outlier. Subsets of corresponding points have the error due to a lighting condition, other cars moving and so on. To overcome above, our method applies a RANdom SAmple Consensus (RANSAC, well-known as the one of robust estimation method,) algorithm to eliminate these outlier.

Here is the steps of the actual algorithm in our method.

1) Selecting eight sets of corresponding points by a random sampling.
2) Estimating a fundamental matrix .Fi.
3) Calculating an error ef for all sets of corresponding points. An error ef is calculated, as follow as,

$$e_f = \frac{\left|m^T \widehat{F}_1 m'\right|}{\sqrt{p_1^2 + p_2^2}} \tag{6}$$

$$\begin{bmatrix} p_1 \\ p_2 \\ p_3 \end{bmatrix} = \widehat{F}_1 m' \tag{7}$$

4) Enumerating the number of points which has the error ef less than a threshold value.
5) Iterating step 1～4 for a fixed number of times and obtaining a fundamental matrix .Fmax which maximizes the number of points enumerated by step 4.
6) Recalculating a fundamental matrix.F based on all points with the error estimated by .Fmax less than the threshold.

Estimating Depression Angle. In this section, we describe the depression angle estimation method. Our method assumes that a vehicle body and DVR move horizontally to a road plane. This assumption seems to be effected without incidents for a moment such as 30 [msec.].

Thus, the vertical element of T is ascribable to the depression angle of DVR. Under this assumption, the depression angle φi is estimated, as follow;

$$\varphi_i = \tan^{-1}\left(\frac{T_y(i)}{T_z(i)}\right) \tag{8}$$

where i is the index of a image frame which has small rotation angle of y-axis less than a given threshold. The depression angle φopt is selected, as follow as,

$$\text{opt} = \arg\min_{p \in I} \sum_{j \in I} \left|\varphi_p - \varphi_j\right| \tag{9}$$

where I is the set of the image frame number which has small rotation angle of y-axis less than a given threshold.

Extracting Image Points of Leading Vehicle. Projective image points of leading vehicle are extracted by operator in our proposal method. The given image points which defines a rectangle area is then tracked in all frames based on particle-filter algorithm.

4 Experiments and Results

4.1 A Traffic Sign Detection

Here we assess performance based on SIFT feature amount and on the proposed Color-SIFT feature.

Experimental Environment. The experiment was conducted with SIFT feature amount and Color-SIFT feature amount used to identify traffic signs in the vehicle-mounted camera images. Fifteen traffic sign templates were used, as shown in Fig. 5, for traffic sign recognition. Each of the traffic signs used in the template images fit into an area of 150×150 to 180×180 pixels. The mounted camera images were obtained with a video camera installed in the front passenger seat of the vehicle.

Fig. 5. Traffic sign templates used in this experiment

Evaluation was performed in terms of recognition rate, false recognition, and false detection. The recognition rate was expressed as the ratio of the number of signs. Recognition of a traffic sign once or more at any time during its presence in the video image was counted as a sign recognition for calculation of the recognition rate. False detection refers to any case in which a traffic sign was detected during its presence in the video image but not correctly identified. False detection refers to any case in which a traffic sign was detected but placed at a location different from its actual one. The results of the experiment are shown in Table 1.

Table 1. Experimental result of traffic sign recognition

	All of sign	Don't park , Don't park /stop	Stop, Go slow	Crossing	Don't pass, Don't turn, Max speed
Conventional method	36% (24/67)	0% (0/41)	-	100% (3/3)	95.7% (22/23)
Proposal method	92.5% (62/67)	90.2% (37/41)	-	100% (3/3)	95.7% (22/23)

4.2 An Inter Vehicle Distance Estimation

Experiment I. In this experiment, the accuracy of our proposal method was compared with the accuracy of manual calibration method based on the ideal point. The assessment of an accuracy is conducted to estimate several distances, (5, 6, 7, 8, 9, 10, 15, 20 [m]), DVR to a marker laid on the flat road. φ inf is estimated based on the video image sequence recorded while the vehicle is moving on the flat road. Parameters of RANSAC ef and the number of iteration are 0.5 [pixel] and 1000 times, respectively. The experimental result is shown in the Table 2. It shows that our proposal method has the capability of estimating the depression angle accurate enough to estimate the distance automatically.

Table 2. Experimental result of distance estimation (measure:[cm])

Ground Truth	Φopt	Φinf
500	540	553
600	628	644
700	699	719
800	789	815
900	887	919
1000	945	982
1500	1410	1491
2000	1908	2061

Experiment II. In this experiment, the following distance DVR to the leading vehicle is estimated by substituting image points lower sides of the rectangular tracked and extracted by the particle filter algorithm. Parameters of RANSAC are equal to the parameters in the experiment I. Parameters of a particle-filter algorithm, σ, the number of particles and constant value for the calculating a weight are (σx, σy, σv) = (2, 2, 0.05), N = 20 and k = 5, respectively.

Our proposal method is applied to three video image sequences which recorded actual near-miss incidents. Sequence No. 1 was recorded in the daytime. First, the vehicle turned right, and then braked hard suddenly during going straight ahead. Sequence No. 2 was recorded in the evening. The vehicle went straight ahead on a narrow street, and then braked hard suddenly. Sequence No. 3 was recorded in the nighttime. First, the vehicle stopped on a red light, then drive forward and braked hard suddenly during going straight ahead.

Results of the depression estimation in each frame of three sequences are shown in Fig. 6. There are noises caused by errors of eight-point algorithm and KLT-tracker, because the image recorded by DVR is high compression. Additionally, moving objects in the image, e.g. an another vehicle, also influenced the accuracy of these algorithms.

Our distance estimation method based on our proposal method was compared with the datasets of distance calculated based on the camera model and actual rear-bumper length of the leading vehicle. This camera model is well-calibrated by a lot of observed values to reduce the error to less than 2-3%. However, this calibration involves a great amount of time and effort. Of course, the rear-bumper length database construction, too. Results of comparison experiments are shown in Fig. 7.

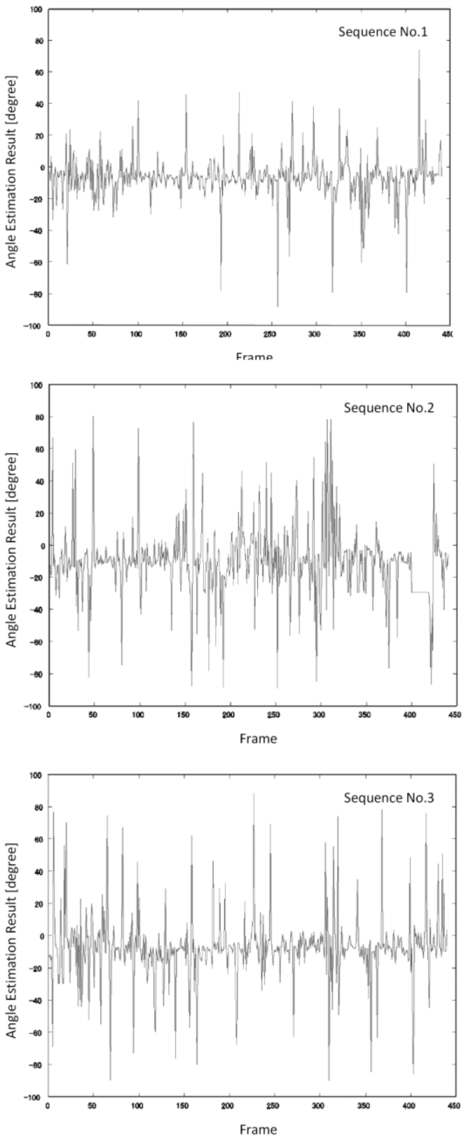

Fig. 6. Depression angle estimation

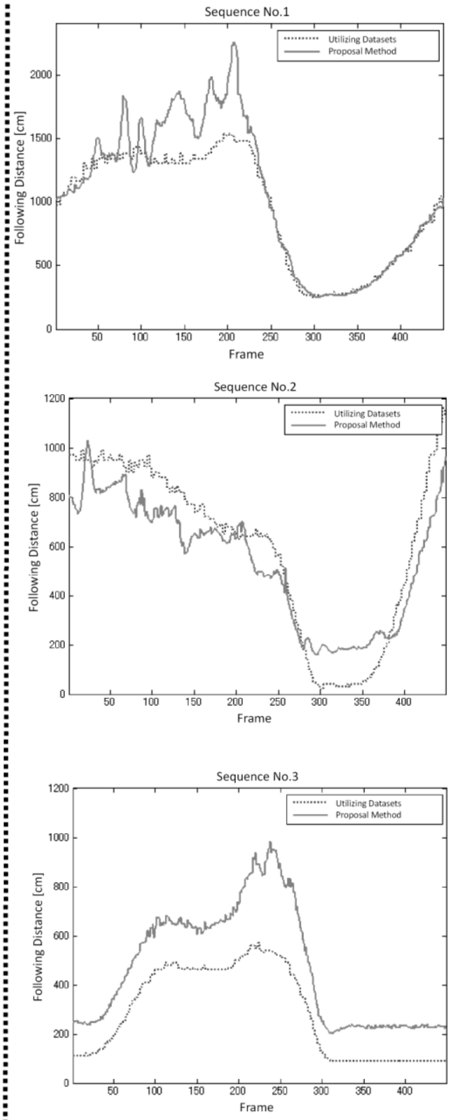

Fig. 7. Following distance estimation

The error from frame 100 to 250 in the sequence No.1 (see also Fig.7) was caused by the suspension vibration during turning right. We find that using the same depression angle φ opt in whole of frames is exert a harmful influence to the following distance estimation. The error from frame 0 to 200 in the sequence No. 2 was caused because of frequent small bumps, too. However, we also find that there is a possibility to reduce a spike-noise or a high-frequency noise by some filtering algorithms. It should be also noted that there is a continuous large error from frame 300 to 350 in the sequence No. 2.

This fail is caused by occluding a part of the leading vehicle with its own bonnet. To overcome above, a robust tracking method against the occlusion is needed. In the sequence No.3, the large error is observed in whole frame. It seems that the depression anlge estimation algorithm did not perform in this video image sequence. During the major part of the recording sequence No. 3, the vehicle stopped on a red light or by hard braking. There may be enough frames to estimate the depression angle. The one of future works is to distinguish between moving and stopping.

4.3 Making Information for a Driving Assessment

The results of the experiments for evaluation of driver assistance technology by the image processing described in Section 4 show that it is possible to perform highly accurate traffic sign recognition and inter-vehicle distance estimation using the proposed method.

By combining the incidence of the coordinate data obtained with this technique and the smart device, it is possible to perform driver assessment. This method holds promise as a means of helping to strengthen a support base for traffic safety by collecting information and presenting it to the driver in forms such as “this no-parking zone is difficult to recognize” and “speeding tends to occur here and accident incidence is high”.

5 Conclusion

In this paper, we have considered the collection of accident data by a smart device and the extraction of data for driver assistance by image processing in order to promote safe driving.

More specifically, we performed recognition of traffic signs in an environment recorded by a vehicle-mounted camera and estimation of inter-vehicle distance from a leading vehicle using image processing. The experimental results showed that the proposed methods enable highly accurate recognition and estimation of information essential for driver support. In further studies, we plan to integrate these information categories, construct a system for presentation of driving assessments to drivers, and work for the construction of a support base for traffic safety.

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The ITS Master Plan of the German Federal State of Saxony-Anhalt

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Abstract. Varied ITS systems exist in Germany and Saxony-Anhalt as well as in other countries and Federal States for several years. In other European and international countries (e.g. USA, Austria, Switzerland, Netherlands) national ITS-Action-Plans have been developed over the last years. They define a network of responsibilities and organizational structures to ensure an efficient and sustainable use of ITS systems. At European level research projects aim the development of a Europe-wide harmonized ITS-architecture for years (e.g. KAREN, FRAME, E-FRAME). The European Commission published an ITS Action Plan (KOM(2008) 886) and a directive to specify a frame for the implementation of ITS in road traffic (2010/40/EU) which also emphasizes this significance. This paper describes the current efforts of the first German Federal State Saxony-Anhalt which currently develops a local ITS Master Plan.

Keywords: ITS Master Plan, ITS Action Plan.

1 Aims and Principles of the Master Plan

An ITS Master Plan is currently being developed as part of the "Applied Traffic and Transport Sciences - Galileo Transport" initiative of the German Federal State of Saxony-Anhalt. The preliminary work carried out in different projects over the last years (e.g. PIEPSER, INVENT, MOSAIQUE, VAGABUND, Regio-INFO and Best4City) have resulted in a wide range of experience for all institutions involved in political and administrative fields in Saxony-Anhalt. The following list provides an overview of all important objectives of the ITS Master Plan:

- To procure optimal connections between overland modes of transport for passenger and freight transport
- To improve the basis of information in the field of traffic and transport (e.g. passenger information and connection protection and electronic ticketing) and in the field of logistics (e.g. the reliability of the supply chain, fleet management and controlling dangerous and heavy goods transport)
- To improve traffic safety, traffic flow and compliance with immission limit values by using intermodal traffic and mobility management

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- To advance the organisation and to establish an efficient cooperation mechanism between all ITS actors in Saxony-Anhalt
- To specify priorities for investment measures
- To ensure seamless access for both providers and users of applications, services and to strengthen competition by guaranteeing interoperability and standardisation
- To ensure that the employees concerned are qualified in coordination with corresponding infrastructure investments
- To establish an ITS culture of knowledge and to develop an SME structure in the industry in order to strengthen the research and industry potential of Saxony-Anhalt

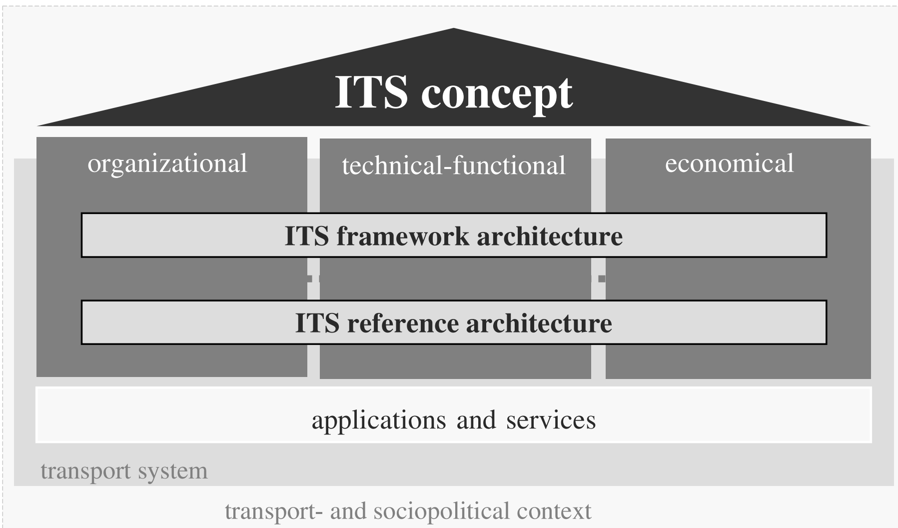

Fig. 1. Aims and principles

2 Topics of the Master Plan

The implementation of an ITS Master Plan requires cooperation and coordination not only with regard to special projects but also afterwards on a day-to-day basis. The institutions concerned therefore have to adopt new aims and develop the necessary skills concerning organisational and staff-related structure. The precondition for the cooperation of independent organisations is the establishment of a comprehensive consensus concerning aims and tasks. The aim of the work on the ITS Master Plan for Saxony-Anhalt is to find an initial consensus that needs to be stimulated by the use of incentives and mechanisms independent of specific individuals.

2.1 Saxony-Anhalt's ITS Concept

Overall concepts represent the commitment of organisations with different aims and interests to one common objective. Overall concepts are designed to give individual actors a shared orientation during complex transformation processes without constricting them in terms of their operational freedom by overloading them with detailed guidelines. Successful overall concepts have to strike a balance between the extremes of a lack of commitment, namely displaying verbal willingness to embrace innovation but actually failing to act, and overconfidence in planning, namely specifying details without considering precautionary measures for altered constellations.

The overall concept of Saxony-Anhalt's call for tenders requires the following attributes:

- Traffic-based and socio-political validity
- High commitment to the implementation of the defined measures
- Orientation to the main objectives, namely efficient use of the traffic infrastructure, a higher level of traffic safety and sensible stages of development
- A description of the organisational, functional and technical aims in a traffic-based and socio-political context
- Suitability as a useful reference for other German Federal States and comparable European regions
- Development on the basis of existing systems
- A clear definition of the "Applied Traffic and Transport Sciences - Galileo Transport" initiative by defining organisational structures and technical and functional architectures
- Openness to future technical developments and additional requirements
- The preparation of conflicts for political decision-making

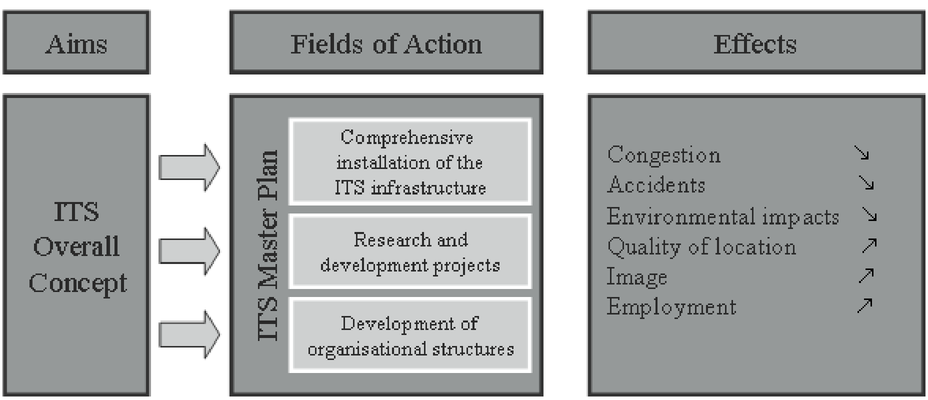

Fig. 2. Aims, fields of action and effects

The targets of the Development Plan of the German Federal State of Saxony-Anhalt of 2010 and the political objectives of Saxony-Anhalt in the fields of transport and social policy, spatial development and environmental policy, research and educational policy and regulatory and financial policy therefore have to be included and a concrete implementation must be carried out. Overall, the described aims result in different fields of action for the development of the ITS Master Plan, as shown in Fig. 1.

A first step of the project currently involves the development of an ITS overall concept. The aim of this overall concept is to clearly specify the traffic and transport policy agreements of, for example, the Development Plan of the German Federal State of Saxony-Anhalt, the Public Transport Plan, the logistics concept and the "Sustainable Demographic Policy in Saxony-Anhalt" strategic concept, to coordinate the activities of the Federal State Government and the subordinate authorities and to make these efforts transparent to the public. It forms the basis for the derivation of the fields of activity and measures. The result of the overall concept should use content, consistency and communication to ensure the necessary continuity of the planned measures. Where these objectives are concerned, the weighting of aims and measures supporting traffic quality is of great importance for traffic participants and the general public. This particularly affects the areas of traffic flow, traffic safety and multi-modality.

2.2 The ITS Modules and Architecture

In Saxony-Anhalt, a wide variety of ITS research projects focusing on the research, testing and transfer of innovative ITS have been implemented in recent years. Within the first field of action, all of the existing and planned Intelligent Transport and Logistics Systems (e.g. the current traffic situation, traffic information services and schedule information systems) and their crosslinking have to be reviewed and documented. These analyses form the basis for the subsequent differentiation concerning the benefit and the specification of areas with further research and development requirements.

Guidelines for the establishment of ITS framework architectures are needed for the sustainable implementation of innovative components and systems for traffic and mobility management but no obligatory and consistent or standardised guidelines for the establishment of ITS architectures currently exist in Germany. Where the abundance of existing data and information from authorities and actors in the traffic sector is concerned, it is far too often the case that these are only incomplete or scattered. Standardised communication between existing and new subsystems is therefore not continuously possible.

The ITS Master Plan for Saxony-Anhalt needs to identify new ways in which an integrative ITS framework architecture that is in line with both the requirements of local actors and the interests of the German Federal Government, as well as those of German and European service providers, can be designed. Existing approaches and current strategies have to be involved in this framework architecture.

2.3 The ITS Launch Plan

Where the ITS launch plan is concerned, the topics of research and development requirements, standardisation and certification, as well as economic aspects like operation and financing, play a major role.

Research and development projects have great potential to advance the development of an ITS architecture and the establishment of a traffic management network. One main stage will therefore be the analysis of existing instruments with the aim of strengthening research and development in the field of ITS. Particularly with regard to the development of infrastructures for intermodal traffic and transport and the necessary structures for communication, standardisation processes and their consequences are a further main focus.

Where the different modes of transport, intermodal traffic and communication structures are concerned, standardisation processes play a major role in the development of traffic and transport infrastructures. The topic of standardisation in general includes a variety of levels:

- Standardisation of traffic infrastructures, vehicles, logistics, operation, etc.
- The compatibility, interoperability, crosslinking of components and systems
- Regulations concerning traffic policy and regulatory policy and the regulation of market competition.

For several years, an increasing number of standardised solutions in traffic technology have been offered at a good price which leads to a faster distribution of ITS. The high and increasing cost pressure forces the responsible public authorities to avoid proprietary technical solutions and to increase the efficiency of existing systems. Data exchange in traffic management based on open communication standards could offer new opportunities.

An important topic concerning the operation of ITS infrastructure is a coordinated ITS architecture including the definition of preconditions for the harmonisation and, where necessary, standardisation of rules, the definition of methods for data collection and processing and the specification of functional and technical requirements. Workshops involving the different actors have therefore been planned.

Furthermore, the Master Plan has to deal with the basic conditions for future ITS architectures, namely finances, staff, the integration of existing systems and the procurement of new systems.

2.4 ITS Research and the Promotion of Education

The commitment of the German Federal State of Saxony-Anhalt to research and development over recent years shows a strategic chronology of projects. During the further growth of traffic management systems and the development of an ITS infrastructure for comprehensive traffic management, new questions, for example those concerning necessary instruments for the financing of projects, the distribution of new requirements and responsibilities and the initiation of strategic alliances to ensure the qualification of young academics, need to be answered.

3 Design, Approach and Methodology

The combination of the ITS overall concept, fields of activity and measures forms the ITS Master Plan. On the basis of inventory control and requirements analysis, as well as the examination of traffic-based and socio-political preconditions, strategic aims and judicial regulations, the following aspects are being developed:

- An ITS framework and reference architecture
- A reference organisation for the operation of ITS

– A concept for the distribution of traffic information for private use
– A launch plan concerning research and development, standardisation and certification, design and integration planning, an operation and financing concept, research and development funding and the promotion of education

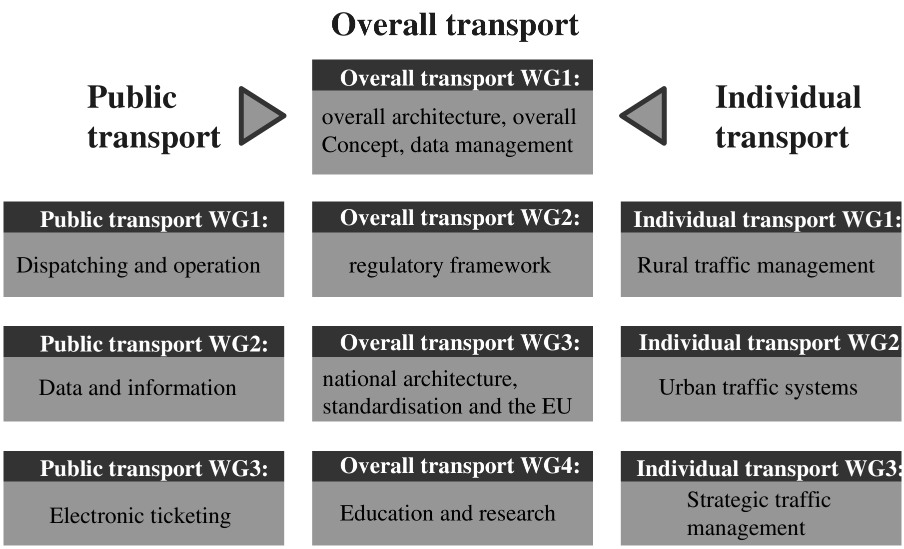

Fig. 3. Workgroups and workshops

Work on these aspects is being carried out in ten working groups containing participants with different areas of expertise (see Fig. 3):

1. Dispatching and operation in public transport
2. Data and information in public transport
3. Electronic ticketing in public transport
4. Rural traffic management in individual transport
5. Urban traffic systems in individual transport
6. Strategic traffic management in individual transport
7. The overall architecture, overall concept and data management
8. The regulatory framework
9. The national architecture, standardisation and the EU
10. Education and research

The ITS Master Plan is being developed in cooperation with the co-signing ministries and their subordinate authorities and commissioned agencies. Furthermore, experts and actors in traffic management from the German Federal Ministry of Transport, Building and Urban Development (BMVBS) and the entire German federal territory are involved on a consultative level. The aim is to determine the scope required in order to achieve comprehensive national objectives and compatible structures.

Existing legal regulations and other regulations (e.g. the guidelines of the German Federal Ministry of Transport, Building and Urban Development (BMVBS), the

German Federal Highway Research Institute (BASt), the Association of German Transport Companies (VDV) or the German Road and Transportation Research Association (FGSV)) are observed. The EU Action Plan and the 2010/40/EU Directive on the framework for the deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other modes of transport particularly have to be considered. Furthermore, current national and EU support programmes have to be taken into account. The examination of these programmes should result in approaches for the active involvement and cooperation of research institutes and companies from Saxony-Anhalt in future research and development programs.

4 Schedule

The European Union's ITS Directive demands a status analysis concerning national measures and projects from the Member States by 27th August 2011. The implementation of the Directive in German Federal Law is required by 27th February 2012, while a report concerning German ITS measures over the next five-year period must be submitted by 27th August 2012. The organisation in subordinate local authorities is the responsibility of the Member States.

Due to the time advantage that Saxony-Anhalt has with regard to the development of a comprehensive traffic system and the development of an ITS Master Plan, the EU-initiated work in Germany and its Federal States offer good opportunities for Saxony-Anhalt to play a major role in the shaping of domestic opinion in Germany. In addition, the EU plans to take the existing ITS specifications into consideration when developing its own specifications.

Two planning horizons form the basis of Saxony-Anhalt's ITS Master Plan. In consideration of the reports concerning the implementation of national ITS measures in Germany in accordance with the EU ITS Directive 2010/40/EU, these horizons are a medium-term period lasting until 2017 and a long-term period lasting until 2022. The first planning horizon will be completed with an evaluation of the implemented measures in order to enable readjustments to be made before the end of the long-term planning horizont.

5 Conclusion

The ITS Directive could be considered to be fulfilled when the required structures have been established on long-distance transport connections. This would, however, not solve the problems in the subordinate road network, especially in urban areas. Efficient traffic management cannot stop at administrative borders and has to consider traffic flow in terms of the entire relevant road network, especially due to the predicted growth of freight traffic. Where the previous laws on the organisation and financing of traffic infrastructure are concerned, some only unsatisfactorily accommodate these new tasks, whilst others do not attempt to accommodate them at all. It is in the interest of the German Federal State of Saxony-Anhalt to influence the development of the new German Federal Transport Infrastructure Plan and the follow-up regulation to the Local Authority Traffic Financing Act (GVFG) of the German Federal Government.

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Risk Analysis as a Basic Method of Safety Transmission System Certification

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Abstract. The implementation of the open transmission standards to railway control systems requires the estimation of Tolerable Hazard Rate corresponding to EU standards. The transmission channel must satisfy the obligatory measures related to the assigned SIL level. Both cable and wireless transmission standards must be analysed corresponding to hardware failure rates in railway control devices. The paper deals with failure analysis in some railway control systems including open transmission solutions. The result based on FTA methods is a good criterion for the introduction of new transmission technologies.

Keywords: risk analysis, THR, FTA, open transmission, PN-EN 50159-2.

1 Introduction

Modern railway control and management systems are computer systems comprising:

- superior systems,
- interlocking systems,
- line systems,
- remote control systems,
- ATP/ATC (Automatic Train Protection/Automatic Train Control) systems.

These systems communicate between themselves by means of appropriate transmission standards and create computer networks. According to the UIC (eng. *International Union of Railways*) and CENELEC (fr. *Comité Européen de Normalisation Electrotechnique*) classifications four safety levels SIL (eng. *System Integrity Level*) have been introduced. Both in Poland and in the European Union, railway control and management systems were assigned to one of the safety levels. The two highest levels (SIL 3 and 4) mean that the possible consequences of a fault of a railway control system, which can happen, are human death or loss of human health. Railway control and management systems responsible for safety on the railway or cross level protection systems belong to the highest safety level. A newly designed and implemented system must possess special safety certifications. To this end proper procedures of system analysis have been introduced. The introduction of new

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computer techniques to safety railway control and management systems required to define new safety criteria. At present the basic quantity criterion of estimation of the system is the THR (*Tolerable Hazard Rate*). According to standard [5], for systems classified to 3 and 4 level, the THR rate is presented in Table 1.

Table 1. THR for SIL 3 and 4

THR	**SIL** (Safety Integrity Level)
$10^{-9} \leq THR < 10^{-8}$	4
$10^{-8} \leq THR < 10^{-7}$	3

The qualification of numerical value of THR is not the only way to perform risk analysis of railway control and management systems. There are also other very helpful methods included in standards like Markov processes, Monte –Carlo methods or the FTA (Fault Tree Analysis) [7]. The FTA method is designed to identify and estimate the probability of initial events. On the whole, the fault tree analysis enables to describe a logical connection between initial events (computer failure, system failure, loss of information etc.) and their effects. The structure of risk analysis is presented in Fig. 1.

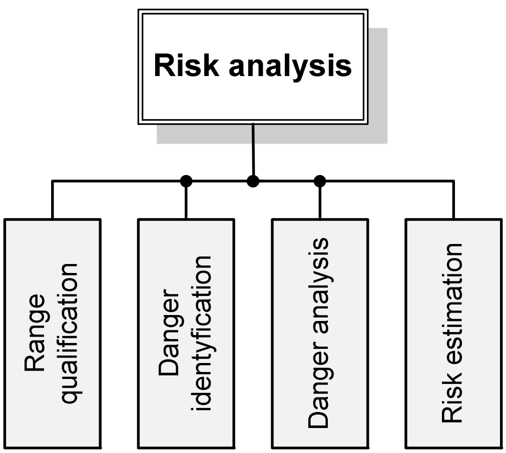

Fig. 1. Basic structure of risk analysis

In the paper the authors calculated the THR – a typical risk rate for cross level protection system and analysed a simplified FTA.

2 Closed and Open Transmission

The currently applied railway control and management systems belong to the group of modern devices based on a new computer and microprocessor technique ensuring much more functionality and efficiency. In accordance with railway standards [7] it is possible to use both radio and cable transmission in railway control systems. Usually a system with radio transmission has one channel and the communication is realized by VPN gates (Virtual Private Network). The basic structure of open and closed transmission is presented in Fig 2.

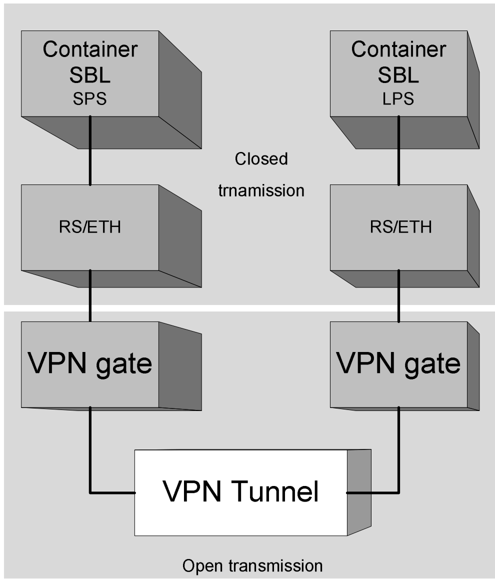

Fig. 2. The basic structure of open and closed transmission

Special cryptographic methods, which protect against unauthorized access, are essential from the viewpoint of safety. On the basis of formula (1) it is possible to calculate dangerous failure rate λ_{NT}. For common CRC32 (Cyclic Redundancy Check) code, the value of failure rate λ_{NT} can be calculated [1]:

$$\lambda_{NT} = \lambda_N \cdot p_{UE} = \lambda_N \cdot 2^{-32} \tag{1}$$

where λ_N is a failure rate of all faults in the transmission channel, $p_{UE}=2^{-C}$ is a probability of undetected failure due to the performance of the transmission code (C – number of redundancy bits). Assuming that a failure of all devices is low 10e-04, the failure rate of a dangerous fault (for CRC32 code) amounts to [1]:

$$\lambda_{NT} = \lambda_N \cdot 2^{-32} = 10^{-4} \cdot (4 \cdot 10^9)^{-1} = 2{,}5 \cdot 10^{-14} \tag{2}$$

3 The Railway Control and Management Systems Risk Analysis

The risk analysis in railway computer systems is one of the most import processes. It concerns systems in the phase of design, implementation and exploitation. From the viewpoint of safety the techniques based on operational data are the most authoritative. In the phase of design the only way to calculate characteristic rates is the forecasting estimation. On the basis of technical documentation the calculations are reduced to the failure rate for each electronic element, card or module [2], [3]. According to standard [5], the THR rate presents formula (3):

$$THR = \prod_{i=1}^{n} \frac{\lambda_i}{t_{d_i}^{-1}} \cdot \sum_{i=1}^{n} t_{d_i}^{-1} \tag{3}$$

where: λ_i – failure rate, t_{di}^{-1} – safe down rate.

For the system, in which the testing is held periodically, the safe down rate equals:

$$t_d = \frac{T}{2} + NT \tag{4}$$

where: T – time of periodical testing, NT – negation time.

Assuming a typical redundancy (*2 from 2*) of a railway computer control system, the THR can be calculated on the basis of formula (2) and (3) [4]. As an example, a cross level protection system is presented in Fig.3.

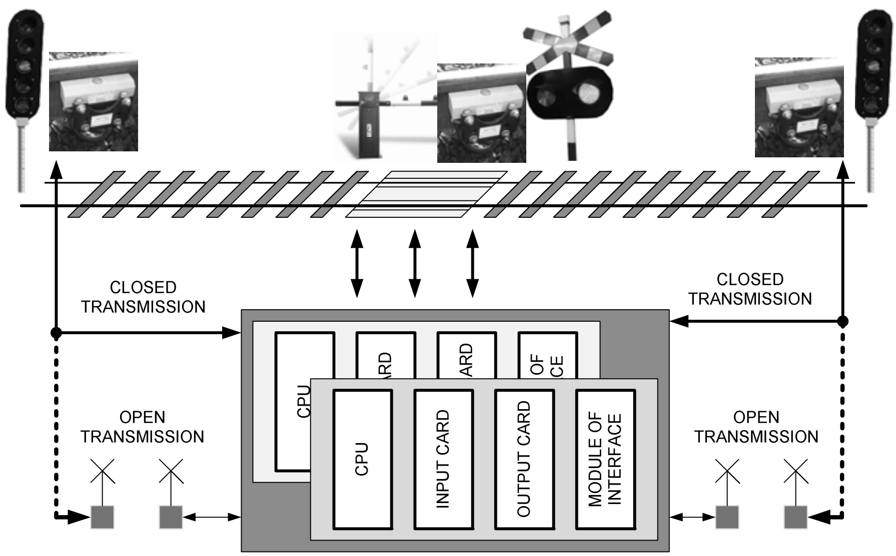

Fig. 3. Example structure of cross level protection system

Assuming values of failure rate and time t_d [4], the estimated THR equals:

$$THR = 5{,}56 \cdot 10^{-12} \tag{5}$$

Railway standards permit to use open transmission. The information from sensors and lights can be sent to the main decision making computer via radio transmission. In such serial structure of transmission, the estimation of THR reduces to formula (1) and THR = λ.

4 FTA Analysis

The FTA method requires detailed information. It is necessary to analyse carefully the possible events. This method can be used, like Monte – Carlo analysis, for quantitative analyses. In a classical description of the FTA analysis there is no time-dependence of individual events, but for testing the time dependence in FTA Petri Nets methods may be used. The paper presents a simplified FTA analysis of computer railway control systems in Fig. 2 and 3. The examples are based on the RAM Commander – ALD Company (demo version) software, and the general assumption was that the top event is the *Critical Fault* and the system uses open transmission. The window of analysed system is presented in Fig. 4.

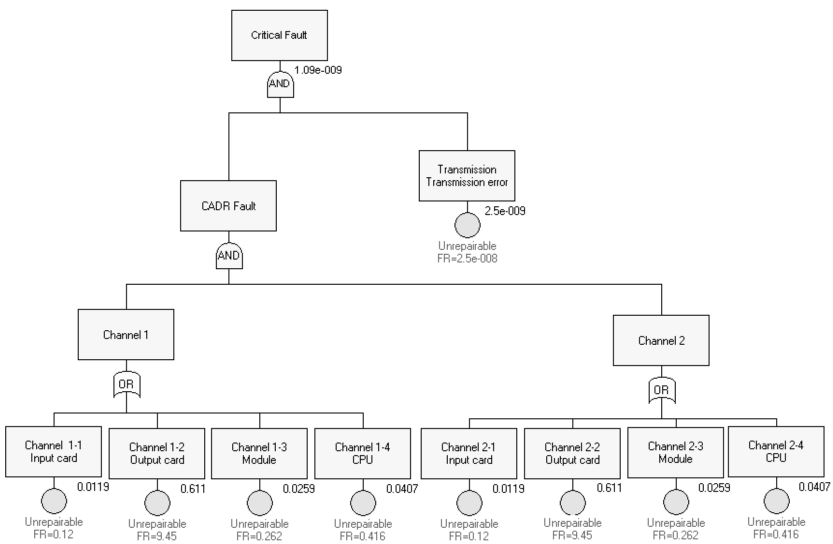

Fig. 4. Windows analysis

To carry out the FTA analysis, with regard to data from forecasting estimation [4], the values of failure rate of each card was assumed:

- Input card 1.21e-05,
- Output card 9.45e-06,
- CPU 4.16e-05,
- Module of interface 2.62e-05,
- Error of transmission on the basis of formula (2).

The example of report is presented in Fig. 5.

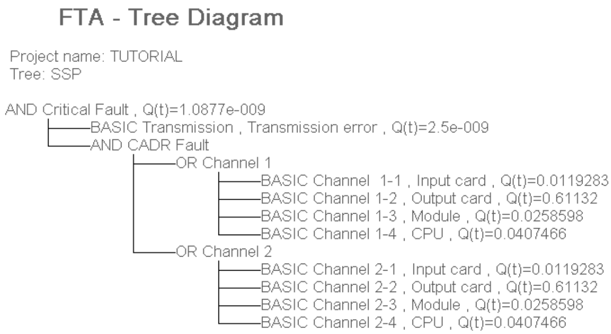

Fig. 5. Report - example

On the basis of FTA trees diagram (Fig. 4) it follows that for such assumption and type of the tree, the probability of failure at a given time point – 100 000h amounts to 1.09e-09. For the structure presented in Fig. 2 and assuming producers data:

- SPS 1(ESP-11) – 4.88e-06 ,
- RS/ETH 1 CONVERTER– 1e-06,
- VPN GATE (Lynx+L210) – 1.7e-06,
- LPS (ESP-11) – 4.88e-05 ,

the example of FTA analysis is presented in Fig. 6. In this example the top event is the *Transmission Error*.

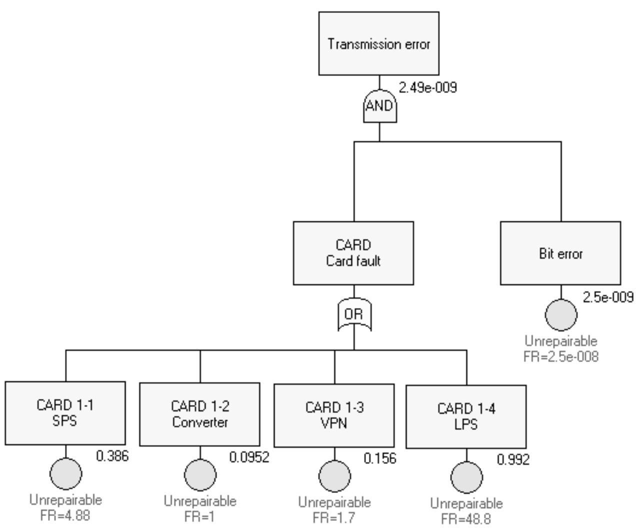

Fig. 6. FTA analysis for example from Fig. 2

The analysis resulted in calculation of the probability of error transmission equal 2.49e-09 (time of analysis 100 000h).

5 Conclusion

The risk analysis of railway computer systems is a discipline which still develops. New computer railway solutions and systems require a new attitude to the risk analysis. It is especially visibly at present in open transmission systems. The FTA analysis or calculated THR presented in the paper are not the only way to analyse the railway computer systems. In the rail standards there are other methods useful for safety analyses. Owing to the RAM Commander (*demo*) software used in the paper it was not possible to provide much more detailed systems analyses, like software problems, the reason of card fault etc. The THR calculated in the paper for the example of cross level protection system confirm a high safety level of such system.

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The Possibility of Using Telematics in Urban Transportation

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Abstract. The paper presents an overview of telematic solutions applicable in urban areas. Such solutions should contribute to a significant improvement of the urban transportation, while solving the cities' current traffic problems. A lot of isolated solutions can already be found in Polish cities; however, one must think about their propagation, preferably, in the overall (system) scale. Therefore, the most suitable stage shall be selected, best corresponding to the state of transport infrastructure in the given town, while taking into consideration the costs of introducing such systems. The alternative solutions are the slow "step-by-step" ones.

Keywords: transport telematics, traffic management systems.

1 Introduction

In recent times, transportation issues in general and urban transportation in particular, received an extra boost. In March this year, a "White Paper" was announced[1] as a plan and as a vision of growth for the transportation sector and of support for mobility. It mentions that "*new patterns of transportation must be developed, allowing the movement of more goods and passengers, using the most efficient means or combination of such means*".

Transportation is the foundation of the economy and society, and the mobility is extremely important for the internal economy and for the quality of life of citizens. Transportation enables economic growth and job creation. Quality, availability and reliability of transport services will be, in the coming years, increasingly important, among other things, due to the aging society and the need to promote public transport. The main features of high-quality services are: attractive schedule, comfort, easy access, reliability of services and integration with other means of transport. Availability of information on journey times and information about alternative routes are equally important to ensure seamless travel "from door to door", both for passengers and for freight transport.

In the urban context, to reduce congestion and emissions, a combined strategy is needed that includes planning, pricing, efficient public transport and infrastructure for

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[1] Brussels, 28.03.2011 KOM (2011) 144 final version.

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non-motorized means of transport. Cities above a certain size should develop plans for urban mobility, which should take into account all these features. Such plans should be fully concurrent with the urban development plans.

In the European Union, over 60% of the population live in urban areas, and a little below 85% of the gross domestic product is generated in urban areas. Cities are the driving force of the economy, they attract investment and create jobs. Thus, they have an essential meaning for the proper functioning of the economy.

Strategy is a fundamental issue in planning the city's development. It defines long-term prospects for the development of the city, and its principal goals are the identification of potential values and perspectives for the city's development.

In this perspective, the branch strategy (policy) for the development of transport has particular importance. It is connected with the fact that the city's transport system determines the proper functioning of almost all its other components. Thus, city transport policy is, in fact, the choice of a particular direction and method for the development of an existing transport system in correspondence with the adopted city development strategy.

Transport policy of the city involves the following important tasks:

- determination of the communication needs of the city in the time-space system,
- determination of the fundamental direction of the development of infrastructure,
- establishing rules for financial management (fees, tariffs, subsidies),
- organization and management of urban transport (selection of structures, systems and forms of ownership).

City transport policy should take into account various aspects, including in particular:

- psychological and social, guaranteeing citizens' access to sources of traffic,
- environmental, resulting from the need to protect the environment,
- spatial, taking into account the need for proper deployment of destinations and sources of traffic within the city and the existing infrastructure,
- economic, resulting from the need to accumulate financial resources to develop a transport system,
- temporal, associated with the need to achieve the desired result in a given time.

Transport policy has long-term (strategic) and short-term (current) dimensions. The strategic dimension involves programming the development of the city transport system. A current dimension is related to the implementation of concrete solutions to improve the functioning of the city transport system.

Important, but often omitted or neglected, initial premises for preparing and implementing the city's transport policy are:

- external effects (costs) associated with each transport activities,
- limited means (resources), generating the need to define priorities for the development of individual subsystems,
- ability and activity in acquiring external funding for development of the transport system,

- measures to increase municipal resource efficiency,
- efforts to organize the spatial layout of the city resulting from the dynamics of settlement and town creation processes.

Commonly observed dynamics of the development of personal transport in the city imposes on public authorities the necessity of an integrated approach. In essence, it consists in giving priority to collective transport, especially in central city areas, and a radical reduction in the use of cars.

Currently, urban areas constitute the living environment for the vast majority of the population and, therefore, it is imperative that the quality of life in these areas should be as high as possible. Therefore, the system considerations should concentrate on the question of urban mobility.

This new approach to urban mobility involves optimizing the use of various means of transport and the creation of co-modality between the different means of collective transport[2] (train, tram, metro, bus, taxi) and the different means of individual transport (car, motorcycle, bicycle, walking). It also includes achieving common objectives in the management of transport demand in order to ensure mobility, appropriate quality of life and environmental protection. In addition, it involves reconciling the interests of road freight and passenger transport, regardless of the means of transport used.

Traffic jams in cities are one of the most important problems of modern transport. They have a negative economic and social impact, and they influence negatively the health of residents and affect the environment and urban fabric. Congestion often originates on urban ring roads and affects the throughput of the whole transport network. The transport system with a smooth traffic would allow people and goods to arrive on time and would limit these negative effects.

Due to lack of space and problems related to environmental protection, there are significant limits to the development of transport infrastructure that is needed to deal with increased movement in cities. In some cases, it would be necessary to build a new infrastructure. However, the first step should be to find solutions for better use of an already existing infrastructure.

Therefore, it is noted that the intelligent transport systems are not sufficiently used for effective management of urban mobility, or they are developed without due attention to interoperability.

Processing of traffic and travel data can be an excellent source of information, assistance and dynamic control of transport for passengers, drivers, carriers and network managers. Toll systems for driving into town demonstrated a positive impact on the flow of traffic. Intelligent transport systems allow for optimized trip planning, better traffic management and simpler demand management. Intelligent charging systems should be based on smart cards, interoperable between various transport means for various functions (such as payments related to transportation, services unrelated to transportation, parking and customer loyalty schemes) and for each area (in the long term for the whole country). The possibility of differentiation of rates depending on the time or the target group (for example, peak / off-peak hours) could

[2] Collective transport is a broader concept than public transport and includes, for example, taxis or transport on demand.

also be part of the system. Flexible and multiple use of infrastructure, such as shifting bus passes, shifting loading / parking zones, may reduce the demand on the limited amount of street space.

One of the critical factors determining the success of mobility in urban areas for travelers is to be able to make an informed choice of means of transport and travel time. It depends on the availability of user-friendly, adequate and interoperable multi-modal travel information for planning a journey. Telematics permits here a dynamic management of information infrastructure.

Additional capacity, sometimes in excess of 20-30% or more, can be gained through more efficient use of road space. This is extremely important because, normally, possibilities for the development of roads in urban areas are often very limited. Active management of urban transport infrastructure can also have a positive impact on safety and the environment. Transport telematics could find use primarily in the management of seamless connections between the networks connecting the urban and the suburban zones.

The efficiency of urban freight distribution can also be increased by intelligent solutions, in particular, through better timing of deliveries, higher loading factors and more efficient use of vehicles. For this purpose, the integrated systems are necessary to combine intelligent route planning, driver assistance systems, intelligent vehicles and interaction with the infrastructure.

This process should involve technology providers, carriers and infrastructure operators.

2 Transport Telematics

The application of transport telematics systems (often referred to as Intelligent Transport Systems - in short, ITS) is one way of low-cost improvement of urban transport systems to increase their efficiency and safety. Telematics systems provide a variety of possibilities for action and impact, ranging from traffic control systems, vehicle stream management in streets network and implementing priorities for specific means of transport thorough information systems for passengers and drivers.

The process of moving people and goods in the city street network is particularly complex, not only because of the considerable dispersion, but mainly because of non-stationarity and non-homogeneity. The desire by many drivers to use the same parts of the street network at the same time leads to exceeding their capacity, the formation of large queues, congestion, and even blocking a part of the city. The effects of congestion are the reduction in safety, efficiency and effectiveness of travel and a negative impact on the environment and health of residents, particularly in inner cities.

Telematics systems create huge possibilities of increasing the availability and efficiency of transport, while reducing expenditures on developing infrastructure. For intelligent solution to meet its role, it is necessary to modernize the existing urban transport infrastructure (or to build it), to connect it to planned telematics investments.

Application of the systems using ITS technology contributed to:

- reduction in spending on transport infrastructure by obtaining the same effects of improved efficiency of the system as in the construction of new sections of roads or upgrading existing ones,

- increase in efficiency of transport networks (measured throughput) without the need for road investments,
- significant reduction in the number of emergencies and victims of road accidents,
- significant saving of travel time and number of standstills,
- significant reduction in exhaust emissions and noise levels.

Telematics systems consist of the following solutions:

- Traffic Management – traffic control based on the collection of transport data related to density, speed and classification of traffic.
- Traffic Information - information systems related to the situation involving the movement of transport, including the information made available via the Internet or RDS-TMC. This feature allows commuters approaching the city to receive information related to the restrictions on movement via the GPS receiver.
- Electronic Fee Collection - collection of fees within the inner city, where the entrance charge applies, every vehicle entering the toll zone is automatically registered in the system.
- Road Weather Information Systems - meteorology related to traffic (possibility of controlling the condition of roads in winter). With this feature, the system will send information to relevant municipal departments about the necessity to deploy salt spreader trucks in the streets.
- Public Transport System - public transport systems (trams, buses). The system receives complete information about the location of all means of public transportation. In the case of an emergency, ambulance or fire department emergency vehicles receive the highest priority along the fastest route.

In comparison to traditional solutions, transport telematics systems offer the possibility of a much broader and more comprehensive impact on the situation on the road, including safety. Traditional messages on the road (e.g. road signs, warning signs) interact only locally and have an impact on the situation only in their immediate vicinity, and thus are limited by sight range and perception of drivers. In addition, traditional road signs are located permanently at a specific road location, and their message is constant, no matter what happens at the particular time on the road, regardless of whether the situation is really dangerous or not. Traffic participants develop habits resulting in insufficient attention to the content of these signs.

Intelligent systems operate in a different way. They cover a large area of the road network with its operation (ideally the entire network), and therefore, also the area beyond the perception of road users. Intelligent systems continuously monitor the road situation on a vast area, processing the data on many factors, which drivers would not be able to analyze because of the selectivity of perception, concentration on driving and the limited range of vision. Intelligent systems provide information normally inaccessible to the driver, while relieving him from the tasks associated with an analysis of the situation and responding to the current developments in the traffic. It is precisely in such circumstances, that the ITS is providing drivers with messages about the situation on the road, providing guidelines for behavior at a given time of continued driving. In addition, ITS facilitate driving and attention to cockpit instrumentation, and in specific cases, it takes partial control over the vehicle.

As far as impact on road safety is concerned, ITS can be divided into two groups: systems designed specifically for safety that reduce the risks on the road in a direct way and systems designed for other purposes, of which the impact on road safety is secondary and indirect. Examples of such direct systems are: accident detection systems and warning systems, which deploy information signs of variable content (e.g. indicating the speed limit, detour, closed lanes), systems detecting violations of law and enforcing law, electronic driver's licenses, an automatic speed surveillance and entry control at a red light, intelligent speed adaptation systems, detection, warning and management of accidents and emergency situations, anti-alcohol ignition lock, etc. Examples of indirect systems are those that improve traffic flow (including automatic toll systems), systems managing traffic and giving priority to public transport, freight transport monitoring systems and information services for travelers, which allow planning a safe route and travel hours.

Road safety depends greatly on the behavior of people: adjusting the driving speed, avoiding driving under the influence of alcohol and other drugs, applying safety measures reducing injuries (especially safety belts, child safety seats and helmets). These three factors have an impact on both the prevention of accidents (accident risk) and their consequences. Therefore, one of the purposes of the application of telematics is to eliminate dangerous behavior.

Another aspect of the use of ITS addresses the increase of traffic hazards related to the gradually growing phenomenon of road congestion. In the last 30 years, the number of cars on the roads has increased almost threefold, and further dynamic growth is observed while the population remains at a similar level. This means that more people are actively involved in road traffic; thus, a higher percentage of the population is exposed to road traffic accidents.

Traffic safety on the road depends on an individual. The behavior and reactions of people are decisive factors in avoiding the threat in a particular driving situation. The task of intelligent transport systems is to support drivers and enable them to make the right decisions and encourage them to observe laws and safety rules. With this in mind, it is worth paying attention to two issues: improving the safety of the road infrastructure and the introduction of safer vehicles.

In the case of introduction of safer vehicles, it is estimated that advanced on-board information systems and advanced driver assistance systems make it possible to improve active safety and reduce fatalities by up to 50%. These include systems for maintaining spacing between vehicles, collision avoidance, lane keeping and visibility in the blind spot, improving visibility in poor conditions, navigation and route guidance. Implementation of ESP - electronic stability program - in vehicles is being promoted. This is an electronic circuit that stabilizes the car path during cornering and takes control over interconnected systems: ABS and ASR. The system activates itself and brakes one or more wheels as soon as its sensor detects a tendency to lose grip of the vehicle's wheels.

No less important aspect of security is a feature commonly referred to as the system security. This means that an intelligent system should be technically reliable, and if a failure occurs, it should proceed in a manner that allows the driver to control the situation without further problems and without creating new dangerous circumstances on the road. It is important to protect telematics systems themselves against the creation of new hazards in traffic on the roads. In the case of failure of an information system or a driver support system, the vehicle should be able to continue driving, which excludes the dependence of the car basic systems on the equipment of secondary importance. It is equally important that when a fault occurs, the driver immediately receives a message about system failure and is informed of its consequences for further driving. This will avoid confusion of a driver unaware of the failure and making wrong assessment of the traffic situation.

On-board equipment must be constructed and arranged in such a way as not to interfere with driving and not divert attention of the driver from the road. At the same time, the instruments have to be fully functional to provide immediate support to the driver in an emergency situation.

System security is a very important aspect because intelligent systems show a constant tendency to increase in complexity. In addition, the vehicle can simultaneously use different devices and their collaboration takes place under a single-board system, which raises the issue of compatibility and interdependence of functioning. In the field of ITS, the following rule applies that well with the increase in complexity of the system increases its reliability.

In turn, traffic and speed management largely contributes to improved safety of road infrastructure. The main cause of accidents is an impossibility to adjust the driving speed to the situation on the road or lack of adequate information about the threat. Conventional speed management on the road usually involves enforcing the speed limit through the formation of road and shoulder sections and traffic organization. Telematics systems offer an alternative and cheaper solutions, such as automatic speed supervision, intelligent speed adaptation and speed management through variable message signs.

ITS can also give the possibility of proportional allocation of costs for the use and exploitation of road infrastructure, mostly funded by taxpayers' money, by charging expenses to its real users through the automatic toll collection. On the other hand, travel information systems can effectively promote intermodality between private transport and different means of public transport. ITS also allows for the gradual optimization of freight, both in terms of the more efficient use of rolling stock and of more precise control of work conditions and behavior of truck drivers, which have a significant impact on traffic safety.

3 Traffic Management Systems

The main task of traffic management systems is to control vehicle traffic in the "working" states by rapid responding to all changes in the traffic processes.

In the process of traffic in the city, one can distinguish sub-processes taking place at different time horizons. Thus, there are relatively fast processes related to current decisions when driving over a distance of a street or intersection (e.g. the choice of lane at the inlet junction). Slower processes are associated with the choice of alternative routes to the destination as well as finding free parking spaces. The slowest processes are related to the decision to travel, including the choice of means of transport. With a process decomposed in such a way, one can associate means of controlling it. Furthermore, one can distinguish operational management, tactical management and strategic management.

Operational management is a direct impact on the traffic for its widely understood stabilization in a working range. The stabilization will consist of regulating any deviations from the desired value, primarily through the traffic lighting. This action applies not only to passenger vehicles, but also to public transport, in the case of deviations from the timetable, and to freight. By compression of motion (variable message signs) and by reducing traffic speed, the oversaturation is prevented. Variable message signs are also used for dynamic allocation of lanes to traffic direction and to means of transport. Control with the traffic lights involves parameters of the control cycle, i.e. lengthening or shortening the cycle (in particular, the double cycles or half cycles), changes in offsets and splits, as well as the sequence of signals, including a double "lighting" in the cycle.

The existing operational approach to traffic control can be divided into constant-time control, adaptive control and hierarchical control. The most widespread systems are the constant-time control systems with rigid coordination (e.g. a "green wave") operating in an open array and implementing multi-program control plans, which involve switching the signaling plans, monitoring the state of traffic and signaling. Their feature is low adaptability.

Tactical traffic management means a direct impact on decision-making process of choosing the route. Direct impact on traffic within the tactical management system is achieved by informing drivers and passengers at stops, with the use of external tables with variable content and navigation systems inside vehicles about alternative routes to reach their destination and to available parking.

Indirectly, on the level of tactical traffic management, the control is accomplished by managing the cycle length, offsets and splits, and the sequence of light signals to prevent blocking the sections of streets and intersections and ensuring adequate and optimized coordination of traffic.

Support for the main traffic, application of priority over local traffic, is primarily used to maintain the coordination of major groups of vehicles and priority for collective transport vehicles.

Strategic management is used to directly influence a decision sub-process related to the movement and choice of modes of transport by supplying transport information, mainly with the use of mass media. Indirectly, strategic management influences the tactical level by setting appropriate criteria and constraints for optimizing the coordination of movement, by preferring public transportation as well as the operational level of management, influencing the parameters of control signals to achieve a desired priority. Increasing the use of public transport usually results in reduced network congestion, since it is often less area-absorbing in relation to individual vehicles, and, thus, lowers the concentration of traffic.

Of all the Polish cities, so far, traffic management system has been implemented only in Poznan. Other cities - Warsaw, Krakow, Wroclaw and Łódź - are in the process of implementing the first stage of traffic management system. Tricity developed a detailed concept of integrated traffic management system (TRISTAR) and proceeded to the phase of contractor works. There is, therefore, a significant improvement over the prior state a few years ago, although, as usual, it is unsatisfactory.

4 Bus on the Phone

One of the problems of modern cities is resignation by inhabitants from collective transport and shifting to their own means of transport. This disadvantageous trend leads to more congestion on streets and increased pollution. However, the choice of cars as a means of transport is not always a free one. The residents of new settlements located far from the center do not have the choice, since public transport does not operate that far, or is very limited (e.g. several runs a day at peak times). An example solution to this problem is in Krakow, where telebuses, i.e. buses on the phone, were introduced.

Telebus is a service created for people living or working outside the city center, where regular urban transport rarely or does not reach at all. Telebuses do not have any traditional timetable, and their routes and schedules depend on customers' current needs. Passengers can individually determine the time of departure or destination of the carrier, and the location of an initial and final stop. Passengers have at their disposal two telephone numbers - for land-lines (free of charge) and for mobile phones. Telebuses were introduced in Krakow as one of the actions undertaken within the project CIVITAS CARAVEL. The telebuses use the same types of tickets as the regular urban transport.

5 Bus Rapid Transit

Bus Rapid Transit is the name referring to various public transport systems using buses. BRT systems, i.e. bus rapid transport, provides more efficient, more reliable service and of better quality quality than ordinary buses.

The purpose of BRT is to provide quality of service similar to light rail transport at a lower cost of investment and the flexibility of bus transport. This goal is achieved through the improvements introduced in the existing infrastructure or by applying the elements of new infrastructure and by adapting rolling stock. BRT buses are granted higher priority by moving on detached bus lanes in the streets - they may also run in mixed traffic.

BRT systems are characterized by:

- reliability, and shorter travel time,
- integration of infrastructure and vehicles to ensure the comfort, quality and access,
- reliable information for passengers about the departure time of next bus.

BRT systems may include complex projects for the entire network or they can only affect the priority at selected intersections. They can also make special priorities in selected transport corridors, such as a dedicated path and a guided bus way.

6 Bus Passes

Bus passes are dedicated lanes for public transport vehicles. Bus passes should be seen by other road users as separate tracks, which cannot be used by vehicles other than the authorized ones. The key issue in the effective functioning of bus passes is the observance of the rights to drive on them. Because such a rule is not always effective, often an automatic control of bus passes is implemented. The method of control, without its limitation of personal checks and is definitely cheaper, is the application of automatic monitoring of traffic in the lanes.

The monitoring of lanes uses the technology of automatic number plate recognition. This technology involves the use of stationary or mobile camera points. This system can be supplemented by several mobile points installed in special vehicles. The automatic monitoring system recognizes license plates of all vehicles traveling in the bus lane and sorts them into authorized and unauthorized ones. In the case of unauthorized vehicles, their data is sent to the penalty ticket center, where penalty tickets are issued.

Such monitoring systems shall be equipped with additional functions, such as an instantaneous and segmental speed measurement of public transport vehicles or an analysis of traffic flow and structure of flow on the bus lane.

Bus-pass lanes can be equipped with separate traffic lights, enforcing priority for the buses at intersections.

7 The System for Classifying and Weighing Vehicles

The system of vehicle classification allows counting the passing vehicles and classifying them according to their speed and length. In order to measure these parameters, two inductive loops need to be installed on each traffic lane. Vehicle classification system consists of a processing module and data-recording module.

The system of automatic weighing of vehicles in motion carries out a series of measurements of the weight of the vehicle, without affecting their safety and driving behavior. The system consists of a combination of the connected weighing plates built in the road surface, including special analyzing devices. The system allows the production of road statistics and detection of, and response to, violations of the permissible weight limit and the use of GSM mobile telephony or other networks, that allow its remote operation and management.

Depending on its configuration, the system can:

- measure the pressure per wheel / axle of the vehicle,
- measure the total mass,
- classify vehicles in terms of length and weight,
- measure the spacing of vehicles in meters or seconds,
- measure speed,
- generate statistics,
- process and transmit data,
- generate alarms.

The task of the system is to detect overloaded trucks and notify the road transport inspectors on duty at the measurement points, in which certified weighing scales are installed. The system can display on a screen (fixed or mobile) the data of the vehicle, allowing its identification (photo, registration number, type, weight).

Currently, the following statistics are provided by the system:

- traffic intensity depending on the time and type of vehicle,
- average speed of vehicles depending on the time and type of vehicle,
- structure of transit and local traffic depending on the time,
- number of vehicles with a given total weight depending on the time,
- individual axle loads depending on the time.

8 City Card

City card is a modern and multi-functional medium for electronic products and services resembling the format of an electronic payment card. The benefits of using a city card are: traceability in the case of lost or stolen cards, widespread availability of electronic sales points, the ease and convenience of using the card, security of transactions, versatility and durability of the card and the ability to implement new services with it. The following towns decided to introduce the city card: Warsaw, Wrocław, Gdańsk, Kraków and Rybnik.

Introduction of a city card system will simplify payment for collective communication and payment of other municipal services. The electronic City Card of the town of Rybnik is unique in the country and is very innovative. Besides paying for travel, it allows paying for a range of municipal services - entrance to the swimming pool, parking fee and other municipal fees. The same card can serve as a carrier of the electronic signature as well as facilitate electronic means of arranging procedures in the city hall.

Also, the town of Katowice Silesian Public Services Card, besides paying for public transport tickets, aims to implement electronic public services and support the management of public administration. The main idea of the project is to build a system of cashless collection and settlement of payment for public services provided by local governments, and at the same time, to provide the information system that enables the collection of demand data for individual services. The card will serve also as an ID of the holder.

9 Park-and-Drive System

Park and drive is the system of parking facilities for people, who commute by car from distant suburbs and use public transport. The drivers leave their vehicles at designated places and shift to public transport to travel to the center of town. Parking facilities of that type are designed to receive the largest possible number of vehicles driving to the center of town and encourage the drivers to take advantage of the offer of collective transport. It is assumed that the driver of the vehicle parked there (as well as his or her passengers) will continue, free of charge, the journey with public transport, based on a parking card.

Parking facilities of this type have functioned long ago in other countries. In Polish conditions, this solution is rarely used. Repeatedly, there were attempts to implement a similar system, but it was often quickly "shut down". As a major cause of the system failure, it was indicated that the parking facilities were located too close to the city center; therefore, they were used as targets rather than the interchange ones.

The idea is worth coming back to, with the application of modular parking systems (moving platforms reminiscent of Rubik's cube). The advantage of modular parking systems is that they occupy relatively little space and, depending on demand, may expand. The essential argument for such a solution is that it is often designed as a self-service system.

Taking into account the features of each city in terms of buffer parking, one should consider the arrangement of parking facilities on the outskirts of the agglomeration, which will reduce the number of vehicles entering the center. The use of such a solution will also significantly reduce personal car traffic in the cities. It shall be noted that with these systems, there must exist a correlation of collective transport, and from the perspective of the efficiency of the whole system, the entirety must be equipped with adequate passenger information system.

Recently, Warsaw returned to the idea of Park and Ride. The main objective of the project of a parking network is to reduce traffic in the center of the capital, which will reduce traffic congestion, lower emissions and improve the circulation of public transport. Parking will be free of charge for those transferring to public transport. The operator has introduced regulations specifying that the user of the parking facility is required to purchase a minimum day ticket. As the result, it is not financially viable to use the parking occasionally, for a shorter stay period.

10 Variable Message Signs

For a long time now, there exist some popular solutions of information signs with a variable content.

Effective collection of meteorological data and their use in traffic control, with the help of variable information boards and signs, influences the fluidity of movement in relation to road conditions and weather conditions. The correct interpretation of meteorological data is closely related to the implementation of algorithms for dynamic speed control and the systems delivering information to the drivers about the various situations occurring on the roads.

Variable message signs can be made in different technologies; however, the most widespread technology is LED, due to possibility of using the full palette of colors at the highest brightness thresholds. At the same time, the design of the matrix displays allows showing any shapes - symbols, signs and text characters.

These devices inform the drivers mainly about weather conditions and speed limits. Recently, their application extended to the control of motion in the lanes, informing about current traffic conditions (e.g. emergencies) or about detour possibilities.

The use of variable message signs improves traffic safety of vehicle drivers and facilitates the effective management of traffic. In an effective way, it affects the behavior of the drivers, who receive the current data about road works, diversions, or the speed limits. Information is presented in a clear manner in the form of short messages to allow for quick responses, and thus to allow the drivers to adapt to the conditions currently on the road. The use of variable message signs improving traffic flow, thanks to central control and informing about free parking space, directly affects the comfort of travel. It also allows the achievement of real influence on the efficient transport management in urban agglomerations.

LED information boards, in a readable way, represent the recommended directions of movement for vehicles in the most dangerous locations, that generate an increased number of vehicles.

Another type of variable message signs are the signs using the panel technology. They use the colors and the symbols of ordinary road signs, while the difference lies in the control mechanism. At any given time, depending on the needs, one road message is shown on them.

11 Passenger Information

Passenger Information System is one of the more important components of modern collective transport. It was created to reduce the involvement of passengers in their search for information, to save time and increase convenience. Until recently these were paper timetables. Traditional ways of informing passengers are replaced by more convenient, efficient solutions and with greater range and extent of information delivered. Good passenger information system is one that, using several media channels, provides passengers with an easy and fast access to information in all places, where such information may be needed while traveling.

Passenger information system allows a quick delivery of information with the use of video and audio to any place where the passengers are located. The main components of the system are:

- aggregate timetable boards with departures and arrivals,
- information boards on platforms or departure bays,
- clocks.

The aggregate timetable is usually placed in the main hall of the station and is the first point of information for the passenger. It provides information about the hours of departure, arrival, line number and bay number from which the vehicle departs. The approaching departure time may be distinguished in an additional way. At the individual departure bays, there are mounted boards presenting data relevant to the passengers at a given bay, e.g. the bay number, the route and departure times. The system of boards can be extended with television monitors in order to provide aggregate information in locations, where the boards are not installed and where lots of passengers reside, i.e. restaurants, lounges, passenger service rooms, etc.

The clocks are installed indoors, consisting of LED modules, the clocks outdoors consist of seven-segment electromagnetic indicators or LEDs. The time indicated by the clocks is synchronized with the reference atomic clock. Since information about the departures is also important for drivers, it is possible to mount aggregate information boards and the clocks at the parking facility for vehicles or even at each parking spot.

12 Toll Collection System for Entry to the City Center

In the process of dynamic growth in the number of vehicles in the urban areas, the likelihood of traffic congestion increases. It is also a consequence of the lack of expandability of the existing urban road infrastructure. As a result, streets and intersections are losing their throughput capability and the transit time increases.

Towns take various measures to reduce congestion, among other things, they introduce restricted access zones, designate bus lanes or separate tracks. These are good solutions if they go along with public transport development and construction of parking facilities. To improve the situation of communication, technical solutions are also used, such as optimization of traffic lights or speed management.

An example of administrative solutions is the system of collecting fees for entering the city center. Such a system should be flexible to assure appropriate throughput of vehicles. Municipal toll systems cannot rely on gates (they slow down the traffic) or subscriptions, which are not always respected. Therefore, automatic electronic toll systems are introduced that recognize and classify vehicles.

The first in the world was Singapore, where a set of solutions known as the "Area Licensing Scheme" was introduced in 1975. Its component was a toll system for entering the central zone with an area of 6 km2. Fees stipulated in the system were in force only in peak hours, but later, became mandatory throughout the day (from 7:30 to 18:30). For a single-entry, the fees were not high, but they had to be effected before entering the area by purchasing a printed-paper authorization valid for a day or month. Originally exempt from the fee were large groups of vehicles, including vans, taxis and vehicles carrying more people. Then the restrictions have been tightened - now only buses and emergency vehicles are exempt from the fee. The impact of introducing fees on the traffic was great - it decreased by more than 70%. After the fees were extended to the whole day, traffic was reduced by a further 9%. In the second half of the 1990s, the zone was stretched to include inner-city sections of expressways, to which the traffic moved to bypass downtown. As a result, on the routes freed from the "traffic jams", the speed has increased more than double. At the end of the last century, the automatic toll collection system was introduced. All vehicles are equipped with a special electronic card reader, which is automatically identified at the road gates and the amount contained on the card is automatically reduced by the toll. Automation has enabled differentiation of fees according to the time and place, that is, the actual contribution to the congestion. During hours of operating the system, a decrease in the number of vehicles and an increase in the average speed was observed. Of course, these changes do not meet massive applause from the drivers. Also, a negative impact was observed on the streets, where the toll was not applied.

In 2003, in London, a fee for entering with a car to the central part of town was introduced, known as "congestion charges" (i.e., for contributing to the formation of traffic jams). The idea to introduce tolls to drive downtown is based on the observation that if people pay for any goods or services directly, they are less inclined to use them lavishly. By introducing fees, London authorities aimed at:

- reduction of congestion,
- radical facilitation of bus traffic,
- increase in certainty about the duration of travel,
- increase in efficiency of downtown cargo handling.

The London system used advanced computer technology from the start. Control takes place via automatic license plate reading from the images taken with the cameras installed on the outskirts. In London, the daily cost of entry is much higher than in Singapore (discounts are applied for monthly or annual fees). The fee is applicable from Monday to Friday, from 7:00 to 18:00. The fee shall be effected on the day of entry via the website, SMS or in selected stores (Pay Points). One can also pay for the entrance on the next day, but then the price increases. Later, the penalty tariff is applied and incremented with the period of delay. Companies are offered the opportunity to register their vehicles in the Board of Transportation, so they can pay the fees "from the bottom". Free of charge are city buses, minibuses with more than 9 seats, taxis, ambulances, police cars, fire brigade, motorcycles, small tricycles, vehicles powered with alternative fuel, vehicles of persons with disabilities and the inhabitants are entitled to 90% discount.

An example of a similar solution is the toll collection system used in Stockholm. The system is an administrative solution, since the entry fee is a form of an environmental tax for congestion imposed on all vehicle owners, who move into the city center. The system covers the whole city center. At the entrances to its area, the checkpoints are installed, which, automatically, without stopping, record the entry and exit of vehicles. The control gate is equipped with a detector and cameras recording registration plates on the front and rear of the vehicle. The information about the vehicle and the time and direction of travel are transferred to the control center and, on the basis of this information, the charges are calculated. They are differentiated - the highest are during peak hours, whereas night journeys are free of charge. The drivers can check the status of fees charged on the website and they receive a summary account every month. It is estimated that the return on investment will take place after four years of operating the system. The profits after that time will be invested in road infrastructure.

Foreign experience allows to conclude that toll systems are one of the better ways to reduce traffic in city centers. Regarding Poland, the solution is proposed by Kapsch company (which also administers the system of electronic toll collection on motorways and fast roads). As far as urban application is concerned, the company proposes several variants of the toll: for driving within the designated area, for entry into the area, for driving a given route, for using infrastructure (e.g. parking). Where it is necessary to restrict access to certain areas in the city (e.g. Old Town), it is possible to use the system of automatic number plate recognition to grant access to the zones only to specific vehicles. Another possibility is to equip a car with an on-board unit.

Displays with LED technology indicating the direction of travel are provided for buses, trams and trains. Installed in or on the vehicle, they provide optimal visualization of travel destination to passengers and they can provide additional information. Displays and other peripherals in the vehicle can be operated with the controllers and on-board computers.

Among the displays at bus stops, there are two types: the countdown and matrix ones. Countdown display is suitable for a fixed-line route. Among the displays, they are distinguished by a low cost of investment in the dynamic passenger information system. Matrix display can be adapted to local conditions and the displayed information can have a variable content.

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Value of Networking in Transport Policy Related to the Road Safety

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Abstract. The paper describes the current situation in the area of European road safety and draws attention to the adverse developments in several Central European countries. It presents the approach of European SOL project in relation to the actual Slovakian national road safety plan for the period 2011 – 2020. It underlines the added value of networking and contains recommendations for building multi-stakeholder partnerships for road safety at the national and community level.

Keywords: road safety, networking, national plan, strategy, project.

1 Introduction

The degree of road transportation and motorization is constantly increasing. Apart from the undoubted advantages, it causes a heavy loading of the road network and constantly increasing demands on the traffic and its safety. The road safety is actually not only an important traffic and social issue but also an economic one.

There is universal recognition of the tremendous global burden resulting from road traffic crashes, and that the road traffic injuries constitute a major but neglected public health problem that has significant consequences in terms of mortality and morbidity and considerable social and economic costs. According to the WHO and the World Bank [1], a multi-sectoral approach is required to successfully address this problem. While the number of deaths and seriously injured people is falling, studies have shown that faster progress is possible if all effective means are applied (ETSC, PIN 2010).

Road crashes and the road crash injury are no longer seen as "an inevitable outcome of road transport" but rather as "largely preventable and predictable". A core component of this "new paradigm" is the recognition that the road safety is a multi-sectoral issue and a public health issue – all sectors need to be fully engaged in responsibility, activity and advocacy for the road crash injury prevention. A good infrastructure and vehicles must be complemented with commonsense everyday human behaviour and effective trauma care services.

2 Road Safety in Europe

Some 80% of Europeans live in cities. European cities are suffering heavily from the congestion, high levels of pollution, noise, and road crashes, largely caused by

J. Mikulski (Ed.): TST 2011, CCIS 239, pp. 70–77, 2011.

excessive use of private cars. The road strategy depends greatly on how communities choose to manage their transport systems in relation to their overall health and safety objectives and how they are balanced with economic, social and environmental considerations. The growing trend away from the public transport, walking and cycling towards a motorized transport has marked a move towards modes and means of transport that pose comparatively higher costs to society economically, environmentally, and in health terms.

In 2007, for the first time since 2001, the number of people killed on European roads has not decreased in comparison with the previous year [2]. The situation differs between countries.

In Western Europe the number of road traffic fatalities declined in 2007 by 1.2%. However, this decrease was accompanied by a rise in both the number of casualties (+1.4%) and the number of accidents (+5.6%). This data is strongly influenced by the performance of Turkey which has shown significant increases in all three indicators. In 2007, only the United Kingdom and Greece recorded drops in the number of fatalities, casualties and injury accidents. At the same time Denmark, Finland and Sweden have seen their road fatalities increase by 32.7%, 13.1% and 5.8% respectively.

Table 1. Road fatalities in Western Europe [2], [11]

Western Europe	Number of fatalities			
	2007	2009	2007/2006(%)	2009/2008 (%)
Austria	691	633	-5.3	-46
Belgium	1 067	955	-0.2	11
Denmark	406	308	32.7	-88
Finland	380	279	13.1	-94
France	4 620	4262	-1.9	-12
Germany	4 949	4154	-2.8	-313
Greece	1 578	N/A	-4.8	N/A
Iceland	15	N/A	-51.6	N/A
Luxembourg	43	47	19.4	12
Malta	12	N/A	9.1	N/A
Netherlands	791	720	-2.5	20
Norway	233	214	-3.7	- 42
Portugal	854	747	0.5	- 39
Spain	3 823	N/A	-6.8	N/A
Sweden	471	355	5.8	- 41
Switzerland	384	312	3.8	-45
Turkey	5 004	N/A	8.0	N/A
United Kingdom	3 059	2222	-7.2	-316
TOTAL	**28 380**		**-1.2**	

In Central and Eastern Europe the number of road fatalities increased by 6.4% in 2007. This result is all the more disappointing since the region recorded at the same time strong increases in the number of casualties (+6.4%) and in the number of accidents (+6.7%). With the exception of Bulgaria, Estonia, Hungary and Lithuania, which show a drop in road fatalities, casualties and injury accidents, all other countries have been confronted with a rise in the number of fatalities on their roads.

Table 2. Road fatalities in Central and Eastern Europe [2], [11]

Central and Eastern Europe	Number of fatalities			
	2007	2009	2007/2006 (%)	2009/2008 (%)
Albania	384	N/A	38.6	N/A
Bulgaria	1 006	901	-3.5	-160
Croatia	619	N/A	0.8	N/A
Czech Republic	1 222	N/A	15.0	N/A
Estonia	196	100	-3.9	- 32
Hungary	1 232	822	-5.4	-174
Latvia	419	N/A	2.9	N/A
Lithuania	740	370	-2.6	- 128
Poland	5 583	4572	6.5	-865
Romania	2 794	N/A	12.8	N/A
Serbia	962	N/A	6.9	N/A
Slovakia	661	374	8.7	- 184
Slovenia	293	174	11.8	-43
TOTAL	**16 284**		**6.4**	

While many western European countries are making continuous progress in reducing the number of lives lost, fatality rates in many Central Europe countries remain high and in some they are even increasing. In the area of Central Europe the number of road fatalities increased by 6% in 2007. With the exception Hungary, which shows a drop in road fatalities, casualties and injury accidents, all other countries have been confronted with a rise in the number of fatalities on their roads. Countries like the Czech Republic and Ukraine saw their fatalities increase by 15% and 38.1% respectively.

According to the International Transport Forum (OECD, 2008) "Central and Eastern Europe both show significant increases in fatalities. Rapid motorization is a factor in the region but the figures show the lack of continuous and determined political effort in these countries".

Central Europe clearly shows a higher number of road fatalities per million inhabitants than Western Europe. Within Central Europe, the highest value is observed in Poland (143 road fatalities per million inhabitants), followed by Slovenia (129), Hungary (128) and the Czech Republic (126) compared to Italy (96), Austria (88) and Germany (62).

In Central Europe the road safety challenge has reached a magnitude that even puts the overall competitiveness, the attractiveness as location for working and investments as well as the quality of life in the most seriously affected parts of the cooperation area at a considerable risk. Road crashes have a severe negative impact on the social and economic situation in these countries, costing up to 2% or more of the GDP.

2.1 Current Situation in Slovakia

In the past few years Slovakia has adopted a series of legislative measures to reduce the burden of traffic accidents and life losses. As far as the road accident rate is concerned, it was positively influenced by the adoption of Act No. 8/2009 Coll. on Road Traffic and of the implementing regulation No. 9/2009. According to the information from the Police Headquarters, the change in this indicator is rather short-term. Evolution can be assessed positively thanks to the fact that the road-crash fatality, the number of road accidents, the number of lightly injured and the number of seriously injured dropped down. The only parameter not following this positive trend was the number of the accidents caused by drunken driving.

An important document, that was the basis for the introduction of several successful actions, is the National Plan for Increasing the Road Safety for the 2nd term of 2005 with the Outlook by 2010. The plan referred to the ambitious "Road Safety Action Programme" which aims to halve the number of road deaths in Europe in the next decade and consisted of a detailed analysis of the actual development of road traffic accident rates, experiences with the implementation of measures in the past and also contains measures for the individual departments in the following fields: A. vehicle safety, B. road safety, C. traffic education and culture, D. health education and traffic psychology, E. traffic safety legislation, F. traffic safety and traffic fluency control, G. promotion in media, H. national coordination, I. international cooperation.

The National Strategy Action Plan for the Road Safety by 2020 is being drafted now, that will be focused mostly on developing data systems, improving safety-conscious planning and construction of roads, promoting public awareness of risk factors. It calls also for activities to reduce the work-related road traffic injuries and graduated driver licensing programmes for novice drivers.

Reducing the number of fatalities due to road traffic accidents (the death within 30 days since being involved in the accident) by half by 2020 compared with the reference year 2010 is considered the main numerical goal of the national plan to increase the road safety in Slovakia. The main cross-sectoral objective is to continuously improve standards of road safety [3].

The plan contains 9 framework objectives which are classified into three main areas: Human Factor, Safety of Road Infrastructure, Vehicles and Intelligent Transport Systems. These are divided into 23 areas of implementation measures and organized in more than 88 individual tasks. Experts from various departments will cooperate on fulfilment of the tasks with the Council of the Government of the Slovak Republic for Road Safety (BECEP) – the leading road safety agency in Slovakia. By their implementation an important decrease of the causes and negative consequences of traffic accidents in Slovakia should be achieved.

There is a need to build stakeholders' commitment due to a cross-sectoral nature of the programme.

3 Multistakeholder Partnerships

It is an important aim to improve the quality of life for citizens and communities by preventing road crash, road trauma and economic loss. One of possible approaches is to generate a continuous cooperation among different levels of administration on the one hand, and different local entities on the other, to build up a Network made of vertical and horizontal connections.

Relevant stakeholders should include different sectors of society – the government, business, civil society – and relevant areas within the government – including health, transport, roads, education, justice, finance, tourism, labour and environment. In addition, different levels of government – national, state and municipal – share responsibilities for coordinating the road crash injury prevention within a country.

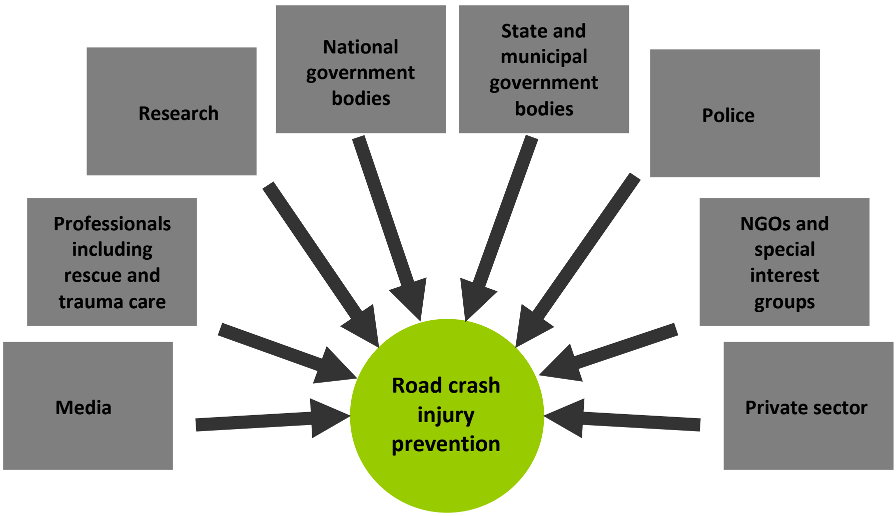

Fig. 1. Types of stakeholders that can support road crash injury prevention efforts

Multi-stakeholder partnerships that bring together different sectors and disciplines within the framework of a targeted "safe system approach" offer the greatest possibility of innovative, comprehensive and sustainable solutions to the road crash injury prevention. This partnership can unite working teams around the main risk factors in road crashes and road crash injury – from the highest levels of government to local schools and villages — toward sustainable, locally-owned and managed solutions.

Benefits and opportunities generated by the collaboration could be numerous, including:

- building synergies and reducing overlaps in activities and expenditure,
- ensuring that programmes are in the public interest as the opinions of many stakeholders are incorporated,
- stronger more comprehensive programmes that have a broader geographical scope and an increased chance of impact,
- improved stakeholder relations and improved stakeholder knowledge that provide long-term benefits for them,
- increasing community sustainability as different partners share responsibilities for the implementation and funding.

Multi-stakeholder partnerships for the road safety can have diverse objectives. They can bring stakeholders together to develop and implement a comprehensive intervention on a single issue, such as seat-belts and child restraints. They can also bring stakeholders together to plan, monitor and evaluate a comprehensive multi-issue road safety programme. They can function for a limited time – such as for a single project – or longer term – such as to coordinate a multi-year single issue intervention or programme. They can be formed at different levels of government – national, regional and municipal. In all cases, they should be guided by a lead government agency in charge of overseeing the road safety that will have the ultimate authority to act on recommendations of the group.

At the national level, a multi-stakeholder partnership may have the primary role of discussing and advising on policy issues and providing guidance, resources and networks to assist projects at the regional and/or municipal level.

Regional and especially municipal level partnerships may be more operational. They can bring stakeholders together to design targeted multi-stakeholder programmes that are in line with the national policy objectives and monitor and evaluate progress.

3.1 Networking in the Context of the SOL Project

SOL is a project co-financed by the European Programme of Territorial Cooperation “Central Europe” (CEE). It represents a significant regional road safety programme and it will contribute to the global road safety with critical knowledge, experience and tools. This project involves 8 countries of Central Europe: Germany, Italy, Austria, Slovenia, Poland, Czech Republic and Hungary. Project partners from Poland are ITS - Motor Transport Institute (“Institute Transport Samochodowego”) and WORD OLSZTYN – Regional Road Safety Centre in Olsztyn (“Regional Centrum Bezpieczeństwa Ruchu Drogowego w Olsztynie”). The project aims at giving professional qualities, experiences and tools to local public administrations to increase the road safety in their competence areas. Its planed activities are described in Fig. 2.

The SOL is linked to a global work – it seeks to assist communities in the area of Central Europe (CEUS) implementing the main recommendations of the World report on the road crash injury prevention (The World Bank), including an overall increase in political commitment towards the road safety, developing activities based on the evidence rather than “ad-hoc”, developing strategies and action plans, allocating resources to the main road safety risks, implementing projects, monitoring and evaluating impacts.

Materials and tools produced within the SOL will bring benefits to the road safety in the region and can inform and contribute to similar actions in other regions of the world. The SOL also brings significant and needed funding towards an increasingly deadly and common public health issue in the CEUS region and the world.

The Work Programme is designed to generate a continuous cooperation among different levels of administration on the one hand, and different local entities from different CEE Countries on the other, to build up a Network made of vertical and horizontal connections.

Fig. 2. Pyramid model of SOL project activities [7]

Firstly, a top-down input is required, as the SOL experts team must reach the local communities, recognize and choose the most active ones, in order to supply them with the necessary professional skills and tools to get the awareness of the focal issues concerning their own community.

Secondly, the local communities, once endowed with the above described skills and tools, will be fostered to get started a stable connection with the upper level in order to communicate the main discovered needs (also thanks to the skills built in the top-down stage) and get an active role in building an action plan and a consequent pilot action, with a bottom-up input. This combination of top-down and bottom-up inputs is going to create a vertical network made of interconnected realities, in permanent cooperation, sharing useful data and knowledge.

On the other side, local communities and the technical team are going to perform networking from a horizontal point of view, with local communities from different CEE countries, implementing a real transnational cooperation in the field of road safety, sharing data and successful practices in order to reduce the number of fatalities on the CEE roads.

4 Conclusion

Global, European and regional examples show that the road crash and the road trauma prevention can be sustainable. It is necessary to build on good practice experiences and to facilitate long term measurable improvement in the Central European Area by empowering local communities and local citizens with the knowledge, skills and networks they need to work to make their roads safer.

Many countries show similar weaknesses in dealing with the road safety issues on the political and technical levels. Political commitment, professional capacity and institutional structures are not robust enough to stem the growing number of deaths and injuries from road crashes. Therefore a transnational working approach is favoured in order to facilitate mutual learning processes that envisage a higher level of professionalism in dealing with this issue.

The government, business and civil society need to collaboratively and actively participate in programmes for the prevention of road traffic injury through injury surveillance and data collection, research on risk factors of road traffic injuries, implementation and evaluation of interventions for reducing road traffic injuries, provision of pre-hospital and trauma care and mental-health support for traffic-injury victims, and advocacy for prevention of road traffic injuries. The role of networking and building multi-stakeholder partnerships seems to be crucial.

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Cloud Drive: A Computing Architecture for a Scalable Driving Safety Management System

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Abstract. In Japan, taxi, bus, and cargo truck operation companies are required by law to commit to driving safety management. Driving safety management is achieved by a cyclic process consisting of collecting sensory information, assessing driving safety, and improving driving based on the results. At this time, this is performed by transport company personnel. In this paper, an architecture and its implementation for a scalable driving safety management system are proposed. The system consists of smart devices and services provided by a cloud computing infrastructure. The smart devices are connected to 3G wireless networks used to collect and send sensory information such as video image sequences, acceleration, and GPS data. The services available in the cloud computing infrastructure are a time-series sensory data storage service, image analysis service for driving assessment, and real-time feedback service.

Keywords: driving safety management system, software architecture, cloud computing, smart wireless devices.

1 Introduction

A transport safety management system program [1] has been in effect in Japan since 2006. It calls on railway, vehicle, maritime, and air transport operators to construct and continuously engage in safety management systems using the PDCA cycle, and is directed toward instilling a culture of safety and safety consciousness throughout transport operator organizations by national evaluation of the constructed systems.

At present, taxi, bus, truck, and other vehicle-related transport operators generally collect driving information using drive recorders [2] and perform safety assessments based on that information. This presents the challenge of finding effective methods

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for collection, consolidation, and evaluation of the huge volumes of driving information that are generated daily.

In this paper, we propose an architecture for a transport safety management system using smart devices and the cloud system, and describe its experimental implementation. The smart devices include a camera, accelerometer, GPS, and 3G wireless communication, which facilitates the development of applications for driving information collection. Collection and analysis of this information in the cloud system enables the use of higher level, more refined methods of safety assessment than those currently employed by the individual transport operators.

2 Cloud Drive: Development Objectives

2.1 Background of Development

Since the initiation of the transport safety management system program in 2006, transport operators in Japan have engaged in developing and deploying various forms and configurations for safety management. For taxi, bus, truck, and other vehicle-related transport operations, many of the operators have deployed systems using specialized terminals called drive recorders, which are specialized devices that monitor the state of vehicle operation with a small CCD camera designed to capture and record images of the vehicle surroundings in the event of hard braking, collision, or other impact [2]. The recordings include both accidents and hazardous circumstances in which no accident occurred. The safety management personnel of the transport operators use these recordings as a basis for provision of guidance on driving safety.

This methodology, however, is not without problems. A key problem is the difficulty of collecting the huge volumes of information generated daily by tens to hundreds of vehicles and applying it to assess degrees of danger. With drive recorders having no communication capability, the information collection involves great expenditures of time and labor. Assessing degrees of danger based on visual examination of the drive recorder information is particularly time consuming and costly. Feedback to the drivers is therefore slow, despite the recognition that rapid feedback is desirable for provision of effective guidance.

A second basic problem that may be noted relates to the current lack of methods for coordination of transport safety management systems among transport operators, requiring effort by each organization to separately develop their driving safety system. For small operators in particular, the cost of a specialized system and management specialists presents a high hurdle to system adoption and maintenance, and the information that can be collected is therefore limited. It is highly desirable to enable operators to transcend their corporate boundaries and share information relating to sites of frequent accidents and other factors for safe driving, as it would enhance the effectiveness of their own safety management.

We are engaged in the development of a Cloud Drive system, incorporating smart devices and the cloud system, for resolution of these problems.

2.2 Cloud Drive System Configuration

The smart device employed in the Cloud Drive is an in-vehicle device that provides a high-resolution camera, GPS, accelerometer, communication, and other functions in a small housing. It also provides a rich development environment, thus facilitating application development.

The information recorded in the course of driving includes video images captured by the camera, positioning by GPS, and accelerometer readings. The information is transmitted to the cloud system via a 3G network.

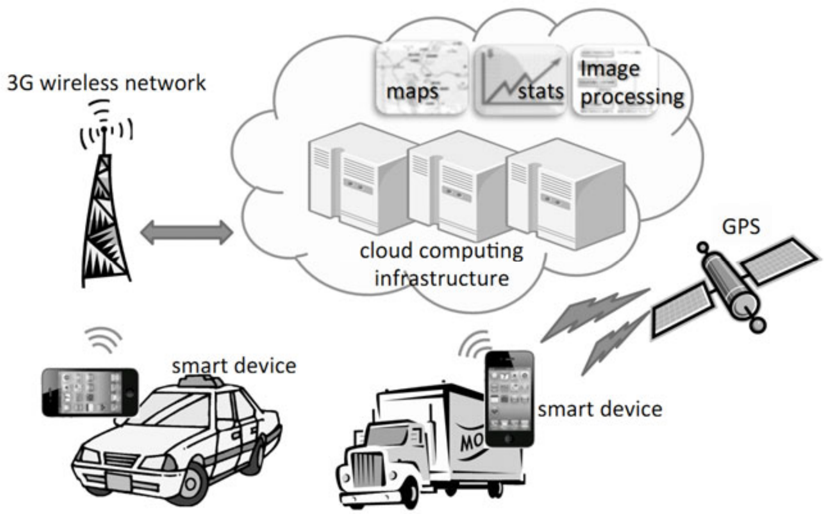

Fig. 1. Overview of proposed system

The information transmitted by the smart devices is collected in the cloud system, where it is used for automated driving assessment based on image processing, positioning, analysis of hazardous spatial and temporal zones, statistical information processing, and other purposes. In the Cloud Drive, the cloud system is utilized as the basis for their accomplishment and provision of the related services. Among other advantages, this enables flexible response to load increases accompanying a rise in the number of users. The consolidation of the information in the cloud system also enables analysis and assessment based on larger volumes of information volume and obviates the need for server installation and performance of these services at each operating site.

In this way, it is possible to achieve high-level assessment, with collation of information from various types of vehicles, comprehensive danger assessment, and safety information feedback in real time. In the following section, we discuss the architecture of the proposed system.

3 Proposed System Architecture

3.1 System Requirements

The requirements for the proposed driving safety management system are essentially as follows.

1. Accommodation of multiple analytical methods: Various automated analytical methods have been proposed for intervehicle distance estimation and traffic sign recognition from video image sequences captured by cameras in smart devices, recognition of hard braking and hazardous sites from information acquired by acceleration sensors, and other types of information [1–3]. New analytical methods and improvements are continually emerging, and it is necessary for the system to readily accommodate these in a modular fashion.
2. Accommodation of multiple assessment methods: In this system, various methods can be incorporated for objective calculation and feedback on the degree of driving safety by the driver, based on maintenance of intervehicle distance, incidence of hard braking, and other measurements, and it is necessary for the system to flexibly accommodate these methods.
3. Support of heterogeneity and limited computational resource of smart devices: Smart devices are rapidly evolving, with multiple models and versions that differ in performance levels and functions. It is therefore difficult to assume a particular performance level or technology in smart devices for operation of the proposed system.
4. Robustness for unstable communication environments: As the smart devices are used in vehicles, they may pass through areas outside the range of the 3G wireless network. For this and other reasons, it is necessary for the system to be robust to use in unstable communication environments.
5. Efficient access to multimodal, large-volume time series sensor data: A broad variety of video, acceleration, position, and other data simultaneously and seamlessly stream to the Cloud System from many smart devices, and it is necessary for the system to maintain operation without loss of use.

3.2 Layering Design in the Cloud System

On the client (smart device) side, the focus is on sensor data collection and transmission. Analysis is performed on the server (cloud computing system) side. This minimizes the processing requirement for the smart devices, which are limited in computation resources, and enables the performance of complex analytical processing without dependence on smart device type or version. Performance of the analytical processing on the server side makes it possible to add or modify the processing methods as necessary and to perform dynamic addition of new servers at any time in response to processing requirements.

The overall system functionalities are essentially as follows.

1. Cloud computing system functionalities
   Sensor data management, multimodal sensor data analysis, integrated assessment, notification and other message transmission, and automatic scale-out (not described in this paper) by dynamic server addition.

2. Smart device functions (not described in this report)
   Sensor data collection, compression, and transmission, and user notification.
3. Role of end user
   Installation of smart devices and applications, and applications operation.

In this report, we classify and hierarchize the services of the cloud computing functions (1 above) as shown in Fig. 2, with a description of each layer following.

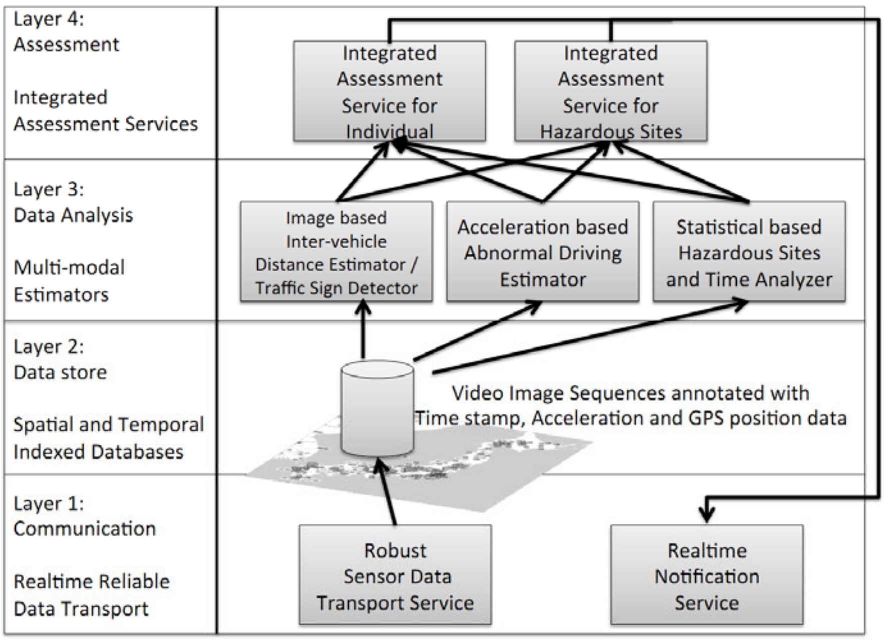

Fig. 2. Cloud driving safety management system layer (left) and its implementation examples (right)

Layer 1: Robust Communication for Smart Devices

This layer provides robust communication with the smart devices. The mobile communications environment of the smart devices tends to be unstable, and the image data and sensor information uploaded to the cloud system are often high in volume. A communication protocol that ensures this communication is therefore essential. A related requirement is the provision of a means of temporary storage and retransmission of data under adverse communication environments. On the cloud side, this is performed by the Robust Sensory Data Transport Service. It is also necessary to ensure delivery of driving safety information to the user from the cloud system. SMS (short messaging service), email, iOS device notification services, and other methods can be used, and the Realtime Notification Service plays the role of hiding the details from the upper layers.

Layer 2: Datastore for Time-Series Sensor Data

This layer performs storage of time-series data acquired from numerous smart devices and filtering for extraction of information required in the upper layers. Information obtained from the smart devices includes video image sequences, acceleration sensing, GPS longitude, latitude, and altitude, and electronic compass directions. This information is synchronized, integrated into a stream, and transmitted.

For the system to ascertain the driving state in real time, it is necessary to acquire the requested data with minimal delay by stream data processing. Statistical processing is also necessary, as the other analytical modules in the upper layers specify particular spatial and temporal zones, and extract information accumulated by numerous smart devices. For this purpose, it is necessary to include both a spatial index and a temporal index in databases for faster lookup of required data.

It is generally difficult to achieve a database system that can simultaneously meet the real-time data processing and spatio-temporal data-mining requirements. We therefore propose an architecture which meets each of these requirements with a separate database management system (DBMS) that feeds data from the lower layers as appropriate.

Layer 3: Data Analysis

The Data Analysis Service layer extracts high-level information from the information from the lower layers by image analysis, statistical processing, and other means.

Important information for objective driving evaluation for individual drivers, such as intervehicle distance, distance to traffic signs, and hard braking and acceleration incidence, is inferred from changes in image and acceleration sensor readings. Two of the present authors have proposed a method for intervehicle distance estimation and for estimating distance to traffic signs [3,4]. In addition to this type of information analysis method, for evaluation of the driving of individuals, it should also be possible to incorporate an analytical method capable of providing outputs on spatial or temporal zones of frequent hard braking or other occurrences through integration of the large volume of sensor information obtained for individual drivers.

Layer 4: Assessment

Safety assessment based on objective data analysis values from multiple perspectives [5] and feedback to the driver by appropriate real-time notification and other means are performed in this layer.

Comprehensive assessment of the individual's level of driving safety from perspectives such as maintenance of intervehicle distance, response to traffic signs, and incidence of hard braking and other actions enables calculation of an objective value as an indicator, and it is possible to promote the provision of feedback to the driver based on this driving safety indicator. Inclusion of a module for this comprehensive assessment and feedback may thus also be considered. By identifying specific spatial and temperate zones where hazardous driving arises for many drivers, it is also possible to perform safety assessments of road and traffic environments and to alert drivers before they drive through those zones.

4 Conclusion

In this report, we have described driving safety management performed in Japan using drive recorders and current problems relating to its efficiency, and proposed a system architecture for raising the efficiency and accuracy of driving safety management using smart devices, which are fast becoming commodities, together with a cloud computing system. In this architecture, the smart devices are focused on collecting and transmitting sensor data, and we propose a method for analysis of the data and driving safety assessment in the cloud system. This minimizes the need for processing by smart devices having limited computing resources and enables the performance of complex analytical processing without dependence on smart device type or version. The location of the analytical processing in the cloud system enables addition and modification of analytical methods as they become necessary or desirable. It also enables dynamic server addition in response to increased processing needs and thus makes it possible to meet the requirements at any time. In this paper, moreover, the described layering of the cloud system functionalities for driving safety management clarifies the functionalities themselves and the scope of their modularization. In short, we have proposed a system reference model for a driving safety management system that can serve as a design guide for its concrete implementation.

On a final note, Fig. 3 shows a scene from an actual driving experiment, including the display of the video image and acceleration data acquired and relayed to the cloud in real time using the iPhone 4 as the smart device. The experiment demonstrated, for a video sequence of a certain length (approximately 30 s), that it is possible to transmit the video images with no need for special protocol modification.

Fig. 3. Scene from driving experiment showing smart device image, acceleration and GPS data collection display, and real-time transmission

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Travel Behaviour and Alternative Modes of Transportation

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Abstract. A high number of vehicles have caused strong congestion, mainly in city centres. A sustainable development of transport contains two essential physical activities. These are a formation of the traffic flows divided into different means of transportation that cover the pro-environmental transport on one side, and an innovation technology development to reduce the negative results of transportation for the surroundings on the other. There is – apart from the two factors already mentioned – a huge need for changes in the travel behaviour of people making the trips as well as a need for changes in the approach to the problem of a city development in terms of mobility.

The knowledge of decision-making factors in the mode choice is important during the transport processes designing. The traffic distribution modelling should follow principles of sustainable development. It requires undertaking steps to increase competitiveness of alternative transportation modes.

Keywords: travel behaviour, sustainable development, alternative modes of transportation.

1 Introduction

The travel behaviour of people is challenging for institutions that influence the development of transport systems in cities and regions. The problem becomes particularly important as the number of travels is constantly growing with the increase in motorization at the same time. The congestion is a negative phenomenon of modern cities as the most of journeys is made by taking a car[1]. Thus, it becomes necessary for a modal distribution of traffic to be altered towards means of transportation with low impact on the environment (environmentally friendly transportation). Switching from a car to a bus or a tram decreases the number of vehicles on the roads. One bus can replace from 30 – when only seats are taken into consideration – up to 70 cars depending on the adopted ratio of people to cars. The paper discusses general decision-making factors in the mode choice. The steps to increase competitiveness of alternative transportation modes were also described.

[1] Effects of various modes of transport on the traffic flows for selected infrastructure components have been analyzed, among others, in [15] and [16].

J. Mikulski (Ed.): TST 2011, CCIS 239, pp. 86–93, 2011.

2 Travels and Modes of Transportation

Well-functioning transport system is a system that operates according to the needs of people[2] and demand for travel. This is the main reason for the authorities responsible for the shape of urban or regional transport system to know the actual flows of people.

The subdivision of travel was performed with the following passenger motivation categories included: home – work (H-W), work – home (W-H), home – education (H-E), education – home (E-H), home – other (H-O), other – home (O-H), non-home related (NHR). All journeys can be divided into different categories depending on the activity of people. Hence, there are journeys associated with domestic activities (maintaining the households), recreation, social life and socializing, and others (Table 1). They can take a form of complex transport chains with the change of mode of transport while having been implemented. Examples of travel chains are shown in Fig. 1.

Table 1. Travels in relation to activity categories [14]

Household sustaining	**Recreation and other diversions**	**Social activities**	**Others**
Work Work-related Shopping (general and other) Medical care Household obligations Pick-up/drop-off passengers	Hobbies Exercise/athletics Rest and relaxation Spectator athletic events	Visiting Casual entertaining Formal entertaining School Culture Religion	Incidental travel

Choosing a mode of transport is subjective and each time these choices are made due to personal reasons of the people making a journey. The problem of such selection is complex and particularly difficult to predict as it depends on a number of quality factors. Examples of quality factors affecting the mode of transportation choice are shown in Table 2. For example, the part-time students[3] of the Faculty of Transport at Silesian University of Technology, when asked what factors had influenced their choice of transportation the most; they indicated the total travel time as the most important, and then they chose the costs of travel and the ability to select a route.

[2] General definition of sustainable development (important also for transportation development) was presented in the Brundtland Report: '…sustainable development is the one corresponding to the needs of today's generation and not jeopardizing the capabilities of future generations, fulfilling the current and future needs. It is based on two fundamental assumptions:
- firstly, one has to focus on the concept of needs and in particular the basic needs of the poorest,
- when meeting the current and future needs one needs to take into account also the limited capability and must not ignore the limits set by the natural environment to the technological progress and to the social order…'

[3] In Poland, they study on weekends (so they can work during the week).

A mutual influence of motivation and these factors, as well as the dependencies associated with the choice of means of transport have been studied – among others – in [2], [13], [14], [21], [26], [28], and [29]. The weight of particular factors varies due to cultural differences in different countries. A geographical distribution of places of residence and the main travelling destinations also has a big influence on the mobility and the modal distribution of traffic (among others in [1], [4], [8], [11], [19], and [22]). Khattak and Rodriguez [11] have noticed that, among other things, a specific location of houses in a close proximity to the infrastructure (so-called “neo-traditional design”) increases short distance travels while lowers the number of passenger cars involved in travelling to the number of total journeys. Some of these factors can be converted to the transport requirements by identifying the most effective transportation solutions, such as the shortest travel time, the fewest transfers (or direct connections), the lowest cost, and others.

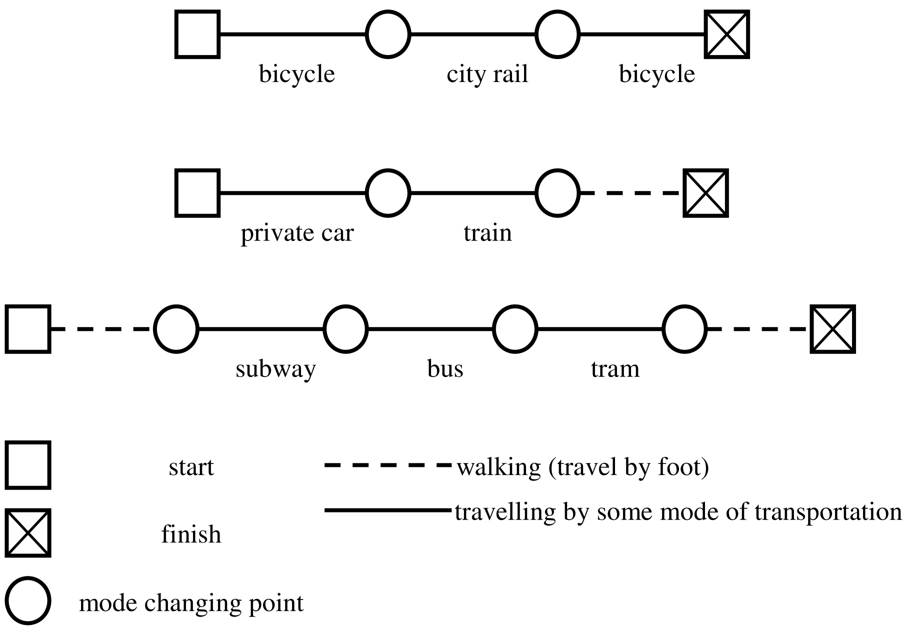


Fig. 1. Examples of travel chains [own work]

At a constant growth rate of the number of vehicles entering the city an effect of a strong congestion is observed more and more frequently. Congestion may be minimised by reducing the share of private passenger vehicles in the traffic [9], [10]. Therefore, it is important to define the capability to develop alternative means of

Table 2. Examples of quality factors affecting the mode of transportation choice [own work] and [12], [24], [25]

Category	Specification
Time	• time necessary to pass to stop/railway station/car park • time necessary to pass from bus-tram stop/railway station/car park to the destination • waiting time for the means of transportation • travel time
Distance	• distance source-destination • distance necessary to pass to stop/railway station/car park • distance necessary to pass from bus-tram stop/railway station/car park to the destination
Accessibility	• number of mode changes • time of day • place to car park near the destination
Atmospheric conditions	• temperature • rain • snow • slippery surface
Others	• safety in vehicle • possibility of deciding abort the route • possibility of „being brought” to the destination • sitting place • costs of travel • habit

transportation stimulating the change of habits of the city and suburb inhabitants, so far using daily their private vehicles.

3 Necessary Changes

Two general factors support the change of modal split. There is a huge need for changes in the travel behaviour of people making the trips as well as a need for changes in the approach to a problem of a city development in terms of mobility.

The change of modal split can be realized by changes of the image of alternative means of transportation and providing effective relocation-related information. Both national and regional media should participate in the activities of supporting the alternative means of transportation and suitably influence the transportation behaviour of the society. Table 2 presents the examples of daily information and the suggestions of how the media could support the sustainable development. Unfortunately, the urban public transportation is usually treated by the media as an obstruction to private cars. Direct information provided using modern technologies is another way to reach

Table 3. Selected activities of the media influencing the image of the transportation systems [own work]

Current approach	Desired approach
Undisputed priority for private cars	Pointing out the sustainable transportation as the right development direction
Criticism of the solutions reducing speed in the cities	Showing the positive and negative examples with the right explanation
Showing congestion without explaining the roots or pointing at some of road infrastructure elements (for example ways for buses) as the reason for congestion	Support in the form of effective guidelines for city and regional travel, with the support for alternative means of transportation
Frequent lack of wider perspective for the city transportation system	Change of image of public transportation – from the second category service to the recommended solution

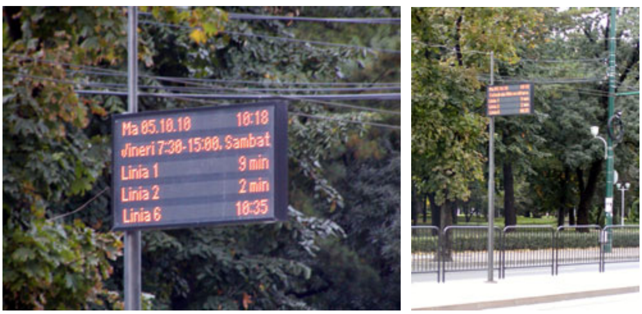


Fig. 2. Electronic information for passengers of clean means of transportation (Timisoara, Romania). [own work].

people and change their travel behaviour (Fig. 2 shows an element of the passenger information providing the information that covers the current traffic conditions, such as real time delays).

As far as the clean means of transportation are concerned, particular focus should be kept on building dedicated lanes for urban public transportation, for bicycle traffic and other forms like car-sharing and car-pooling[4]. Fig. 3, 4 and 5a illustrate the examples of such solutions. What's more, there is a need to build safe bicycle parks (currently rarely used)[5]. Example is shown in Fig 5b.

[4] Car-sharing – a system of using a public passenger vehicle at a fee (per hour or per kilometre). Car-pooling – the use of one vehicle by more passengers travelling in the same direction.

[5] Preliminary survey in Katowice (Poland) emphasised a general problem of travels by bicycle – deficiency of dedicated lanes (50.4% of asked person) and deficiency of safe bicycle parks (30.7%).

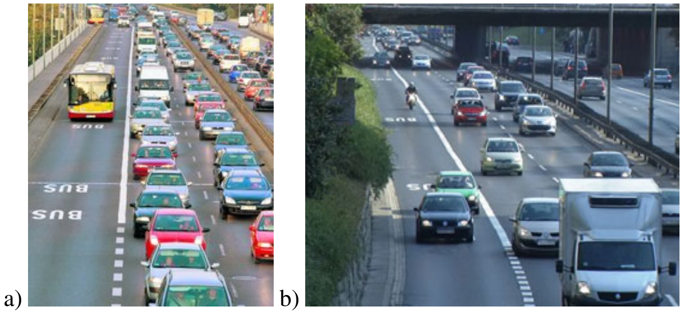


Fig. 3. Dedicated lanes for buses [11] (a) and vehicles breaking the law (b) [20]

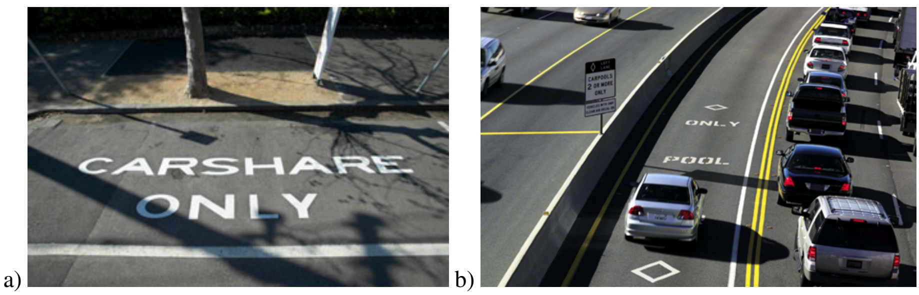
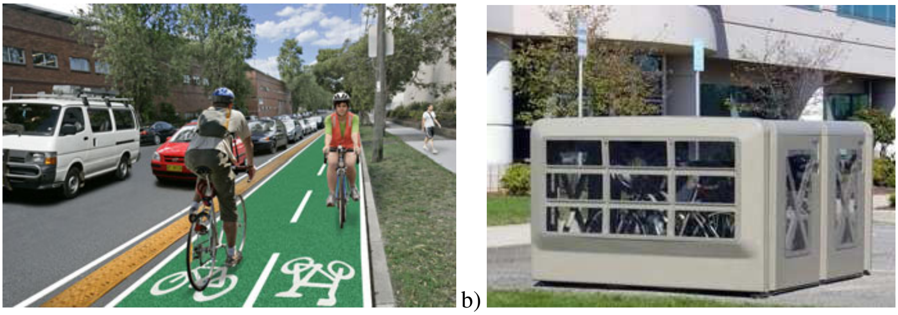


Fig. 4. Infrastructure for co-travellers, a) park places for car-sharing [5], b) dedicated lane for car-pooling [18]

The integration of activities in wider areas is very important. Companies should also support the activities aimed at the improvement of pro-environmental transportation. They should help to promote the right means of transportation. These activities include [6], [7], and [27]:

- subsidising the purchases of bicycles and building safe bicycle parks on the company premises,
- providing company-owned bicycles for personnel use,
- safe bicycle parks for the clients,
- employee benefits in form of subsidised public transportation city tickets,
- parking space priority for the employees using the shared commuting systems,
- introduction of charges for the use of company car park or payment of an allowance for the employees using other means of transportation,
- discounts for retail clients presenting personal monthly tickets for municipal public transportation,
- purchased product delivery services, to discourage the clients from coming to the company premises on their private cars.



a) b)

Fig. 5. Bicycle infrastructure, a) dedicated lanes in Sydney [17], b) locked bicycle box (safety parking) – a proposition from Wroclaw [3]

4 Conclusions

The changes are necessary. The reduction of congestion in the cities is possible by changing the modal split of the traffic. It requires the physical activities in the field of traffic engineering, implementing a right transportation policy, media information, business activities and informing the society about the changes undertaken. Only full targeted integration will bring proper results - the sustainable transportation.

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Evolving ITS Architecture – The Czech Experience

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Abstract. This paper deals with the issue of sparse practical use of ITS architecture. Various approaches to ITS architecture in the world have been studied to capture the missing concepts and proposition has been made how to evolve with the Czech ITS architecture from just a research topic into real world praxis. The proposal is based on four different levels. First is the Organization that shall be accomplished by setting up a so called ITS Forum, second is the Conception with the ultimate goal to find common interests. The third is Information for relevant ITS applications and final level of our approach is Realization that shall be simplified by development of needed tools. All this should prepare the Czech Republic for pan European ITS services.

Keywords: ITS architecture, tools, ITS forum.

1 Introduction

According to the definition in encyclopaedia Britannica [1] architecture is the "*art and technique of designing and building, as distinguished from the skills associated with construction.*" And is further explained as: "*The practice of architecture emphasizes spatial relationships, orientation, the support of activities to be carried out within a designed environment, and the arrangement and visual rhythm of structural elements, as opposed to the design of structural systems themselves.*"

This meaning of the architecture shall be transposed to ITS world, but it is not easy to do so. The act of transposition carries out some problems, mainly because the architecture in construction conveys a in-years-proven way how to build things in order to do it safely, effectively, efficiently and in harmony with the surroundings, in ITS however this background does not exists.

1.1 Benefits of ITS Architecture?

ITS systems are complex installations and with growth of their scope the risk of potential problems grows [4]. The problems are hidden in effectiveness, manageability, maintainability, extendibility, refurbishment over time and overall costs of the installed systems. For example, ITS systems for public transport, parking, and traffic management and traveller information [5] implemented in one geographical region

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shall cooperate, at least to a certain level so to produce benefits of synergy, rather than to counteract or contradict each other.

According to [2] and [3], the basic objective for the creation of a transport-telematic architecture is the achievement of the interoperability between individual telematic applications, including the maximum use of available infrastructure by all telematic applications, while keeping their own individual system requirements (technical requirements: safety, reliability, availability, integrity, etc.; transport related requirements: transport comfort, minimization of external requirements of the transport related process, maintaining transport policy objectives at national and European level, etc.) [13]. It is evident that architecture has different hierarchical levels of use coming from high level plans and conceptions to detailed system architectures that defines “the screw position” in an appliance. In the middle a so called Framework architecture resides that individual ITS architectures can be developed from [8], [11]. The principal advantages of this are quicker, and therefore cheaper, production of a suitable architecture and that the framework architecture guarantees using compatible system design across very large areas.

2 Levels of ITS Architectures

The concept of ITS architecture ranges from relatively simple definitions of a single telematics system to “huge” definitions of a complex telematics system describing several viewpoints of the system, together with its deployment plan, process and object oriented procedures, cost benefit analysis etc. The viewpoints of an ITS architecture are constructed using different perspectives (e.g. functional, physical) and may go into different level of details. From the general point of view this variety of approaches can be broken down into two basic concepts of an ITS architecture: high-level and low level ITS architectures [7].

2.1 High-Level ITS Architectures

High-level ITS architectures are used to provide a description of the functionality and communications needed to provide the services expected by stakeholders from a particular ITS implementation. Within a high-level ITS architecture the functionality is shown as the "component specifications" required by ITS to implement the services and with the "communication specifications" describing how the links between the "components" will be provided. All of the "specifications" are technology independent and are intended to be used as inputs to the procurement part of the overall ITS implementation process.

High-level ITS architectures are created by (or for) national and regional governments, municipalities, research projects, etc. Most widely used are the European Framework ITS Architecture and the US National ITS Architecture.

Creating high-level ITS architectures is a precursor to the creation of low-level ITS architectures. The "bridge" between them is provided by the component specifications and communications specifications which are used in the procurement process.

2.2 Low-Level ITS Architectures

Low-level ITS architectures are used to describe the detailed design of the components and the communications [12], which are needed for ITS implementations. These architectures are created as part of the design activity that commences once procurement has been agreed and use the "component specifications" and "communications specifications" as their starting points. The term "components" is used because the functionality described in the specifications may be realised using either hardware, software, or some combination of the two. The use of particular technologies will almost always form a part of the low-level architectures.

For many ITS implementations, several low-level ITS architecture viewpoints may need to be developed. The actual number will depend on how many "specifications" have been produced. In simple terms the creation process for each low-level ITS architecture viewpoint will be an expansion and refinement of the "component specifications" and "communications specifications" from which the ITS implementation is being made.

3 Existing High-Level ITS Architectures

High-level ITS architectures can be used to create other high level ITS architectures in national states or regions and are also used to create low-level ITS architectures. This paper deals with the issue of ITS architectures usage in general. We feel that all levels of architecture as well as all viewpoints are needed to successfully develop an integrated ITS system. ITS architecture is therefore not only a set of diagrams, tables and functionalities; it is a set of rules and it needs an organization to implement those rules. Without them the ITS architecture is a pointless exercise. We focused our study on European ITS framework architecture, its inferred ITS architectures and also US National Architecture in order to find main similarities and differences.

- European ITS Framework Architecture FRAME started in 1998 by the project KAREN. It was developed in response to the need for a single reference platform in Europe, which would provide a basis for the development of ITS products and services throughout the European Union. Due to subsidiarity within EU member states, ITS cannot be covered by a single definitive architecture and thus a framework (meta model) of ITS architecture is needed. As it is framework architecture, its goal is to assist the development of national, regional or even project architectures. It is further supported via EC R&D projects.
- The US National ITS Architecture [10] was developed in 1996 and provides a common framework for planning, defining, and integrating intelligent transportation systems. It defines logical and physical architecture, implementation, standards oriented components and user services that describe what the system is to do from the user's perspective. It has been designed to be used for the development of consistent "regional architectures", with the aim of facilitating the earlier-stated goal of national interoperability. ITS architecture is supported by federal government and projects that are aligned with national ITS architecture could apply for a partial federal funding.

However, the creation of the architecture is "the easy part" [6], once it is created, it has to be continuously maintained and supported. Optimal solution is the support by government and even embedded in requirements for ITS projects. Without available support and regulations an ITS architecture will never be widely used.

It is necessary to say that even though there are several reports about usage of developed ITS architectures, they were, according to authors, used mainly in R&D projects that have developed them or have personal connection to the developers. The answer how to alleviate this problem is the key focus of this article.

4 Definition of a Problem

After many years of development of System architecture for ITS in Europe we were questioning ourselves – why we do not see its wider practical use in real practice and what we can do to enable it. For example the Czech national ITS architecture was created in 2005, in compliance with the European ITS Framework architecture. Seeing no real footprint of this Architecture in daily practice, in 2009 project "ITS architecture" was set up to investigate an recommend the best approach to get the Czech ITS architecture back on the track. Apart from looking into ITS architecture, studying results of various approaches, we were also looking around trying to capture the missing concepts. As one of the enablers of use of ITS architecture is its connection to rules and standards. This is because they primarily ensure compatibility between various sub-systems that may be produced by a number of different manufacturers. So the linking of architecture and standards was also part of the problem definition.

5 Discussion

ITS architectures are well studied topic with a lot of results in European / national research and development projects. Authors believe that this field have been sufficiently and thoroughly investigated and is mature enough for real world deployment. However, the research undertaken by the authors identified several problems, causing that we do not see wider use of ITS architectures in European region. Following key reasons for no real use were identified as:

- missing support from authorities and industry,
- problem of hugeness and
- related lack of supporting tools and information.

From all analyzed approaches, the National ITS architecture of the USA seems the most promising as it is quite pragmatic, focusing on real use, lowering costs, turning clients from being held in vendor lock-in into real clients, and setting up needed funding, organization and providing support by information and tools.

Our proposal is based on Aristotelian logic for a system. It has four elements (steps) that are developed step-by-step. If one is missing the system does not work properly. First is the Organization that shall be accomplished by setting up a so called ITS Forum, second is the Conception with the ultimate goal to find common interests. The third is Information for relevant ITS applications and final level of our approach is Realization that shall be simplified by development of needed tools.

5.1 Organization and Conception

First step is the Organization that shall be accomplished by setting up a so called ITS Forum, where all stakeholders will be represented, see Figure 1. The ITS Forum shall be governed by the Ministry of Transport and its goal would be to prepare a long-term ITS strategy for ITS systems deployment in the Czech Republic. The base of the organization element is to get people from relevant public sector together with connection to suppliers to create a common platform (Forum) to discuss, develop, implement and promote national rules governing ITS.

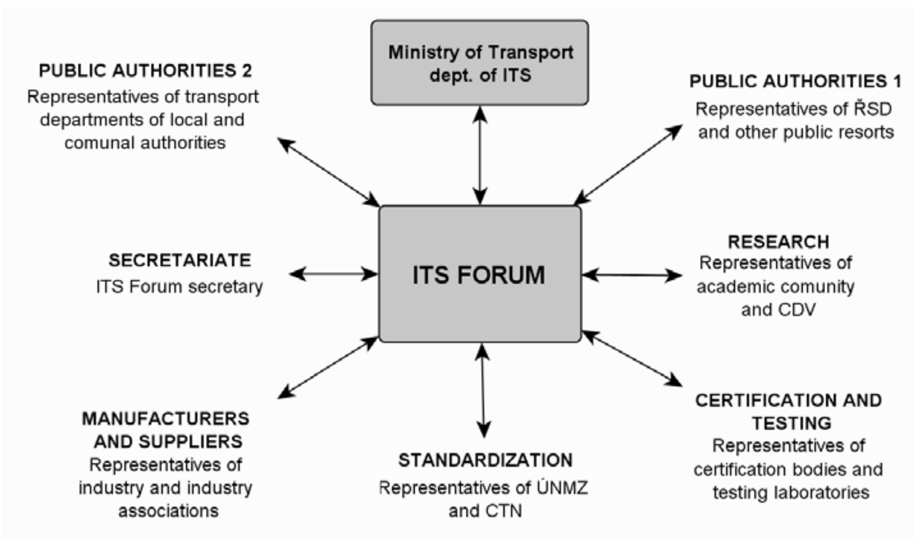

Fig. 1. Proposed organizational structure for effective ITS implementation

The second element is the Conception with the goal to find common perspective in ITS applications. The long term plan ("master plan") should raise policy objectives, appropriate answers from the field of technology and ITS applications and set up a frame for an open market competition – sustainable budget, common rules (standards and architectures), incentive system for regional investors (administration) and rules for ITS projects assessment and ITS realization enforcement; respecting transparency in the form of publishing maximum of information or at least in the form of auditing solutions by an independent body.

5.2 Information

The third step is Information for relevant ITS applications supported by ITS strategy that shall be provided by ITS Forum by means of education, web portal and a knowledge system, taking advantage of the results of Czech projects STANDARD and ZNALSYS. One of the Information relevant tasks is a way how to use standards.

Using technical standards to improve cooperation / interfacing of individual system components is one of the main reasons for having an ITS architecture. While standards could not be linked to the architecture directly (or it is very complicated) there is need to know them while designing the system or preparing contract condition [9]. The problem in the world of ITS standards is hugeness. There is nobody to be able to read all the ITS standards; there should be a tool to help anyone to orientate quickly.

Therefore, creation of database of excerpts from standards together with web search tool supported by different search patterns (key word, categories, full text search) have been researched in the Czech Republic within the project STANDARD. The excerpts are strictly formalized text about a standard, with emphasis on its intended use, they do not describe the scope of the standard, nor replace the standard itself, their purpose is to provide the reader the possibility to make a good choice among the standards for his/her intention and guide him/her to buy and use the standard, simply said its purpose is the marketing of the standard.

Such freely accessible database of excerpts shall make linkage of standards to the architecture irrelevant and also should speed up the process of system development by giving the users tool easy to use, which would help them to find out the right standard. To update the database (extracts of standards and terminology) regularly there should be an administrator financially supported but independent on business interests. Therefore the tool should be supported by European funds as a means of vital contribution to worldwide ITS harmonization.

Other primary reason for having architecture is consolidated ontology. The creation of common terminology from international and national sources is a long term intention and work. If there is an official proclamation about mutual European and Asian and American approach to ITS cooperative systems and there is a common work programme settling down the important issues it would be right to start with terminology consolidation first to avoid the subsequent confusion of common understanding of terms on international level and second within translations onto national level, example of such effort could be seen at www.slovnikdopravy.cz for the Czech Republic, for terminology within the field of Transport.

The common harmonized terminology could save much time as to document creators (ITS legislation makers, ITS calls for tender documentation makers, ITS standards makers etc.) as to other stakeholders – users of produced documents. They should just pick up already codified terms when creating a standard or a European legislation.

5.3 Realization

The fourth step is the Realization that should offer some useful tools both to the investors and the market to support ITS architecture creation, ITS systems design consistency and control followed by verification whether a project fulfils national rules and can claim for some funding from national incentive system.

Many of the analyzed architectures have tools for selection of concrete architecture from provided national architecture. In the USA a tool called Turbo Architecture is used and it is an interactive software application that assists transportation planners and system integrators. In Europe it is Oscar (France) and Browsing and selection tool for FRAME architecture. Since the European approach is more flexible it does allow users only to select functional architecture and divide it to physical components. This is actually enough, but due to lack of finances the tools need some upgrades, mainly on user-interface and functional levels.

First problem to solve in the Realization phase is how to make the tool more usable for the people that really shall use it – system engineers. While they are creating system requirements and drawing first drafts of system architecture, they use standardized software, like Rational Rose or quite popular Enterprise Architect.

Therefore we decided to transfer both selection and browsing tools into plug-in of Enterprise Architect, the software that engineers use daily for other purposes. This plug-in, called RAPID, let users to develop ITS architecture models. It allows user not only to browse and select through entire ITS architecture, but also to search in full text for required function/user need, easily add new functions and data flows. Finally the selection process is made intuitive so the engineer can always check what the related functions to function he/she is deciding to select are.

6 Conclusion

ITS architecture is a powerful tool that can ease the creation and enables the compatibility of ITS systems. The ITS architecture shall "step up" from just being a research topic to be the real implementation guide. The public authorities have to have on their agenda to develop and enforce use of the ITS architecture, to incorporate other stakeholders (local authorities, industry, independent organizations ...) under umbrella of ITS Forum and finally (within the responsibility of ITS Forum) to look after its use / enforcement and development in the following situations:

- preparation of new ITS projects by public authorities,
- verification that the ITS project calls / bids / realizations meet required criteria,
- financial support from national level to projects on regional level that are compliant with the requirements of ITS architecture,
- update, support of use, creation of informative materials about ITS architecture,
- maintenance and support of tools for creation of ITS architecture,

Core principle is to **maximize transparency by publishing maximum information** about real projects or at least by auditing projects by independent bodies. All this could lead to better understanding of true ITS architecture meaning that it is a good tool for consistent long term planning at the regional level that assures the implementation of common practice supported by the state to reach interoperable ITS solutions even across borders. To gain common understanding is the first step for using ITS architecture as a handy tool against high costs and isolated ITS systems.

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An Intelligent Approach to Wear of Piston-Cylinder Assembly Diagnosis Based on Entropy of Wavelet Packet and Probabilistic Neural Networks

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Abstract. The diagnosing of combustion engines with vibration methods is especially difficult due to the presence of multiple sources of vibration interfering with the symptoms of damages. The diagnosing of engines with vibro-acoustic methods is difficult also due to the necessity to analyse non-stationary and transient signals. Various methods for selection of usable signal are utilised in the diagnosing process. Changes of the engine technical condition resulting from early stages of wear are difficult to detect because of the effect of mechanical defect masking by adaptive engine control systems. The paper presents an attempt to evaluate the wear of a piston-cylinder assembly with the aid of vibration signal recorded on spark ignition engine body. The subject of the study was a four-cylinder combustion engine 1.2 dm3, based on the measurement of accelerations of body vibrations and entropy of wavelet packet transform for fault pattern identification. According to the studies carried out, it is possible to utilise probabilistic artificial neural networks for the evaluation of the clearance in piston-cylinder assembly.

Keywords: internal combustion engines, artificial neural networks, diagnostics, on-board diagnostics.

1 Introduction

The constantly growing requirements connected with the environment protection forced the creation of an effective diagnostic system which would be universal and which could be applied in all types of cars. First tests with such system were conducted in 1988 in the USA and the system then got a name of OBD – On Board Diagnostics. From the moment of its creation the system constantly evolved and was gradually reaching a stronger position on the automotive market. Since the beginning of the year 2000, in European Union countries, all newly registered motor cars with magneto ignition engines must have an on-board diagnostic system. Since 2004 this obligation was also applicable to the motor cars with Diesel engines and since 2006 the OBD must also be present in newly registered lorries.

The OBD application is aimed at the elimination of off-board measurement and diagnostic systems and their replacement with one unified system with the use of

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which the control and diagnosis of the driving system could be conducted with view of the future control of the whole vehicle [9], [12].

Because of the design complexity and the number of the processes during the work of an internal combustion engine, it is an object which is really hard to diagnose. Preliminary tests show that many of the damages occurring in the engine are not detected by the diagnostic system. The common cause of that fact is that the functioning of the adaptive steering algorithm of internal combustion engines. It may lead to compensation (hiding, adaptation) of the early stages of the development of the operational use or mechanical defects. The methods applied so far in the tests of gas emission during the technical service and car diagnosis cannot be treated as a reliable criterion of the engine technical condition. Monitoring the condition of the steering system of the engine by an on-board diagnostic system does not enable to find damages in their early stages of development. It causes that the vehicle may be used with increased emission and in conditions which cause the decrease of traction properties or which speed up the wear of engine elements, a dangerous phenomenon for the safety of road users.

The tests show that there is a need for creation of new diagnostic methods which would enable an early identification of defects. It is then the right decision to start the research in order to give more possibilities to diagnostic systems by their expansion with the use of an additional diagnostic system based on different symptoms.

As the tests conducted in many different laboratories all over the world show, the vibroacoustic phenomena are one of the possibilities of gaining information about technical condition. The choice of these phenomena as sources of information results from many different reasons such as: the vibrations are the reflection of the most important physical processes among which there is the proper functioning; vibroacoustic vibrations as information carriers are distinguished by a huge information capacity; the way the vibroacoustic vibrations are registered enables a fast measurement in natural working conditions [1], [2], and [7]. Vibroacoustic diagnostic signal can be registered with the use of a sensor placed directly on the mechanism or with the use of microphone placed in the surrounding of it. Depending on the applied sensor, the diagnostic signal is described with sizes characteristic for a vibrating movement (shift, speed, acceleration, frequency and phase) or used in acoustics (speed of sound, acoustic pressure, volume). In order to apply the informative possibilities in full there is a need to check, which measurement method will be the best for a given type of occurring defect of particular elements of driving system including the internal combustion engine. A vibroacoustic signal is a complex signal coming from many sources. Division of the signal into constituents is only possible when the characteristic features of the signals generated by particular kinematic pairs are known.

The main problems of vibroacoustic diagnostics are the identification of the methods of sound division into such constituents, which could be assigned to particular sources and the setting of assessment rules for the condition of a given kinematic pair on the basis of the achieved signal. Here, the knowledge of the characteristics of vibroacoustic signals and the methods of their processing is necessary. That is why many laboratories conduct tests to find the right tools, the significant element of which would be the algorithms that could organise the process of collecting, ordering and processing the vibroacoustic signals, according to defined rules, enabling the classification of conditions and supporting the conducted identifications of mechanisms shaping them 1], [2], and [7]. Different specifics and conditions of such tasks related to a given object are the reason why, although there are many proven and widely applied and approved algorithms of vibroacoustic signals analysis and a huge number of rules of concluding based on them, they are still characterised by insufficient degree of identification by the determinants describing them [1].

Vibroacoustic signals generated by particular kinematic pairs and the fittings of the internal combustion engine are usually non-stationary [8]. It results from the occurrence of non-linear phenomena caused, for example, by the existence of clearances or non-linearities of characteristics of elastic elements. Characteristics of signals frequencies depend significantly on the path of transmittance propagation of constituent signals from the sources of their existence to the point of measurement. Vibrations measured on the engine block are characterised by complex features due to the superposition of signals coming from different sources. It should also be pointed out that the early stages of defect development in elements of driving units, among them the internal combustion engines, contrary to an advanced stage not always cause a significant increase in the vibroacoustic signal strength [4]. That is why the diagnosis of internal combustion engine defects with the use of vibroacoustic methods is a difficult process and one which requires the application of advanced methods of signal processing [4], [5], and [6]. Symptoms of defects achieved as a result of advanced methods of vibroacoustic signals processing may serve as models used in the course of design of diagnostic systems based on the artificial intelligence methods, among them on the artificial neural networks.

The biggest difficulty in the process of designing systems using artificial intelligence is, as it is also mentioned in the literature, the necessity to approach each of the tasks individually [3], [7], [10], and [13]. So far, the unified guidelines of how to build and teach such networks have not been worked out.

2 Setting up the Model for Piston-Cylinder Assembly Clearance

The data in the experiments carried out is derived from time runs of the vibration accelerations in the engine body. The subject of tests was a Fiat Panda with a 1.2 dm^3 SI engine. The tests were carried out in the roller bench. The vibration acceleration signal of the engine body was measured perpendicularly to the cylinder axis with a sensor placed at the 4th cylinder. An ICP type vibration acceleration transducer and a data acquisition card controlled by a program developed in the LabView environment were used for the measurements. The signals were recorded at the velocity of 2500 rpm, at the sampling frequency of 40 kHz. During the tests, 23 runs of accelerations of the engine body vibration were recorded before the repair, and 27 runs of accelerations of the engine body vibration were recorded after the repair, including full operating cycles within the rotation angle of 0-720º. The engine repair involved the replacement of worn pistons which reduced the clearance in the piston-cylinder assembly.

The analysis of time runs excluded the possibility to use them directly as the data for neural classifiers. The repair of the engine did not explicitly affect the character of changes in local measurements derived from the vibration signals (Table 1). The measurements of average position, differentiation, the group of slope measure and the distribution kurtosis of measurable variants of vibration accelerations in the time domain did not allow the clearance in the piston-cylinder assembly to be explicitly identified.

Table 1. Selected measures obtained from vibration accelerations

No	Name of measure	Value of measure before repair	after repair	Δ [%]
1	Root mean square	101.2600	95.3200	5.8611
2	Mean value	50.2920	48.3720	3.8175
3	Mean absolute deviation	49.9510	48.1990	3.5063
4	Kurtosis	13.8170	14.1390	-2.3309
5	Crest factor	9.8759	10.4910	-6.2260
6	Clearance factor	1.3834	1.3769	0.4678
7	Impulse factor	2.0133	1.9706	2.1247

A simultaneous analysis of the time and frequency related properties of signals by means of a wavelet transform is more and more frequently used in diagnosing combustion engines [7], [11].

A wavelet analysis consists in signal decomposition and its presentation as a linear combination of the base functions known as wavelets. The features distinguishing this method of signal analysis from other methods are multilevel signal decomposition, a variable resolution in time and frequency domains and the possibility of using base functions other than harmonic functions.

The original signal x(t) passes through two complementary filters and emerges as low frequency – approximations signals A(t), and high frequency – details signals D(t). The decomposition process can be iterated, with successive approximations being decomposed in turn, such that a signal can be broken down into many lower-resolution components (Fig. 1).

The signal x(t) can be represented by:

$$x(t) = \sum A\ (t) + \sum D\ (t) \tag{1}$$

In the conducted experiments, the signals of vibration accelerations underwent decomposition at one to ten levels. Next, the entropy of approximations and details on levels were measured:

$$E = -\sum s^{2}(t) \cdot \log\left(s^{2}(t)\right) \tag{2}$$

where:

$s(t)$ – analysed signal.

The results obtained indicate the possibility of distinguishing different states of engine operation, using for this purpose the signal entropy, calculated at subsequent decomposition levels.

Results were determined after conducting the proper process of standardizing and scaling, where the input data for neural classifiers built were based on probabilistic neural networks.

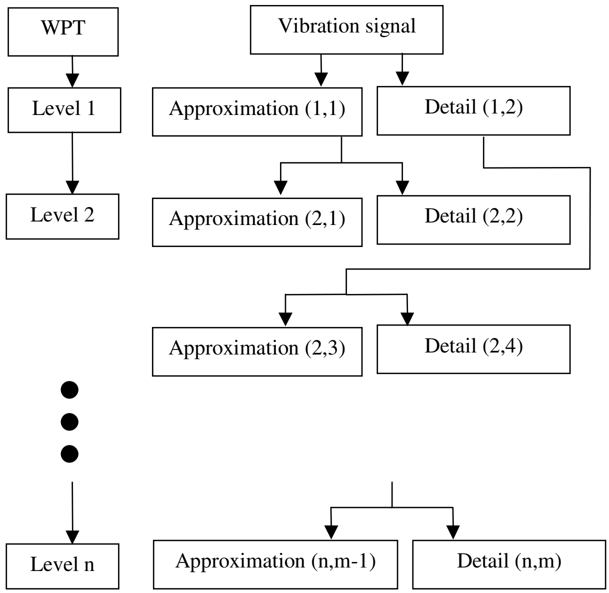

Fig. 1. Idea of packet wavelet signal decomposition

3 Neural Classifier for the Piston-Cylinder Assembly Clearance

In the modern literature, there are examples of broad applications of systems using artificial neural networks for solving complicated tasks from various technical, medical or economic fields [3], [7], [10], and [13]. The basic feature of the artificial neural networks is the possibility of modelling any nonlinearities, maintaining the resistance to interferences and the ability to generalise the knowledge acquired in the process of learning, enabling an analysis of new cases of a given phenomenon. In this connection, this study attempted to use the artificial neural networks to classify various states of engine operation.

For the studies carried out, artificial neural networks of PNN type were utilized (Probabilistic Neural Networks) [10], [13]. The probabilistic neural networks are used as the neural classifiers dividing the set of data into a determined number of output categories. They are of three-layer structure: input, hidden and output layer.

The structure of probabilistic neural networks is shown in Fig. 2.

The number of hidden neurons equals the number of teaching samples, and the number of output neurons equals the number of classification categories. Each radial neuron models the Gauss function focusing on one teaching model. Output neurons sum up the output values of hidden neurons belonging to the class, which corresponds to a given output neuron. The network output values are proportional to the nucleus estimators of the probability density function for various classes. Following the application of normalization ensuring summing up to one, they produce estimation of the probability of belonging to individual classes. While using such network type, proper smoothening coefficient γ should be selected. It represents the radial deviation of Gauss functions and is a measure of the range of neurons in the hidden layer. This value, when too low, causes the loss of knowledge generalizing property by the network, and, if too high, prevents the correct description of details. Similarly to the radial networks, the value of γ coefficient is determined experimentally. A high learning speed is one of the greatest advantages of PNN type networks, whereas their complexity is the main drawback.

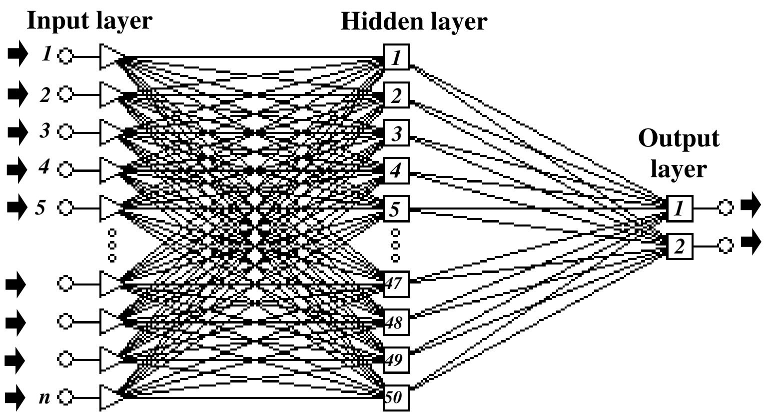

Fig. 2. Structure of probabilistic neural networks

In the experiments aimed at the construction of a proper neural classifier of PNN type, the performance of the network for 86 various values of γ coefficient were checked.

In each conducted experiment the neural network had a task to classify registered vibrating signal to one of two classes corresponding to an engine with and without the clearance in the piston-cylinder assembly. Neural classifiers contained 2 neurons in the output layer.

In the research, the determined values of the vibration signal entropy were assumed to be the input data for the neural networks. Some variants of the input data sets, varying with the adopted number of decomposition levels, were checked. The adopted number of the decomposition levels corresponded to the number of inputs of the neural network. Table 2 shows the results of the experiment. The obtained results of the dependence of coefficient‘s γ influence on the classification error value are presented in Fig. 3 and Fig. 4.

With the experiments carried out, it was possible to set up properly operating neural classifier. This result was obtained for γ coefficient value within the ranges depending on the level of decomposition. For γ coefficient out of these ranges, a significant increase in the classification error was noticeable.

Table 2. The best achieved results for probabilistic neural classifiers

The level of WPT decomposition	γ parameter	The lowest test error value [%]	The level of WPT decomposition	γ parameter	The lowest test error value [%]
Level 1	0.01-3	0	Level 6	0.2-10	0
Level 2	0.01-4	0	Level 7	0.2-12	0
Level 3	0.03-5	0	Level 8	0.3-11	0
Level 4	0.05-6	0	Level 9	0.3	4
Level 5	0.07-8	0	Level 10	0.5	4

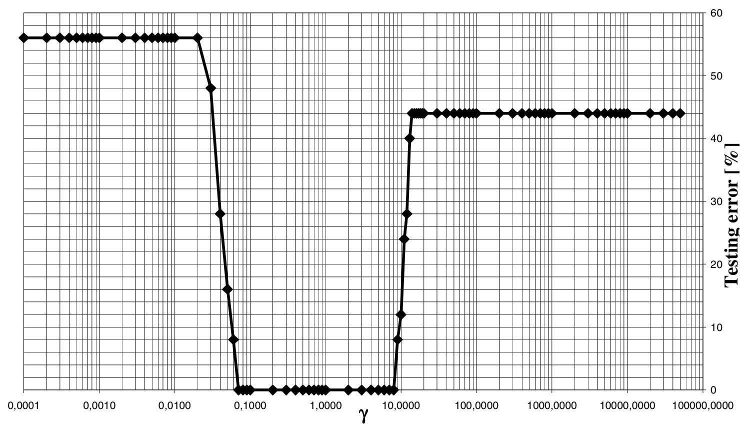

Fig. 3. The effect of the γ coefficient on the correctness of the PNN neural network classification – 5th level decomposition

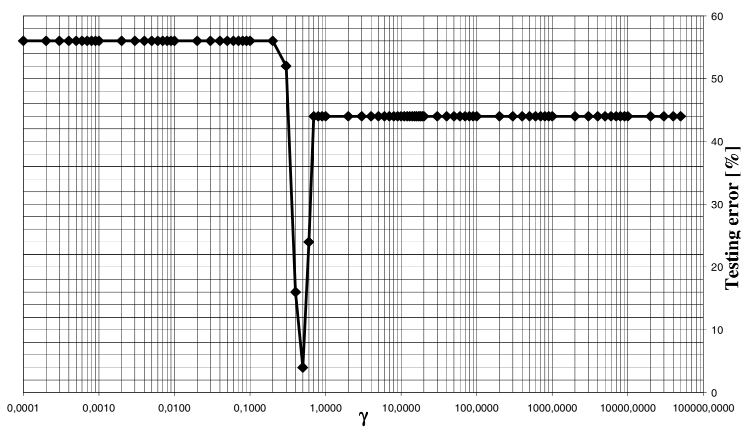

Fig. 4. The effect of the γ coefficient on the correctness of the PNN neural network classification – 10th level decomposition

4 Conclusion

The studies have proven that it is possible to build a correctly working neuron classifier capable of recognizing different conditions of engine work.

As part of the study, the descriptors calculated on the basis of the vibration acceleration signal registered on the engine block were proposed to serve as the source of information on the engine condition. The results have corroborated the effectiveness of using the signal approximation and detail entropy, acquired from the wavelet packet decomposition, as the base for building models of engine operation.

The use of a probabilistic neural network with a correctly selected value of coefficient γ enables obtaining a faultless classification.

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Diagnosing of Disturbances in the Ignition System by Vibroacoustic Signals and Radial Basis Function – Preliminary Research

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Abstract. Currently applied on-board diagnostic systems enable to find a simple defect if it exceeds the boundary values. If the damage does not exceed such values, measured with the use of intermediate values, which are the criteria for the assessment of exhaust fumes emission, such damage may remain unidentified by the imperfect model of the system. Preliminary tests show that some mechanical damages even over the admissible sizes do not constitute the basis for the reaction of the diagnostic system. At present, failure symptoms found in the signal, are more and more often studied with the aid of artificial intelligence methods. The major issue referred to in the literature related to methods of artificial intelligence is the method for creating the data used in the process of neural network operations. The ability to set up models is the guarantee for a successful classifying process using neural networks. The paper presents an attempt of detecting disturbances in the ignition system by measuring the engine block accelerations and noise based on these, building patterns for radial artificial neural networks (Radial Basis Function – RBF).

Keywords: internal combustion engines, artificial neural networks, diagnostics, on-board diagnostics.

1 Introduction

Automotive vehicles powered by internal combustion engines predominate on the roads in Poland, Europe and globally. Car manufacturing concerns strive at gaining new customers and offer them more perfect, ergonomic, economical, more reliable, durable, and safer and more ecological products. All those features are important for the users of vehicles, but in the social aspect, the safety and the ecology become the most important. There is a clear tendency now to treat globally the environmental hazards originating from motorisation together with threats to safety.

In recent years the rise of the number of vehicles registered for the first time on the territory of Poland can be observed. Among them there are both new cars and those imported from abroad. The rise in the number of vehicles has a negative influence on the number of road accidents which is on the increase and on a higher pollution of the environment. Both the road safety and the pollution of environment greatly depend on

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the technical condition of the automotive vehicles using the roads. In order to maintain the necessary level of technical condition of the vehicles the right diagnostics is needed.

Currently applied on-board diagnostic systems which are standard equipment in a car enable to detect the chosen defects which influence the emission of toxic elements in exhaust fumes. Tests show that such systems do not detect all possible defects allowing to detect only the simple defects. Additionally, some of the mechanical defects even over the permitted limits are untraceable for the currently used systems [5]. It happens because of the adaptive steering of the engines which camouflages the appearing defects.

At present, there is a lack of a diagnostic method which is efficient, gives straightforward results and enables to assess the technical condition of the engine and to detect the possible defects in as early stage of their advancement as possible [1], [3], [4], [6], [8], [9], and [10]. It is then necessary to work out a system which would give better possibilities for the on-board diagnostic systems by their enlargement with the use of an additional system based on other diagnostic symptoms.

On the basis of tests it can be concluded that the vibroacoustic signals emitted during the operation of an internal combustion engine carry the indispensable diagnostic information. Tests conducted in many different scientific laboratories aim at creation of the right tools which would process the vibroacoustic signals for diagnostic purposes [2], [3], [7], and [9]. Various specifics and conditions of tasks related to particular objects cause that, although there are many reliable and applied algorithms of vibroacoustic signals analysis and a huge number of inference rules based on them, there is constantly a need to conduct research connected with this topic. Working out the right algorithms of signal processing gives a possibility of designing descriptors of mechanical defects which occur in internal combustion engines and which will serve in the process of diagnostic system development which uses the artificial neural networks. The literature points out that the biggest difficulty in the process of designing systems using artificial intelligence is the necessity of individual approach to each task [2], [7], [11], and [12]. So far, such unified directions of construction and teaching for such systems have not been developed. At the same time the literature shows the lack of rules concerning the choice of those parameters and mentions the need of their formulation on the basis of experimental method of trials and errors.

2 The Results of the Tests

The main purpose of the research was to determine the effect of the disturbances in the ignition system on the vibration signal characteristics. Different states of engine operation were simulated as part of the studies, i.e.: fully operational engine, cylinder no. 1 off, cylinder no. 2 off, cylinder no. 3 off, cylinder no. 4 off, pair of cylinders no. 1 and no. 4 off, pair of cylinders no. 2 and no. 3 off.

The object of the tests was a four-cylinder, four-cycle engine of a Volkswagen Polo car with swept capacity 1.0 dm^3 with magneto ignition, adjusted to alternative power supply with the use of LPG gas fuel.

Before the tests began, the engine had been adjusted to them in the following way:

- the air filter had been dismantled and the air-escape of the crankcase of the engine had been led to the outside of the vehicle;
- for the test period the ventilation of the cooler had been switched off so that the noise of the working ventilator had not interrupted the measurement;
- a sensor of angular orientation of the crankshaft had been fixed with a spare wheel adjusted to cooperate with it. It enabled to mark the top centre (TC) for the first and fourth piston and to register the angular position of the crankshaft;
- an optic-electronic sensor of the angular position of the distribution shaft was mounted in order to mark the TC of the first piston;
- a microphone was placed in the mounting created on the bonnet of the vehicle;
- sensors of vibrations of engine body acceleration were placed as follows: sensor of axial vibrations was placed in 1/3 of the height of the cylinder liner of the first cylinder in the front of the engine, sensor of perpendicular vibrations was placed in 1/3 of the height of the cylinder liner of the first cylinder in the back of the engine.

The tested object was an internal combustion engine built into the car. The measuring equipment used in testing consisted of:

- a PC computer with NI PXI 4472B data acquisition card;
- two piezoelectric converters (vibration sensors);
- a Norsonic signal analyser with a capacitor microphone;
- an optoelectronic sensor of angular position of distribution shaft;
- a sensor of the crankshaft angular position.

The following data was collected during the tests: the angular position of the crankshaft, the distribution shaft position, the acceleration of the engine body vibrations in the axial direction, the acceleration of the engine body in the perpendicular direction, the acoustic pressure. Signals were registered with the sampling frequency of 50 kHz.

Tests were conducted for the following rotational speeds of the engine: 850 r.p.m. (idle run), 2400 r.p.m., 2850 r.p.m., 3400 r.p.m.

Experiments were conducted for an engine powered with petrol and LPG gas.

Examples of registered signals are presented in Fig.1.

Registered signals were processed with the use of Matlab – Simulink software.

The major issue referred to in the literature related to methods of artificial intelligence is the method for creating the data used in the process of neural network operations. The ability to set up models is the guarantee for a successful classifying process using neural networks [2], [7], [11], and [12].

The input data for artificial neural networks were 22 measurements marked out of registered signals in the time domain x(t). Based on registered signals of vibration accelerations of engine body in the axial and perpendicular direction and of acoustic pressure, the following diagnostic amplitude measurements were marked – Table 1.

Quartiles, also called percentiles, characterise the measurable value, which divides the ordered set of all values into 25% and 75% - quartile 1; and 75% and 25% – quartile 3. Quartile 2 (median) defines the value above and below which the same number of observations is to be found.

The neural classifiers RBF used in the experiments have seven output neurons. Each output of the network had a task, which was to show one particular state of the engine (no damage or one of six simulated damages).

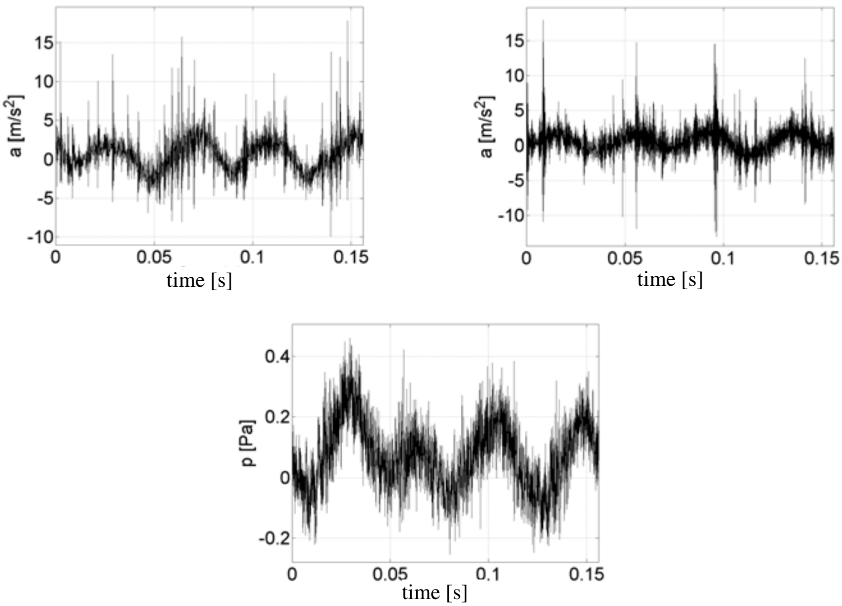

Fig. 1. Vibrations in perpendicular direction (a), axial direction (b), acoustic pressure (c); n=850 rotations/min, petrol, cylinder no. 2 off

In the first experiment, it was decided to construct a neural classifier which would determine one out of seven states of the internal combustion engine and would work independently from the rotational speed of the engine and the type of powering. The teaching and testing data consisted of the marked measurements from time signals registered by vibration sensors (axial and perpendicular direction) and microphone by four rotational speeds of the engine and two methods of powering (petrol and LPG). Table 2 shows the results of the experiment.

For data coming from vibration signals registered in the direction perpendicular to the axis of the cylinder of the internal combustion engine it was impossible to finish the experiment.

Because the obtained results were unsatisfactory, it was decided to try to build two independent neural classifiers working on the data registered for one type of fuel (either petrol or gas). It was assumed that the system diagnosing the engine condition will be independent of the rotational speed of the engine. That is why the input data was the measurements marked from the signals registered by different rotational speeds of the engine. The results of the experiment are presented in Table 3.

Also in this case the satisfactory results were not achieved and the experiments were not completed for classifiers built on the basis of data coming from vibration signals in the direction perpendicular to the axis of the cylinder.

The next conducted experiment was performed in order to check, if the construction of a properly working neural classifier identifying the states of the internal combustion engine is possible, when the engine works on one particular rotational speed and is powered by one type of fuel. The achieved results are presented in table 4, 5, 6 and 7.

Table 1. The diagnostic amplitude measurements

No	Name	Equation	No	Name	Equation
1	maximum value	$x_{\max} = \max\limits_{0<t<T}(x(t))$	12	harmonic mean	$\bar{x}_{har} = \frac{N}{\sum_{i=1}^{N} \frac{1}{x_i}}$
2	minimum value	$x_{\min} = \min\limits_{0<t<T}(x(t))$	13	quarter deviation	$\sigma_{qd} = \frac{1}{2}(q_3 - q_1)$
3	peak to peak value	$x_{p-p} = \frac{1}{2}\left(\max\limits_{0<t<T}(x(t)) - \min\limits_{0<t<T}(x(t)\right.$	14	average deviation	$\sigma_{ad} = \frac{1}{N}\sum_{i=1}^{N}\left\|x_i - \bar{x}\right\|$
4	signal energy	$x_e = \frac{1}{T}\int_0^T x^2(t)dt$	15	positional variability coefficient	$PVC = 100\left(\frac{\sigma_{qd}}{q_2}\right)$
5	quartile 1	q1	16	variability coefficient	$VC = 100\left(\frac{\sqrt{\sigma_{std}^2}}{\bar{x}}\right)$
6	quartile 2 (median)	q2	17	peak coefficient	$PC = \frac{x_{p-p}}{x_{RMS}}$
7	quartile 3	q3	18	backlash coefficient	$BC = \frac{x_{P-P}}{\left(\frac{1}{T}\int_0^T \sqrt{\left\|x(t)\right\|}dt\right)^2}$
8	root mean square	$x_{RMS} = \sqrt{\frac{1}{T}\int_0^T x^2(t)dt}$	19	shape coefficient	$SC = \frac{x_{RMS}}{\frac{1}{T}\int_0^T \left\|x(t)\right\|dt}$
9	variance	$\sigma_{std}^2 = \frac{1}{N}\sum_{i=1}^{N}(x_i - \bar{x})^2$	20	impulse coefficient	$IC = \frac{x_{P-P}}{\frac{1}{T}\int_0^T \left\|x(t)\right\|dt}$
10	mean value	$\bar{x} = \frac{1}{T}\int_0^T x(t)dt$	21	asymmetry coefficient	$AC = \frac{\frac{1}{T}\int_0^T (x(t)-\bar{x})^3 dt}{\left(\sqrt{\frac{1}{T}\int_0^T (x(t)-\bar{x})^2 dt}\right.}$
11	geometric mean	$\bar{x}_{geo} = \left(\prod_{i=1}^{N} x_i\right)^{\frac{1}{N}}$	22	kurtosis	$K = \frac{\frac{1}{T}\int_0^T (x(t)-\bar{x})^4 dt}{\left(\sqrt{\frac{1}{T}\int_0^T (x(t)-\bar{x})^2 dt}\right.}$

Empty spaces in the results table mean that it was impossible to finish a planned experiment with given input parameters (engine rotational speed, type of fuel).

The results, achieved during the tests, show that far better results can be achieved for a neural classifier designed for clearly specified point of the internal combustion engine work and not for the diagnosis of the engine condition independently of the parameters of its work.

Table 2. The best achieved results for neural classifiers of RBF type – experiment 1

	Microphone	Vibrations in axial direction	Vibrations in perpendicular direction
γ parameter	13	15	–
The lowest test error value [%]	68.94	45.12	–

Table 3. The best achieved results for neural classifiers of RBF type – experiment 2

	Microphone	Vibrations in axial direction	Vibrations in perpendicular direction
γ parameter	30	19	–
Type of power	petrol	petrol	petrol
The lowest test error value [%]	62.44	28.94	–
γ parameter	19	14	–
Type of power	LPG	LPG	LPG
The lowest test error value [%]	54.90	29.43	–

Table 4. The best achieved results for neural classifiers of RBF type – experiment 3 (n=850 rotations/min)

	Microphone	Vibrations in axial direction	Vibrations in perpendicular direction
γ parameter	30	40	15
Type of power	petrol	petrol	petrol
The lowest test error value [%]	14.75	1.38	45.25
γ parameter	30	40	0.0001 - 12
Type of power	LPG	LPG	LPG
The lowest test error value [%]	18.44	1.78	81.70

Table 5. The best achieved results for neural classifiers of RBF type – experiment 3 (n=2400 rotations/min)

	Microphone	Vibrations in axial direction	Vibrations in perpendicular direction
γ parameter	13	15	–
Type of power	petrol	petrol	petrol
The lowest test error value [%]	35.36	6.03	–
γ parameter	50	19	0.0001 - 12
Type of power	LPG	LPG	LPG
The lowest test error value [%]	30.58	8.15	81.70

Table 6. The best achieved results for neural classifiers of RBF type – experiment 3 (n=2850 rotations/min)

	Microphone	Vibrations in axial direction	Vibrations in perpendicular direction
γ parameter	9	9	–
Type of power	petrol	petrol	petrol
The lowest test error value [%]	33.14	13.21	–
γ parameter	17	11	0.0001 - 50000
Type of power	LPG	LPG	LPG
The lowest test error value [%]	24.31	5.06	83.04

Table 7. The best achieved results for neural classifiers of RBF type – experiment 3 (n=3400 rotations/min)

	Microphone	Vibrations in axial direction	Vibrations in perpendicular direction
γ parameter	30	9	0.0001 - 900
Type of power	petrol	petrol	petrol
The lowest test error value [%]	37.34	13.21	83.75
γ parameter	16	13	30
Type of power	LPG	LPG	LPG
The lowest test error value [%]	31.22	15.51	29.30

3 Conclusion

The smallest classification error occurred in the case of RBF type neural networks, which were taught and tested on the data coming from vibration signals registered on the engine body in the axial direction.

On the basis of the achieved results the best values of coefficient γ, which would enable the achievement of the lowest error values of classification for designed RBF type neural classifiers, cannot be marked no matter the input parameter connected with the work of internal combustion engine. Achieved results show the necessity of checking the functioning of RBF neural networks by different values of parameter γ.

The conducted experiments show the necessity of using the data achieved as a result of more complex algorithms in the process of neural networks teaching. It is then necessary to conduct more experiments in order to check the analysis of type DWT, WPT, EMD etc. for the initial processing of signals and in order to achieve the models of classes of internal combustion engine damages on their basis.

At the same time, the gathered results show that the construction of a diagnosing system which consists of a few classifiers designed to work with the data coming from particular states of internal combustion engine (set rotational speed and way of powering) is a better idea than the construction of one neural classifier which should diagnose particular states of engine without the knowledge of its working parameters.

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Petri Net-Based Functional Representation of a Level Crossing

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Abstract. It is commonly known that the main entity that causes accidents on level crossings is a user of the level crossings. User's behaviour in the area of the level crossing heavily depends on the type of its protection. According to the Slovak level crossings statistics performed by the Slovak Rails, the "most dangerous" crossings are the ones equipped with a level crossing signalling system and an optical warning device. The main aim of the paper is to present a functional representation concept of a level crossing with various types of protection. The modelled level crossing has defined parameters with regard to the Slovak conditions. The Petri nets are used for the description of system behaviour. In conclusion, model comprises of a simple set of states and events that respond to transitions between these states in discrete time periods.

Keywords: approach, level crossing, Petri net, place, protection, safety, specification, transition.

1 Introduction

The accidents at level crossings (LCs) are caused by one or more interdependent factors that simultaneously affect the risk at the level crossing (LC). Those factors include, but are not limited to a type of signalling system, specific characteristics of a level crossing and its surroundings, environment in its immediate vicinity and, most importantly, a human factor. Based on the identification of these factors, numerous methods that should recommend an optimal type of signalling system have been developed in the world. Those methods, in general, assess the impacts of mentioned factors on the possibility of an accident occurrence. Different countries though proceed quite differently to the determination of the most suitable type of signalling system. Nevertheless, they possess a profound method that can handle any type of level crossing in respective country.

This paper's motivation is a study that has been done at University of Žilina recently and has been aimed at the safety of Slovak level crossing and possible ways of its improvement. The other aims of this paper cover the assessment of the current state of Slovak LCs (Chapter 2), identification of possible hazards that could lead to an accident (Chapter 3), identification of other's countries approach to this problem (Chapter 4) and suggestion of applicable solution (Chapters 5, 6).

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2 Types of LC Protection by the Means of Their Safety

The various protection systems of Slovak level crossing are part of the document [1]. From the reasons of limited number of pages we will not describe these systems in the paper.

2.1 Types of LC Protection Used in Slovak Conditions

Currently, there is a total of 2220 level crossings present in the network of Slovak Railways (Table 1). All of these level crossings are considered to be protected, at least by the means of St. Andrews cross [2].

Table 1. The number of level crossings according to their type of protection

LC description	Number of LC's
Total number of level crossings	2220
No signalling	1144
Signalling	1076
Mechanical barriers	100
Light signalling without barriers	454
Light signalling with barriers	522

2.2 Slovak LC Accident Statistics According to the Type of Protection

Based on available accident statistics at Slovak level crossings in [2], we created a dependency of number of accidents that occurred on different types of level crossings within a particular year (Fig. 1). This figure shows that in the terms of level crossing accidents, the crossings equipped with warning lights without barriers appear to be the "most dangerous". On the contrary, the minimum quantity of accidents occurred on level crossings equipped with old mechanical signalling. This fact can be explained due to the presence of Slovak Railways worker at this type of level crossing.

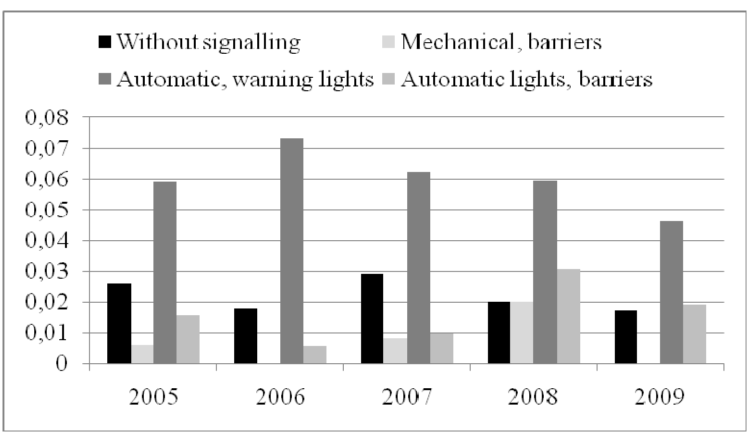

Fig. 1. The number of accidents per level crossing type

According to the obtained results we can draw conclusions that the highest attention of our research should focus especially on crossings equipped with warning light signalling without barriers and on crossings with no signalling. Then we should find various options (i.e. technologies) affecting the mental processes of road user that lead him to comply with established rules of the road traffic.

3 Existing Risk on Level Crossings

An accident at LC can be caused by one cause alone, or by combination of more causes. The degree of importance of the accident-causing factor can range on a scale from the least important (irrelevant) to the most important. In praxis, a weight coefficient is assigned to the respective factor to reflect its importance. In general, there are four distinct groups of these factors, as seen in following sections.

3.1 Road Traffic Characteristics

Road traffic volume, speed and type of a vehicle, road class and range of vision are amongst of the most important factors related to the characteristics of the road traffic.

3.2 Rail Traffic Characteristics

Category of railway characteristics is comprised of factors like rail traffic volume, speed, length and type of the train, approaching time to a level crossing, number of tracks, type of level crossing protection, etc.

3.3 Human Factor

Behaviour of the humans at a level crossing has a great importance in the field of level crossing safety (either on unprotected crossings or on protected ones by any type of the protection system). The most often criticized human behaviour, regardless of motivation, is an attempt to cross the level crossing while the warning is activated. This is closely related to the speeding near and at the level crossing, the fatigue, the use of drugs that extend the driver's reaction time, inability to see or hear the warning and causing the damage (whether it is intentional or not) to the level crossing protection system.

3.4 Type of Environment

An occurrence of an accident can be also influenced by factors related to the vegetation around the level crossing, current weather, position of the sun and its intensity, the geometry of the level crossing, presence of the water bodies that could flood the area etc.

4 The Determination of LC Protection

There have been identified some specific factors in Slovakia that can increase the overall risk related to a level crossing. Traffic moment (product of road and rail traffic volume), category of the railway track, class of the road, range of vision and local conditions are amongst the most important ones. They also serve the purpose of selection of an appropriate level crossing interlocking system. On the other hand, if the change of an actual protection method is in question, then the decision is based only on road volume value and previous occurrence of accidents at the level crossing. There are neither unified rules nor regulations though on how to assess the contributions of those factors on the selection of the most appropriate interlocking system, so the selection is based solely on the agreement of three sides – a representative of Slovak Railways, state authority and traffic police. Following section summarises the approaches and methods of selection of a suitable type of interlocking system that are currently used in other countries according to [3], together with the factors they reflect.

Some countries use simple parameters to determine level crossing protection. The category of these approaches is called Parameter Gate (PG). Parameters correspond to the numerical representation of some factors affecting the occurrence of an accident. The choice of these parameters depends on the considering of their impact on the occurrence of an accident. In most cases the traffic moment is considered to be the most important parameter.

The second category of approaches is the Simple Weighted Factor (SWF) category. These approaches are also based on selected parameters, but the parameters are weighted according to their relevance in the accident-occurring process.

Approaches, where the weighting coefficients for each of the input parameters are constructed in a complex manner, are called Complex Weighted Factor (CWF). They often use some modelling tools that allow expressing links between different parameters and the causes and consequences of accidents. These approaches tend to reflect the highest possible number of different risk-influencing factors of a level crossing.

The fourth category of approaches is called Statistically Driven Approaches (SDA), where the derivation of weighting coefficients of parameters is performed by statistical methods and historical data about each level crossing.

5 General Introduction to Petri Nets

One way how to make the process of choosing of the appropriate type of interlocking more effective is to create a model of a level crossing, through which it would be possible to obtain the required dependencies. Petri nets are an appropriate tool for modelling of complex systems or processes, such as the transport processes, because they allow graphical illustration of the structure of the system, its behaviour as well as the qualitative and quantitative analysis of the problem and its decomposition into smaller parts.

Petri nets are bipartite oriented graphs consisting of places, transitions and edges. Places are represented by circles in Petri nets, rectangles represent the transitions and edges are oriented arcs that connect places and transitions [4]. Current status of the modelled system is expressed by the distribution of tokens. Change in the system is modelled by firing a transition. The transition can be triggered (according to the simplified firing rule) only if all sites prior to the transition are marked with tokens.

The process of firing a transition could be shortly described as follows: from any incoming place to a transition a certain number of tokens disappear (this number depends on the arc multiplicity), since they are consumed by the transition, and appear in all the outgoing places (Fig. 2 shows an example).

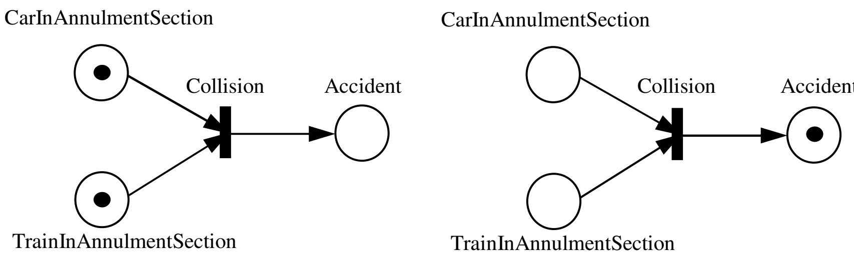

Fig. 2. Simple example of the transition activation process in Petri nets

6 Case Study

Aim of the case study is to present a description of a traffic process, where the description of possibility of car and train collision is emphasised.

6.1 Model Description and Input Parameters

Model represents an exemplary level crossing on a single track equipped with interlocking system with light signals and half barriers. Road crosses the track at the 90° angle. The road is a standard (in Slovak conditions) 1st class road with two lanes, each heading one direction. The relevant part of track comprises of three sections – approaching section, annulling section and departing section. The atypical part of the model is that it reflects the field of vision of the road user, i.e. the ability of the driver to spot an approaching train (from the point in front of the warning board) can be obstructed by wild vegetation or poor weather conditions. However, the field of vision is in Slovakia assumed to be satisfactory at all level crossings, as described in [5]. Given the highest safety integrity level of all level crossing interlocking system (SIL4 is mandatory), the model does not assume with the hardware failure of the interlocking system.

6.2 Basic Model of Level Crossing with Defined Parameters

Based on the chosen assumptions and conditions, the functional model of the level crossing has been created (Fig. 3). Model is comprised of three basic parts (subnets).

First subnet is related to the road user. In the initial state of this subnet the token occupies the *CarLeftLC* place. In this state of the subnet, only one transition – *CarApproachingLCArea* – can fire. This transition represents an approach of the car to the area in the front of warning board. It is assumed that the driver stops here and makes themselves sure that there is no approaching train in the annulling section. The correct judgement of the driver heavily depends on their actual field of vision. An optimal field of vision is achieved by clearing the relevant area from vegetation and other possible obstacles that could prevent the driver to spot an approaching train. Nevertheless, the reality is often far from this optimal situation. Sometimes, the visibility can be obstructed by local weather conditions, e.g. a fog.

Given the good visibility at the level crossing, there are two different scenarios possible – first, the driver checked that there is really no train approaching (represented by both *NoTrainApproaching* transitions) and the second, when driver can actually see the train in the distance (the *TrainApproaching* transitions).

Given the bad visibility, another option is possible in addition to the two mentioned above – the driver cannot see the train and if they does not respect the activated warning, they can collide with the train. This driver's possible behaviour is represented by the *CarAndTrainAtLC* transition.

When one of the six transitions fire (i.e. *NoTrainApproaching, TrainApproaching* or *CarAndTrainAtLC*) the token reaches one of the *CarInAnnulmentSection* places, which is self explaining – the car is in the annulment section and three different scenarios can take place from now on. In the first scenario, the car clears the annulment section and the subnet reaches its initial state. In the second scenario, the collision of the train and car occurs, which means an accident happens. The third scenario is described as an *almost collision* scenario. The latter scenario is not summed up in the accident history of the level crossing (because in reality it cannot be revealed unless the level crossing is under camera surveillance), but can increase the risk at the respective level crossing. At last, if there has an accident occurred, it has to be removed in order to continue in the traffic process. The model is also restarted by this operation. The traffic volumes of the road and railway traffic are implemented to the model through the *CarApproachingLCArea* and *TrainClosingToApproachingSection* transitions.

Second subnet of the model describes the movement of the train through three track sections. There is a clear resemblance between this subnet and the subnet that describes the movement of the car. The only real difference (other than in function) is in the test arc that specifically affects the behaviour of the model. Basically, it is a bidirectional arc that connects place with transition. After firing a transition, the token in the place connected to this transition with a test arc is not consumed.

The last and the simplest part of the model is the subnet that represents the actual behaviour of the level crossing, as seen from the driver's point of view. It is comprised of two places, *BarriersOpen* and *BarriersClosed*. Firing of transitions between those places is conditioned by the presence of the tokens in places *TrainInApproachingSection* and *TrainInDepartingSection* respectively.

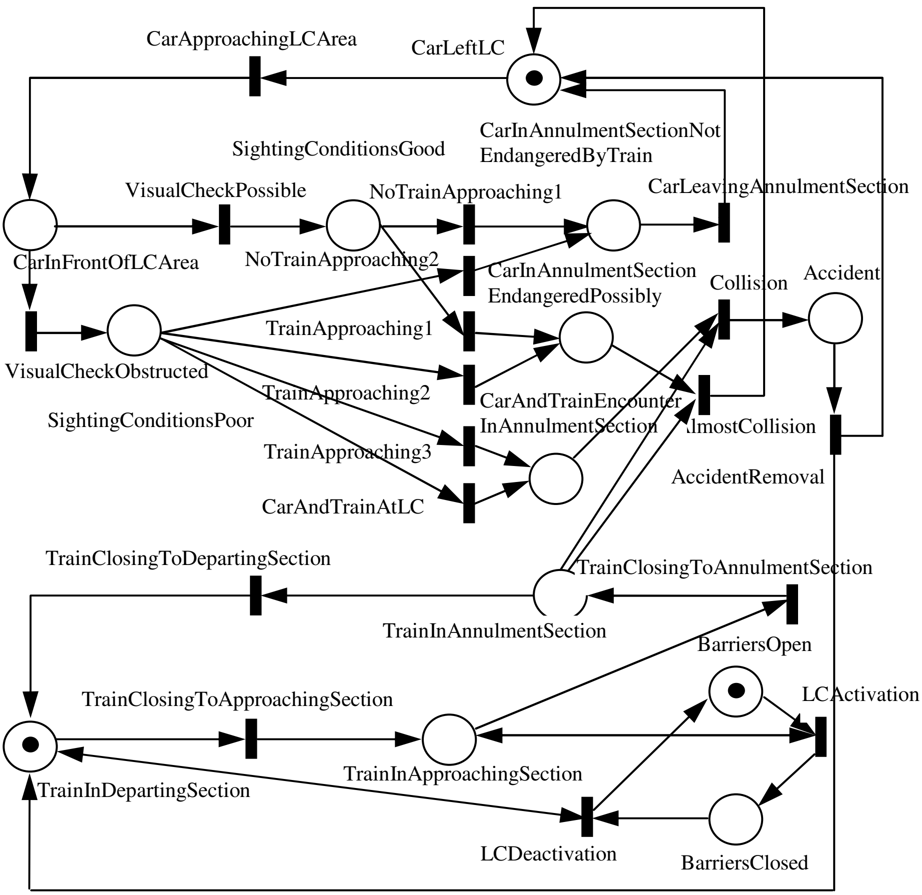

Fig. 3. Petri net model of a level crossing

7 Conclusion

The functional model presented in the paper serves as a necessary solid foundation for further work on appraisal of respective accident-affecting factors of the level crossings in Slovakia. The model will be conveniently extended as new factors will be added to the model, in order to create a comprehensive functional model of the level crossing. Current state of the model can be subjected to various formal verification methods that are provided by the Petri nets theory.

Despite the complexity of the current and future form of the model, it still is and will be understandable by non-experts in the field, which makes the representation of the quantitative as well as qualitative results easy and directly applicable as a form of recommendations on increasing the safety of the current level crossings. Eventually and if applicable, the risk at the level crossing will possibly be decreased through an application of innovative technologies at specific level crossing, which will also be implemented in the single Petri net functional specification.

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Mathematical Apparatus for Safety Evaluation of Cryptography and Safety Codes Used in Safety – Related Communication System

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Abstract. The paper deals with the problems of safety evaluation of a combined system, which consists of the cryptography and the safety codes applied in the safety communication layer within a safety-related system. In most cases the cryptography codes are combined with the safety codes which increase the performance of the cryptography system. In these applications it is very important to realise the optimisation of the selection of safety and cryptography codes parameters so that the probability of errors in the output of the cryptography decoder caused by electromagnetic interferences (EMI) will be under guaranteed safety integrity level (SIL). The main part of the paper presents the numerical results of an average probability of block cryptography codes used in praxis (block ciphers 2-DES, 3-DES, AES) with a combination of several code words lengths of safety block channel Hamming codes depending on the bit error rate (BER) of the noise communication channel.

Keywords: safety-related communication system, cryptography code, safety code, safety integrity level, probability of error, bit error rate, code word length, 3-DES, AES, Hamming codes, safety evaluation.

1 Introduction

The cryptographic techniques are primarily used in security critical applications, e. g. banking sector, e-health, road traffic [1] or SCADA/HMI systems [2]. However, there may also be useful applications of cryptographic techniques in the safety critical systems, mainly in very important sub-parts of these systems – the communication parts. There are basically two types of cryptographic systems: symmetric and asymmetric cryptographic systems. In most systems the key is the secret part, whereas the encryption/decryption algorithm is public. Nowadays many symmetric or asymmetric algorithms were developed in parallel with methods of the key management system mainly for wireless communications [3], [4] and new methods are permanently developed. Only some of them are recommended for use in safety critical applications, where a failure can cause damage to persons, property or the environment. The situation is even worse in the process of quantitative safety evaluation of cryptography mechanisms which are designed for safety-critical control systems [5], [6]. Today the cryptography standards for commercial areas (e. g. financial sector, company

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information systems, ...) are well known, e. g. [7], but for applications of cryptography in systems increasing the safety integrity level (SIL) the methodology for safety evaluation is absent.

The cryptographic techniques are recommended for use within safety-related applications (e. g. safety-related control systems in the railway transport or dangerous industrial process control) if malicious attacks within the open transmission network cannot be ruled out. This is usually the case when safety-related communication uses a public network, a radio transmission system, wireless technology (Wi-Fi, ZigBee,…) and a transmission system with connections to public networks mainly via the internet. The cryptographic techniques can eliminate masqueraded messages and support confidence of transmission, authentication of source messages and message integrity which can be corrupted during transmission. A practical demonstration of the cryptography code use in safety-related control system is the message authentication code MAC which is recommended for use within safety critical railway applications in the Euroradio system developed within the European Train Control System (ETCS) [8].

The degree of effectiveness of cryptography mechanism depends on the strength of the algorithms and the secrecy of the keys.

General requirements for a cryptography code are described very well in the standard for railway applications [9]. For a developed application with cryptography mechanism the proof of safety must be submitted. The safety case for the cryptography mechanism shall demonstrate the appropriateness of the following:

- technical choice of cryptographic techniques, including
    - performance of encryption algorithm (selection of symmetric or asymmetric cryptography system and the mode of operations),
    - characteristics of key (key length, frequency of key update, physical storage of keys,…),
- technical choice of cryptographic architectures, including
    - checking the correct functioning (before and during the operational phase) of the cryptographic processes,
- management activities, including
    - production, storage, distribution and revocation of confidential keys,
    - management of equipment,
    - review process of adequacy of cryptographic techniques, in relation to risks of malicious attacks.

The choice of the safety code and cryptographic techniques shall be determined according to the following [9]:

- whether or not an unauthorized access can be ruled out,
- the type of cryptographic code proposed.

In general two possibilities of safety-related access process realizations are recommended: the access protection layer inside every safety-related device or a separate access protection layer, which is common for several safety-related devices. The second solution can be useful in those cases where groups of safety-related devices which are connected by a local area network (LAN), have to communicate over open transmission systems (see Fig. 1). In this case the cryptographic functions can be combined with gateway functions which are normally required when a LAN is connected to a, for example, wide area network.

The access protection process can be performed by different modes [9]:

a) enciphering of the messages;
b) adding a cryptographic code.

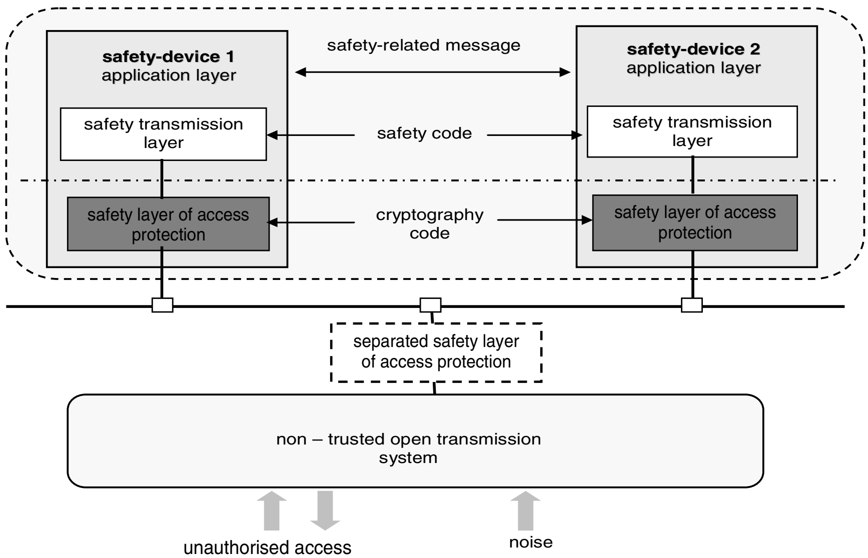

Fig. 1. Principle of two possibilities of safety-related access process realizations within safety-related communication

2 Safety Analysis of EMI Effect on a Combined Communication System

The cryptographic techniques can be combined with the safety encoding mechanism or provided separately. In the majority of applications the safety code is located in the safety layer "transmission protection" and the cryptography code in the safety layer "access protection", Fig. 1. Let us assume the end – to end communication system illustrated in Figure 2 which consists of the safety and the cryptography codes on the transmitter side and the safety and the cryptographic decoder in the receiver. The use of safety code increases the performance of the cryptographic system [10]. We farther assume the application of the block cipher (as the cryptography code) and the linear block correction channel code (as the safety code). Messages (plain text) of length n are first enciphered by a block cipher of length k and than coded by some type of safety code, thereby the code word w is created. Then the messages are transmitted across the noise communication channel. In the receiver the code word w is first decoded in the safety decoder, which corrects the communication errors with the value of corrected error probability, then the cipher code word c_w is deciphered in the cryptographic decoder and the plaintext is created. The distribution of communication errors for wrong selection of parameters of the cryptography and the safety codes can overrun the possibility of safety decoder to correct the errors. This is why we must very sensitively select these parameters and define the bounds of probability of the cryptography code words depending on features of the safety code and on the conditions within the communication channel.

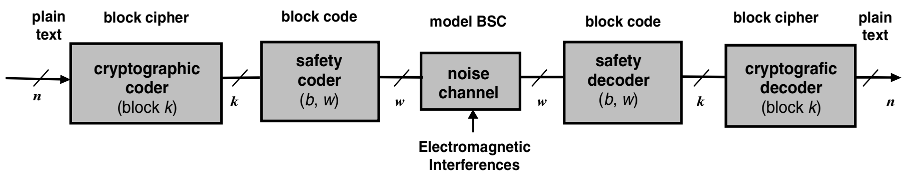

Fig. 2. Combined communication system

Nowadays for secure critical applications the computational block ciphers, e.g. modification of Data Encryption Algorithm (DES) 2-DES or 3-DES are recommended which work with the block length of $k = 64$ bits. More frequently a new block cipher Advanced Encryption Standard (AES) – Rijndael is recommended for use with the processed block length of $k = 128$ bits. For safety critical applications the cryptography system with a secret key is recommended based also on a block cipher in the cipher block chaining (CBC) mode [11]. The application of the stream cipher in safety-related communication systems is dissuaded [9].

Concerning the safety codes applications within safety related - communication systems, the linear block detection codes are recommended with the decoding principle based on the syndrome technique of determination. This requirement is satisfied by a group of channel block codes, from which for the purpose considered cyclic codes based on cyclic redundancy check (CRC) are mostly used. Recently the possibilities of error correction block codes are studied, primarily if the safety codes algorithms are effective and very well known, e.g. Hamming codes; possibly non-binary Reed Solomon codes up to now using their decoding possibilities [12]. A safety-related application requires that one safety code secures the messages of different lengths.

As it is illustrated in Fig. 2 the block safety code processes the block of length b to which the redundant bit r adds, whereby the code word of length w is created.

Note

In this paper the safety error correction codes are assumed, which parameters are marked as (b, w) instead of (n, k) usually applied in the channel theory. Symbols n, k are used for parameters in the input and the output of the cryptography coder (as it is illustrated in Fig. 2).

As it is well known two parameters are used in the process of safety evaluation of the block correction codes: the minimal Hamming distance of code d_{min} and the probability of uncorrected error of code words w in length.

The probability of uncorrected error of code word p_w depends on the bit error rate p_b of used transmission channel. In practice the different types of transmission channels have different values of p_b and a different behaviour of noise in specific media. In many cases the model of binary symmetric channel (BSC) or q-nary symmetric channel (q-BSC) are assumed.

If the linear block safety code with minimal Hamming distance $d_{\min}$ is applied, the code can correct β errors in code word of length w, whereby $d_{\min} \geq 2\beta+1$ must be valid. For the determination of the probability of uncorrected errors p_{w} in code word w, when the BSC channel with bit error rate p_{b} is assumed, the following is valid

$$p_w \leq \sum_{\|i=\beta+1\|}^{w} \binom{w}{i} p_b{}^i (1-p_b)^{w-i}, \tag{1}$$

what can be approximated by

$$p_w = \binom{w}{\beta+1} p_b{}^{\beta+1} (1-p_b)^{w-\beta-1}. \tag{2}$$

If we assume the independence of errors in the input of the cryptographic decoder in Figure 2, it is possible to present the relations for the probability of error of cryptography word p_{cw}, what is described in the next part.

3 Error Probability Bounds of a Combined Communication System

If we want to keep the relations for the probability of error of the combined communication system illustrated in Fig. 2 we must first describe the error probability of cryptography code word in the output of the safety decoder separately of the safety code.

Let us suppose the cryptography text bits of blocks k are erroneously received by the cryptographic decoder as a result of random noise or other interference. As the erroneous bit proceeds through the decoder of cryptography code each of n consecutive output bits may be affected. No output words are in error unless the received cipher text block contains a bit error in at least one of its n bits. Assuming the independence of input bit errors for probability of cipher code word p_{cw} the following equation is valid

$$p_{cw} = p(w|be)[1-(1-p_b)^n, \tag{3}$$

where $p(w/be)$ is the probability of an error in an output word given that there is a block error at the cryptographic decoder.

Within communication between cryptography text blocks and plaintext blocks an error in a received cryptography text block is transmitted at least to one bit of output block. Repeating the analyses for successive output bits the relation for an average probability of an error in an output word is determined [13].

$$\overline{p}(w/be) = 1 - \prod_{i=1}^{n} \frac{2^{n-1}-1}{2^{n+1-i}-1} = \frac{1-2^{-k}}{1-2^{-n}}. \tag{4}$$

Combining this relation with (3) we obtain the average error probability of cryptography code word for block cryptography code as

$$\overline{p}_{cw} = (1-2^{-n})^{-1}(1-2^{-k})[1-(1-p_b)^n]. \tag{5}$$

With the use of the Taylor series expansion we obtain

$$\overline{p}_{cw} \approx (1-2^{-n})^{-1}(1-2^{-k})(1-2^{-k})np_b. \tag{6}$$

The relation (6) is valid if the following condition is fulfilled

$$p_b << 2(n-1)^{-1}. \tag{7}$$

If we want to derive the relation for the average error probability (5) for combined communication system illustrated in Figure 2 we must include the effect of error correction possibilities of the safety code into this relation. The preceding derivations of the cryptography error probabilities were based on the condition of independency of bit errors at the input of the cryptographic decoder. However, assuming the independence of the input word errors we can relate the word error probabilities at the output of cryptographic decoder to the word error probabilities as at the input. This assumption is valid when the block codes are used for the error correction and the symbol errors at the input to the decoding system are independent.

Let us define parameter h as the number of input words that can cause a train of external origin in an output word. Because the value of h is equal to the number of input words that overlap some of the n-1 bits in output words we can write

$$h = \left\| \frac{n-2}{k} \right\| + 1. \tag{8}$$

The value $\|x\|$ marks the largest integer less than or equal to x. Let $P(t)$ describes the probability that the train of external origin extends into an output word. From the theorem of total probability the probability of cryptography code word p_{cw} is [13]

$$p_{cw} \leq p(t) + p_w, \tag{9}$$

therefore

$$p_{cw} \leq 1-(1-p_w)^h + p_w \leq (h+1)p_w, \tag{10}$$

where p_w is the probability of error of code word in the input of cryptographic decoder. For the block cipher we can modify relation (10) to

$$p_{cw} \leq 1-(1-p_w)^{n/k} \leq \frac{n}{k} p_w. \tag{11}$$

The expression of an average error probability of cryptography code word is complicated. The following relation is shown in [13]

$$\overline{p}_{cw} = (1-2^{-n})^{-1}(1-2^{-k})[1-(1-p_w)^{n/k}]. \tag{12}$$

The integer n/k denotes the number of words in a block.

4 Results for Choices of a Combined Communication System

The results of the average error probability of the combined system were obtained for systems, which nowadays comprise computationally safe block ciphers with block length of k = 64 bits (e.g. valid for 2-DES or 3-DES) and k = 128 bits (e.g. valid for AES) with the combination of single-error correction safety block Hamming codes depending on the bit error rate p_b of communication channel for several lengths of plaintext n.

First, the probability of uncorrected error for several lengths of Hamming codes from 7 to 1023 bits was determined. As it is well known Hamming codes are the perfect channel codes because of favourable rate between the information and the redundant part. Minimal Hamming distance d_{min} = 3 is typical of the Hamming code and $n = 2^m - 1$ is valid for the length of code words, where m is a natural number. In Table 1 the results of the probability of uncorrected word p_w for a valid length of Hamming codes according to relation (2) were determined, at which the bit error rate of communication channel p_b=10^{-5} is assumed.

Table 1. The pprobability of uncorrected code words for several lengths of Hamming codes ($p_b = 10^{-5}$)

Code word length	7	15	31	63	127	255	511	1023
p_w [-]	5.89 10^{-9}	1.00 10^{-8}	4.64 10^{-8}	1.95 10^{-7}	7.99 10^{-7}	3.23 10^{-6}	1.29 10^{-6}	5.17 10^{-5}

For each code it is possible to determine all characteristics of the probability of uncorrected errors in the code word depending on the bit error rate if the application is required as it is illustrated in Table 2 for (127, 120) Hamming code.

Table 2. The average error probability of combined communication system versus p_b

p_b	10^{-8}	10^{-7}	10^{-6}	10^{-5}	10^{-4}	10^{-3}	10^{-2}	10^{-1}	2^{-1}
p_w [-]	8 10^{-13}	8 10^{-11}	7.99 10^{-9}	7.99 10^{-7}	7.9 10^{-5}	7 10^{-3}	2.3 10^{-1}	1.23 10^{-4}	7.8 10^{-3}
$\overline{p}_{cw}$ [-] **k = 64**	1.25 10^{-10}	1.25 10^{-8}	1.24 10^{-6}	1.24 10^{-4}	1.23 10^{-2}	X	X	X	X
$\overline{p}_{cw}$ [-] **k = 128**	6.2 10^{-11}	6.25 10^{-8}	6.24 10^{-7}	6.24 10^{-5}	6.17 10^{-3}	5 10^{-1}	X	X	X

Note: The communication system consists of cryptography code with code word length k = 64, k =128 and (127, 120)

When we combine the safety code with the cryptography code (as it is illustrated in Figure 2) and we assume the noise channel we must to optimise the length of code words in dependence of the cryptography code word and the message length in the input of the system that the probability of error p_{cw} in the output of cryptography decoder will be under the guaranteed SIL. The spread of residual errors within transmitted messages, which were not corrected by the safety decoder, can cause that the system will cause a hazard state. This is why in the process of safety synthesis it is necessary to know all characteristics of p_{cw} (if the parameters are known) and then select the right parameters accordance in the noise characteristic of communication channel or length of transmitted messages. Let assume the length of message 10^4 bits and the length of the cryptography block cipher k = 64 bits and k =128 bits then the result of p_{cw} value for the Hamming code word (127, 120) is illustrated in Figure 3. The results were determined using relation (13) which is a modification of (12) using Taylor series expansion, because for selected parameters the required condition (14) is accomplished.

$$\overline{p}_{cw} \approx \frac{(1-2^{-k})}{(1-2^{-n})} \cdot \frac{n}{k} p_W . \tag{13}$$

$$p_w << \frac{2k}{n-k} . \tag{14}$$

In Table 2 the X fields mark that the condition (14) is not fulfilled.

If we use the detection safety code and we do not know its parameters, we can approximate the value in relation (2) by the worst case (according to standard [9]) $P_w = 2^{-r}$, where r is the number of redundant bits. Let us assume that the safety code with r = 16 bits that the probability of undetected error of code word $P_w = 2^{-16}$ (according to standard [9], so called the worst case) and the message length $n = 10^4$ bits. Then the graphical results of $\overline{p}_{cw}$ dependence of the code words k = 64, k = 128 and k = 256 in the input of cryptographic encoder are illustrated in Fig. 3.

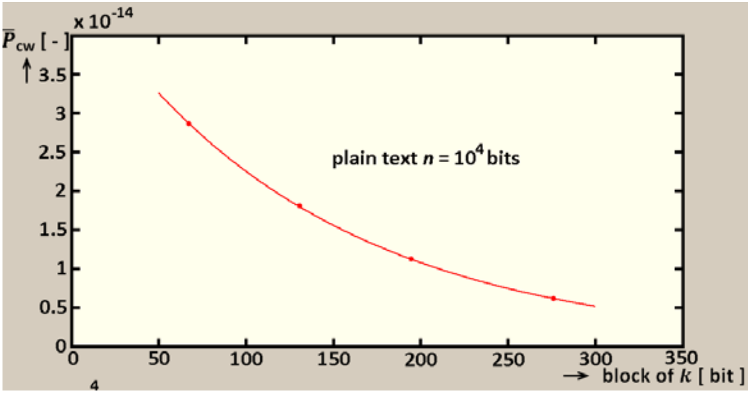

Fig. 3. Example of an average error probability of the cryptography code word vs. k

5 Conclusions

The safety-related communication systems must be resistant to random failures, which can occur in HW elements of a transmission system or in a noise communication channel. We can eliminate the effect of electromagnetic interferences (EMI) applying safety detection or correction codes. When the safety code is combined with cryptography codes the effect of EMI is shifted from the block of safety code to the block of cryptography codes. In this case the optimisation of the parameters selection of both codes is a very important task of the designer of a safety-related system according to the required safety integrity level. The noise effects on the communications system can be determined in several ways. The standards much recommend the mathematical model based on a probabilistic access. The paper describes first the mathematical apparatus for the probability of uncorrected errors valid for linear block safety codes, and then the relations for average error probability of cryptography block codes are mentioned with the orientation to block cryptography cipher with practically used blocks of 64, 128, 256 bits in length. Results include the numerical values of the average error probability of combined systems, consisting of valid length of Hamming codes with the combination of block cipher DES, 2-DES, 3-DES and AES.

Within the safety analysis of a safety-related system it is necessary to take into consideration that the mathematical apparatus for an average error probability of cryptographic decoder with the combination of safety error correcting codes is based on several initial conditions, e.g. BSC model of communication channel, independence of errors in the input of cryptographic decoder, which in real conditions are not necessarily fulfilled. In this case the approximation for the worst estimation (probability of error 2^{-r} for safety code) is very often used and by the resulting relation connected to several lengths of the original message and of cryptography codes. Also it is very important matter to determine all characteristics of p_{cw} versus the bit error rate of communication channel for each transmitted length of message. The process of safety analysis described in the paper for several combinations of safety and cryptography codes can be used after modification of input parameters for the safety analysis of another type of the block cipher and block safety code.

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A Modular Weather and Traffic Data Acquisition Network to Improve Green Traffic Management

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Abstract. Climatologists forecast drier summers and more humid winters in Germany and Central Europe over the next few decades. If incidents such as storms, thunderstorms or floods increase, then the consequences on traffic, the economy and the mobility of people will also increase. Furthermore, coping with climate changes and protecting the environment plays a more and more significant role. New environmental laws and guidelines in Europe force politics and economy to act which requires e.g. innovative concepts for traffic management. Risk protection can only be assumed if the risk is known in due time. In extreme cases, target-oriented information can save lives, protect infrastructures, increase safety and save energy. In order to gain this information, a modular data acquisition network is necessary for the cost-efficient capture of traffic and environmental data.

Keywords: green traffic management, data acquisition network, weather and traffic data.

1 Introduction

With the steady increase of the frequency and intensity of storm events during the last few years, the question emerges on how society can protect itself from such dangers and damages in an appropriate way. Early warning systems play an essential role as they inform the persons affected in time and allow the quick initiation of activities. In most instances, existing systems are specially developed for the emergency services and the fire department or they are general systems for the spreading of information to the person affected. However the particular requirements for traffic are inadequately taken into consideration.

In addition, the traffic management must deal even more with questions of environmental protection and climate change. The limit values for air pollutants defined by the European Commission will increasingly determine the terms of the traffic management. Since the 1980s, significant progress has been achieved in the reduction of harmful emissions. The development of new engines and pollutant control equipment, the ban of toxic substances in fuel and better traffic planning also contributed to this progress. However, there are still large problems regarding noise and some air pollutants (e. g. CO2, NOx or particulate matter).

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2 Local Data Acquisition

The efficiency of traffic management is dependent on the availability of a powerful traffic data acquisition network, functional data processing and digital media (e. g. Internet, Mobile Phone Apps, Digital Audio Broadcasting [4]) for the provision of traffic information. High investments and running costs of technical means are a real obstacle for the wide implementation of Intelligent Transport Systems (ITS) in a whole city or region. Here alternative ideas are requested to tackle the problems on rolling out ITS in cities.

In order to be able to value the interaction between traffic and environment as well as the effects of weather events and climate changes at regional level, it is necessary to gather suitable characteristics in high temporal and spatial resolution. The goal of the ongoing research and development work is the concept and practical implementation of a modular weather and traffic data acquisition system. This system is the basis of the distributed capture and processing of traffic data, environmental data and weather information as well as their transmission and integration into an environment-oriented and sustainable traffic management.

In traffic and transport there are already numerous sophisticated processes and models for the data capture and data fusion as well as for the determination and prediction of the situation on roads. For weather events, the local prediction quality can be improved considerably by a compact measuring network and the use of additional prediction methods. With the technologies used up to now (radar, satellite photos), local effects can be estimated only roughly. In particular, dangers by thunderstorms or floods are hard to forecast. The establishment of a compact measuring network often fails because of the high costs for acquisition and maintenance of the measuring stations.

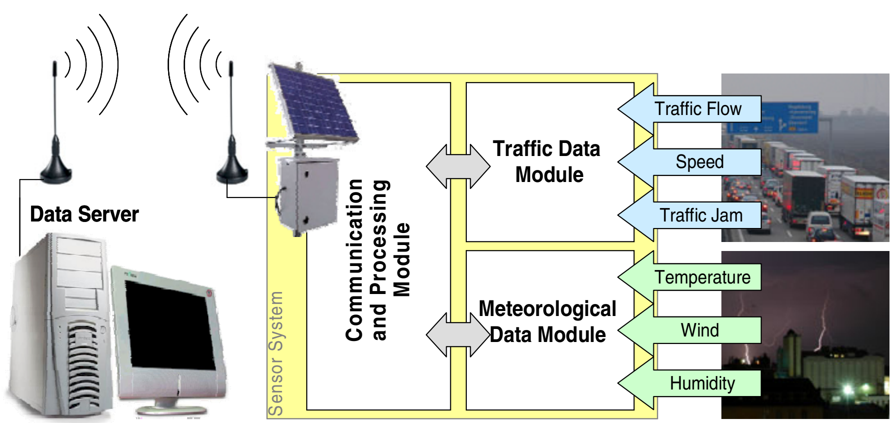

Fig. 1. Modular sensor system for the distributed capture of traffic and environmental data

Alternatives through the use of other measuring devices (e. g. private measuring stations, municipal measuring networks) as well as the interlinking of small, cost-effective measuring stations have hardly been examined up to now. One research goal is to improve local traffic and weather predictions by developing innovative and reasonable sensor systems and to speed up the capture and fusion of different measuring data, particularly traffic data (traffic flow, vehicle classes, speed, traffic congestion) and weather data (wind speed, wind direction, amount of precipitation, temperature, air pressure, air humidity, brightness).

Other data such as air pollutants (e. g. CO2, NOx or particulate matter), noise or water levels of rivers can be measured optionally. The sensor system is complemented with a communication module for the wireless data transfer (Fig. 1). The development concentrates on robust and inexpensive solutions for the capture of traffic data and environmental data. The sensors are characterized by low power consumption, so that a self-sufficient operation is possible with the help of solar panels or compact wind generators.

The data of the different sensors are gathered by a standardized interface of the communication system. This approach allows the easy connection of different measuring devices, the standardized processing of the measurement values as well as the modular extension of the system. Thus, the purposeful adaptation to the technical conditions and the transport infrastructure is possible. The modular monitoring devices are integrated into available data and communication networks and deliver information for the regional traffic management and environmental monitoring in Central Germany which is established at the moment.

2.1 Weather Data Acquisition Module

Currently used methods for measuring unusual or extreme weather situations (e.g. heavy rain, hail, thunderstorms) mainly base on data that are gained from measurement systems such as radar, satellite or complex, multi-functional meteorological stations. However, a locally deduced prognosis of weather and associated risks by means of the acquired data can be provided only roughly, since those premium and expensive techniques are available in a limited number, only. An enhancement of the spatially resolved prognosis therefore requires a close-meshed system for meteorological data acquisition. The central goal of the early-warning system is the efficient, situational and reliable distribution of warnings in the case of extreme weather based on an early, individual and goal-orientated information supply [3]. Accordingly, the presented approach focuses on the development and utilisation of low-cost extreme weather sensors, which can easily be integrated into the network of existing meteorological stations as well as traffic data acquisition network.

With regard to the various sources of danger induced by climate change processes, the sensor part in the research work mainly focused on the acquisition of wind (speed and direction) as well as precipitation (rain, hail). Established techniques (rotating cup star transmitter, wind vane, tipping-bucket) to determine these meteorological parameters depend on moving parts, however. Thus they can be maintenance-intensive or tend to fail in the long term use. Within the framework of the presented work a low-maintenance sensor mode of operation is aimed in order to achieve a significant sensor cost reduction and to allow for an increased spatial density of sensor stations. One key component for success of the work therefore consisted of specially developed wind and precipitation sensors which do not contain any moving parts. Detailed results of developed sensor modules can be found in [2], [6].

The sensor principles of precipitation and wind measurement can be combined in a single cost-efficient device. Moreover, it is possible to include also other meteorological sensors such as for brightness humidity or temperature in order to provide for a multi-sensor environmental monitoring tool.

Fig. 2. Completely equipped sensor station with developed wind and precipitation sensors (bottom right) in combination with reference sensors (bottom left and top)

Through the installation of these environmental sensor stations (nodes) a close-meshed network in addition to conventional techniques (premium and expensive meteorological stations, radar, satellite) can be established. Accordingly, numerous meteorological data can be gained with an enhanced spatial and temporal resolution, which provide the basis for an improved and locally concentrated weather prognosis [1], [2].

2.2 Traffic Monitoring Module

An overall knowledge of the inner-city traffic state is a prerequisite for a functioning traffic management both in private and public transport. Today, the acquisition of traffic data is performed mostly by stationary systems. Typically, induction loops, radar detectors, laser scanners, passive infrared detectors and also image processing systems are used for this purpose. Supplementary, floating cars, which act as mobile traffic sensors, transfer their traffic data speed and position.

When using these conventional detection systems several problems can occur. In Germany, stationary induction loops at traffic lights are the common devices for the acquisition of traffic data, though the underlying purpose of these systems is to enable a traffic actuated control of traffic lights. Because such measuring points are rather rare compared to a whole inner-city road network, complex models are applied in order to conclude the entire traffic state from the limited amount of data measured.

Another weak point of traffic management so far is that temporary sensitive areas can not be fully covered (e.g. long time road works and traffic congestions between local detectors). To solve the mentioned problems, traffic monitoring technologies must be functionally self-sufficient and low-cost. They also have to be independent of autonomous, fixed data communication infrastructure. Ideally they can deliver track related traffic data. They can be flexibly mounted at different locations (so called mobile usage) for certain measurement periods.

Facing the above mentioned problems a modular traffic monitoring system was developed. The roadside device is part of a traffic data acquisition network. The general architecture of the traffic monitoring module is illustrated in Fig. 3. Each device sends the gathered traffic data (raw or processed data) of the attached passive infrared detectors to a central device management application. This server application stores the traffic data in a database system. Other systems or applications like traffic and quality management systems, information platforms or mobile devices can access the gathered traffic data, for instance by database queries or via web services.

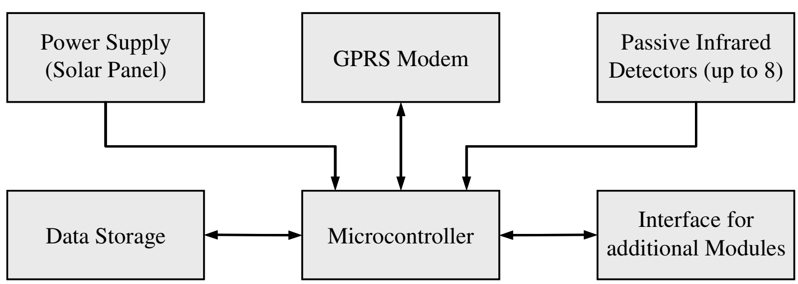

Fig. 3. General architecture of the modular monitoring module (roadside device) [5]

The roadside device uses a solar panel and an accumulator to assure the power supply. Therefore all components of the device have to feature low power consumption. Passive infrared detectors are used to count the vehicles passing the measurement cross section. They can also measure the speed of the vehicles. Through the use of established cellular phone networks (GPRS – General Packet Radio Service), the device is independent from local communication infrastructure. A memory card is provided as storage for traffic data. This also serves as a fall back if the GPRS connection is temporarily not available.

The gathered traffic data are sent to a central application using data telegrams which are conform to TLS (german technical delivery conditions for route stations). The TLS of the German Federal Highway Research Institute define standard telegrams for exchanging traffic data. The roadside device has an interface for additional modules which for instance establishes a connection to meteorological and environmental detectors or a camera system. This interface provides the power supply for additional modules as well as for several communication interfaces.

Fig. 4. Prototype of the modular traffic monitoring module (mounted on a lamp pole, with solar panel and two Passive Infrared Detectors for adjacent lanes) [5]

The roadside devices are mounted with standard clamps e.g. on lamp poles (Fig. 4). The independence of a fixed infrastructure and the use of standard components reduce the investment costs significantly. This feature allows not only the cost-optimised usage for reducing the mesh size of data acquisition networks, but also the instant operation at road work areas.

3 Conclusion

The results achieved so far show that current opportunities in local monitoring of traffic conditions and incidents can be improved by use of new weather and environmental measurement strategies and forecast methods. The concept of distributed modular monitoring devices in a data acquisition network meets the demands regarding self-sufficient power supply, mobile communication and flexible usability.

Therefore an important point of further research aims towards device management and device configuration in heterogeneous sensor and data acquisition networks. Based on the extension of existing traffic and meteorological networks with distributed cost-effective, function-optimized sensor systems a higher spatial and temporal resolution of obtained weather and traffic data can be achieved. But it is hardly known how single actions of the traffic management (speed limits, environment protection zones, diversions, bans on driving) have an effect on environment and climate, and also how legal regulations and limit values can be taken into consideration. The effectiveness of different measures of the traffic management and environmental management shall be analyzed in upcoming field investigations.

The practical implementation and testing of a modular weather and traffic data acquisition system for the distributed data capture is in the focus of a current research project in Magdeburg (MD-E4: Energy-efficient city of Magdeburg – a model city for Renewable Energies). To achieve the ambitious energy savings targets for the city of Magdeburg in 2020, the step-by-step implementation of an intelligent and environmentally-oriented traffic information and management system will be supported in one of the 11 sub-projects. However, this requires a comprehensive knowledge of the traffic and environmental situation. Therefore, the required data should be continuously recorded and evaluated. In this way complicated interaction between environment and traffic can be analyzed. In combination with traffic models and prognosis techniques an efficient and green urban traffic management can be established in the next few years.

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The Advantages of the Use of Cloud Computing in Intelligent Transport Systems

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Abstract. One of Information and Communication Technologies (ICT) benefits for the society are Intelligent Transport Systems (ITS), which make transport more efficient, faster, easier and reliable. Nowadays one of the most important aims of ITS is that these systems must become faster commonly used. Internet services are one of such solutions, cloud computing services, in particular. Generally the cloud computing is Internet-based computing, whereby shared resources, software, and information are provided to computers and other devices on demand, like the electricity grid. The advantages, particularly concerning the technological and economic aspects, of the use of cloud computing services in ITS are described in this paper.

Keywords: cloud computing, intelligent transport systems, information and communication technologies.

1 Introduction

Multiple initiatives have been initiated world-wide to define the key enabling the main aim that the use of Information and Communication Technologies (ICT) will have to play to maximize the social and economic potential of ICT, the Internet, in particular – today a useful medium of economic and societal activity [1], [2].

Intelligent Transport Systems (ITS) are one of ICT-enabled benefits for society, which make the transport more efficient, faster, easier and reliable. Nowadays one of the most important aims of ITS is that these systems must become faster commonly used [3].

Internet services are one of such solutions, cloud computing services, in particular. Generally the cloud computing is Internet-based computing, whereby shared resources, software, and information are provided to computers and other devices on demand, like the electricity grid [4].

The advantages, particularly concerning the technological and economic aspects, of the use of cloud computing services in ITS are described in this paper.

2 Cloud Computing

It is true that the cloud computing is a revolution that will define information technology (IT) in the second decade of the 21st Century. This new form of computing

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is perfectly poised to provide solutions to a host of business problems within organizations large and small [5].

2.1 Definition of Cloud Computing

The cloud computing is a model for enabling convenient, on-demand network access to a shared pool of computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction [6].

In its definition of cloud computing, The National Institute of Standards and Technology (NIST) describes the cloud computing as having five essential characteristics, three service models, and four deployment models. This definition attempts to encompass all of the various cloud approaches [5], [7], and [8].

Essential Characteristics. The following list identifies the essential characteristics:

- **on-demand self-service.** A consumer can unilaterally provision computing capabilities such as server time and network storage, as needed automatically, without requiring human interaction with each service's provider.
- **broad network access.** Capabilities are available over the network and accessed through standard mechanisms that promote use by heterogeneous thin or thick client platforms (e.g., mobile phones, laptops, and PDAs).
- **resource pooling.** The provider's computing resources are pooled to serve multiple consumers using a multitenant model, with different physical and virtual resources dynamically assigned and reassigned according to consumer demand. There is a sense of location independence in that the customer generally has no control or knowledge over the exact location of the provided resources, but may be able to specify location at a higher level of abstraction (e.g., country, state, or data center). Examples of resources include storage, processing, memory, network bandwidth, and virtual machines.
- **rapid elasticity.** Capabilities can be rapidly and elastically provisioned, in some cases automatically, to quickly scale out and then rapidly released to quickly scale in. To the consumer, the capabilities available for provisioning often appear to be unlimited and can be purchased in any quantity at any time.
- **measured service.** Cloud systems automatically control and optimize the resource use by leveraging a metering capability at some level of abstraction appropriate to the type of service (e.g., storage, processing, bandwidth, and active user accounts). The resource usage can be monitored, controlled, and reported providing transparency for both the provider and consumer of the utilized service.

Service Models. The following list identifies the service models:

- **Cloud Infrastructure-as-a-Service (IaaS).** This is really the most basic cloud service model, aligning the on-demand resources of the cloud with tactical IT needs. In this way, IaaS is similar to managed services offerings of the Internet era (i.e., hosting services, storage service providers (SSPs), etc.). The primary difference is that cloud resources are virtual rather than physical and can be consumed on an as-needed basis. In other words, enterprise consumers pay for virtual machines (VMs), storage capacity, and network bandwidth for a variable amount of time rather than servers, storage arrays, and switches/routers on a contractual basis. Typically, enterprises have no control over the underlying cloud technology. As described above, IaaS can be utilized as a temporary resource or used for years at a time. IaaS prices are based upon two factors: IaaS resource consumption and the duration of use. Iaas examples include Amazon Simple Storage Service (S3), SQL Azure, Amazon Elastic Compute Cloud (EC2).

- **Cloud Platform-as-a-Service (PaaS).** Simply stated, PaaS provides the capability to build or deploy applications on top of IaaS. Typically, a cloud computing provider offers multiple application components that align with specific development models and programming tools. For the most part, PaaS offerings are built upon either a Microsoft-based stack (i.e., Windows, .NET, IIS, SQL Server, etc.) or an open source-based stack (i.e., the "LAMP" stack containing Linux, Apache, MySQL, and PHP). PaaS examples include Force.com, Google App Engine, Windows Azure.
- **Cloud Software-as-a-Service (SaaS).** In this model, an entire business or set of IT applications runs in the cloud. Enterprise consumers outsource the entire underlying technology infrastructure to a SaaS provider and thus have no responsibility or management oversight for SaaS-based IT components. Users typically access these applications over the Internet through a thin client interface such as a Web browser. SaaS examples include Google Docs, Microsoft "live" offerings, and Salesforce.com.

There is no hierarchy in these service offerings, rather, chief information officers (CIOs), or IT directors can choose any or all cloud service offerings that fit their needs.

Deployment Models. The following list identifies the deployment models:

- **Private cloud.** The cloud infrastructure is operated within a single organization. In this case, internal groups such as business units consume resources and services provided by a single internal (i.e., the IT department) or external cloud computing provider.
- **Community cloud.** A community cloud is a superset of a private cloud. The cloud supports the needs of several or an extended community of organizations. Again, community clouds can be built and operated by members of the community or third-party providers.
- **Public cloud.** The cloud infrastructure and services are available to the general public or a large industry group and is owned by an organization selling cloud services. Examples of public clouds include Amazon EC2, Google App Engine, Microsoft Azure, or Terremark Cloud Computing services.
- **Hybrid cloud.** The cloud infrastructure is a composition of two or more clouds (private, community, or public) that remain unique entities but are bound together by standardized or proprietary technology that enables data and application portability (e.g., cloud bursting for load–balancing between clouds).

2.2 The Role of the Network in the Cloud Computing

The network acts as the foundation for the cloud computing. The cloud computing moves Web-based applications to the Internet inexorably tying the user connectivity and productivity to the networking equipment. Of all networking technologies available, WAN optimization will play a major role in the transition to the cloud. As this happens, WAN optimization must become a virtual service, support mobile users, support innovative applications and protocols, and provide network visibility at a granular level [7].

3 Advantages Connected with the Standards of Cloud Computing Service Delivery

In economic times like these, leading companies are looking to cloud-computing platforms to deliver business functions ranging from packaged business applications to custom application development at a fraction of the time and cost of traditional on-premises platforms. With this growth in enterprise use of cloud computing comes a corresponding increase in responsibility on the part of vendors to provide cloud computing platforms that offer outstanding service delivery. As the ITS community begins to evaluate and consider utilization of cloud-based services, ITS providers need to consider seven standards every cloud computing platform should follow and connected advantages [9].

They include:

- **World-Class Security.** Provision of world-class security at every level. Security is more than just user privileges and password policies. It is a multidimensional business imperative, especially for platforms that are responsible for customer data. Cloud computing platforms must have detailed, robust policies and procedures in place to guarantee the highest possible levels of:
  - Physical security,
  - Network security,
  - Application security,
  - Internal systems security,
  - Secure data-backup strategy,
  - Secure internal policies and procedures,
  - Third-party certification,
- **Trust and Transparency.** Provide transparent, real-time, accurate service performance and availability information. Cloud computing platforms should provide customers with detailed information about the service delivery and performance in real time, including:
  - Accurate, timely, and detailed information about service performance data and planned maintenance activities,
  - Daily data on the service availability and transaction performance,
  - Proactive communications regarding maintenance activities.

- **True Multitenancy.** Deliver maximum scalability and performance to customers with a true multitenant architecture. A multitenant architecture allows for high scalability and faster innovation at a lower cost. Multitenancy provides customers with the following benefits:
  - Efficient service delivery, with a low maintenance and upgrade burden,
  - Consistent performance and reliability based on an efficient, large-scale architecture,
  - Rapid product release cycles.
- **Proven Scale.** Support millions of users with proven scalability. With any cloud computing service, customers benefit from the scale of the platform. A larger scale means a larger customer community, which can deliver more and higher-quality feedback to drive the future platform innovation. A larger customer community also provides rich opportunities for collaboration between customers, creating communities that can share interests and foster best practices. Cloud computing platforms must have:
  - Proof of the ability to scale to hundreds of thousands of subscribers,
  - Resources to guarantee the highest standards of service quality, performance, and security to every customer,
  - The ability to grow systems and infrastructure to meet changing demands,
  - Support that responds quickly and accurately to every customer,
  - Proven performance and reliability as customer numbers grow.
- **High Performance.** Deliver consistent, high-speed performance globally. Cloud computing platforms must deliver consistent, high-speed systems performance worldwide and provide detailed historical statistics to back up performance claims, including:
  - Average page response times,
  - Average number of transactions per day.
- **Complete Disaster Recovery.** Protect customer data by running the service on multiple, geographically dispersed data centers with extensive backup, data archive, and failover capabilities. Platforms providing cloud computing services must be flexible enough to account for every potential disaster. A complete disaster recovery plan includes:
  - Data backup procedures that create multiple backup copies of customers' data, in near real time, at the disk level,
  - A multilevel backup strategy that includes disk-to-disk-to-tape data backup in which tape backups serve as a secondary level of backup, not as the primary disaster recovery data source,
  - This disk-oriented model ensures maximum recovery speed with a minimum potential for data loss in the event of a disaster.
- **High Availability.** Equip world-class facilities with proven high availability infrastructure and application software. Any platform offering cloud computing applications needs to be able to deliver very high availability. Requirements for proving high availability include:

- Facilities with reliable power, cooling, and network infrastructure,
- High-availability infrastructure: networking, server infrastructure, and software,
- N+1 redundancy,
- Detailed historical availability data on the entire service, not just on individual servers.

For example, Salesforce.com is the leader in enterprise cloud computing. It has more than 10 years of experience in delivering highly available, secure, and scalable cloud-computing applications based on the Force.com. platform. With the Force.com platform, Salesforce.com has set the standard for cloud-computing service delivery. Force.com is the only cloud computing platform that adheres to the seven standards outlined.

4 The Advantages Concerning the Technological Aspects

The most important technological aspects are [8]:

- **Virtualisation** is an essential technological characteristic of clouds which hides the technological complexity from the user and enables enhanced flexibility (through aggregation, routing and translation). More concretely, virtualisation supports the following features [10], [11]:
  - **Ease of use***:* through hiding the complexity of the infrastructure (including management, configuration etc.) virtualisation can make it easier for the user to develop new applications, as well as reduces the overhead for controlling the system,
  - **Infrastructure independency***:* in principle, virtualisation allows for higher interoperability by making the code platform independent,
  - **Flexibility and Adaptability***:* by exposing a virtual execution environment, the underlying infrastructure can change more flexible according to different conditions and requirements (assigning more resources, etc.),
  - **Location independence***:* services can be accessed independent of the physical location of the user and the resource.
- **Multitenancy** discussed above,
- **Security** discussed above,
- **Data Management** is an essential aspect in particular for storage clouds, where the data is flexibly distributed across multiple resources. Implicitly, the data consistency needs to be maintained over a wide distribution of replicated data sources. At the same time, the system always needs to be aware of the data location (when replicating across data centres) taking latencies and particularly workload into consideration. As the size of data may change at any time, the data management addresses both horizontal and vertical aspects of scalability [12],
- **APIs and/or Programming Enhancements** are essential to exploit the cloud features: common programming models require that the developer takes care of the scalability and autonomic capabilities him/herself, whilst a cloud environment provides the features in a fashion that allows the user to leave such management to the system,

- **Metering** of any kind of resource and service consumption is essential in order to offer elastic pricing, charging and billing. It is therefore a pre-condition for the elasticity of clouds,
- **Tools** are generally necessary to support development, adaptation and usage of cloud services.

5 The Advantages Concerning the Economical Aspects

The most important economic aspects are [8]:

- **Cost reduction** is one of the first concerns to build up a cloud system that can adapt to changing consumer behaviour and reduce the cost for infrastructure maintenance and acquisition.
- **Pay per use.** The capability to build up cost according to the actual consumption of resources is a relevant feature of cloud systems. Pay per use strongly relates to the quality of service support, where specific requirements to be met by the system and hence to be paid for can be specified.
- **Turning CAPEX into OPEX** is an implicit, and much argued characteristic of cloud systems, as the actual cost benefit (cf. ROI) is not always clear. Capital expenditure (CAPEX) is required to build up a local infrastructure, but with outsourcing computational resources to cloud systems on demand and scalable, a company will actually spend operational expenditure (OPEX) for provisioning of its capabilities, as it will acquire and use the resources according to the operational need.
- **"Going Green"** is relevant not only to reduce additional costs of energy consumption, but also to reduce the carbon footprint. Whilst the carbon emission by individual machines can be quite well estimated, this information is actually taken little into consideration when scaling systems up [13], [14], [15].

6 Conclusion

Many advantages will be possible in the effort to use the cloud computing services in ITS [16], [17], [18], and [19]. Some of these have been described in the paper.

Web-based applications provide a secured, optimized platform for enhanced collaboration. A cloud collaboration is an ideal communications tool for staff located at disparate locations, or for collaboration with outside agencies or other regional transportation stakeholders. These types of collaboration tools are easy to deploy, extremely elastic, and easily accessible via any secured Internet connection.

Tools, such as Microsoft's SharePoint, prove to be highly effective collaboration platforms for agencies to optimize communications and event coordination. Cloud-based applications such as Google Docs are now providing real-time, live collaboration features.

The cloud-computing model is an excellent platform for providing data storage and data management services. Because cloud platforms are highly elastic, central networking storage or central processing and data management can be scaled in real time.

The cloud computing platform can also provide an optimal tool for monitoring ITS network's performance, as well as for applying efficiently application patches and software upgrades.

Cloud-based platforms provide enhanced and cost-effective security features.

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Development of the IMO e-Navigation Concept – Common Maritime Data Structure

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Abstract. e-Navigation is a concept being developed under the auspices of the United Nations International Maritime Organization (IMO) to bring about increased safety and security in commercial shipping through better organisation of data on ships and onshore, and better data exchange and communication between the two. The IHO is involved in the development of the e-Navigation concept to ensure that any underpinning hydrographic standards, products or services are in place from the beginning. In the paper the Author, a member of the IMO Expert Group on e-Navigation established in 2006, presents recent issues about e-Navigation concept, the common maritime data structure.

Keywords: maritime transportation, telematics, e-Navigation, data structure.

1 Introduction

e-Navigation is the future, digital concept for the maritime sector. Larger and faster ships, greater congestion and reduced manning levels have all provided the impetus for this development. There is a clear and compelling need to equip shipboard users and those ashore responsible for the safety of shipping with modern, proven tools that are optimized for good decision making.

The aim is to develop a strategic vision for e-Navigation, to integrate existing and new navigational tools, in particular electronic tools, in an all-embracing system that will contribute to enhanced navigational safety (with all the positive repercussions this will have on maritime safety overall and environmental protection) while simultaneously reducing the burden on the navigator. As the basic technology for such an innovative step is already available, the challenge lies in ensuring the availability of all the other components of the system, including electronic navigational charts, and in using it effectively in order to simplify, to the benefit of the mariner, the display of the occasional local navigational environment. e-Navigation would thus incorporate new technologies in a structured way and ensure that their use is compliant with the various navigational communication technologies and services that are already available, providing an overarching, accurate, secure and cost-effective system with the potential to provide global coverage for ships of all sizes.

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The main e-Navigation objectives are the following:

- safe and secure navigation of vessels,
- facilitate communications, including data exchange between vessels and shore,
- integrate and present information onboard and ashore to maximize navigation safety benefits and minimize risk of confusion,
- global coverage with consistent standards and interoperability.

It is now appropriate to develop a broad strategic vision for incorporating the use of new technologies in a structured way and ensuring that their use is compliant with the various electronic navigational and communication technologies and services that are already available [5]. The aim is to develop an overarching accurate, safe, secure and cost-effective system with the potential to provide global coverage for vessels of all sizes [2]. Implementation of this new strategic vision might require modifications to working methods and navigational tools, such as inner ship's computer net, charts, bridge display equipment, electronic aids to navigation, positional systems, communications and shore infrastructure.

2 Introduction to e-Navigation Architecture

In creating an e-Navigation architecture, it is important to identify information and data flows, and the interactions between applications and user interfaces. Consequently, there needs to be a data structure to optimize the use, interoperability, flow and accessibility of relevant information and data within the maritime domain (including both ship and shore aspects). It is therefore important to harmonize efforts in data modelling, with the aim of creating and maintaining a robust and extendable maritime data structure. This maritime information and data structure will require some form of overarching coordination to ensure the ongoing management and maintenance of the structure.

The work of implementing the e-Navigation strategy should begin by the outline of an architecture [7], [8], and [10]. To become workable, the current definition of e-Navigation needs to be broken down into detail. The work is complex and will require input from a number of experts. For reasons of efficiency and effectiveness the work needs to be conducted in a systematic and consistent way. There is therefore a need to develop an architecture, a framework, within which the definition of e-Navigation as presented, may be further refined. The detailed definition will address not only the concept and functions of e-Navigation which are non-technical, but also its technical components, as well as the complex relations between these [9].

The initial technical e-Navigation architecture work is based on the understanding of IMO's e-Navigation concept in general, and telematic appraoch to e-Navigation architecture specifically [10].

A sufficiently advanced proper infrastructure needs to be present. This infrastructure would consist of supporting devices, which e.g. allow application software to be executed (i.e. computers, computer peripherals, operating systems, local area network components, etc.). The infrastructure itself becomes more and more sophisticated and is subject to its own requirements, such as reduction of energy consumption and environmental friendliness.

One important principle is the orientation towards information flow instead of technology development. That principle is represented by Fig. 1 below, which shows the shipboard environment, the physical link(s) and the shore-based environment.

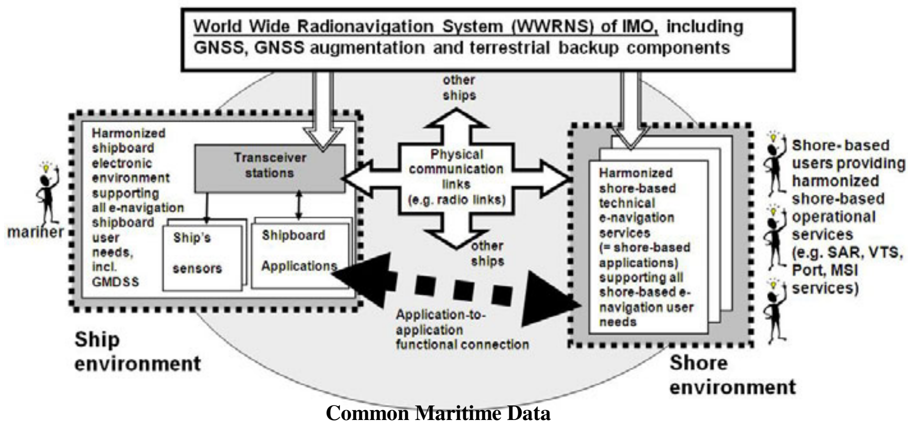

Fig. 1. Conceptual e-Navigation architecture [1], [10]

Fig. 1 is a representation of the e-Navigation environment. On the left there is a single "ship environment". From an e-Navigation perspective, the relevant devices within the ship environment are the transceiver station, the sensors and applications connected to the transceiver station, the Integrated Navigation System (INS) and the Integrated Bridge System (IBS). The GMDSS function has been included in the ship environment, with a direct link to the transceiver station and a link to the World Wide Radio Navigation System (WWRNS).

The bold arrow in Fig. 1 represents the data exchange between the shore-based applications and the "ship's environment", and vice versa. Physical links between (fixed) shore and (mobile) shipboard equipment each employ one or more appropriate methods such as radio or light signals.

Fig. 1 did not convey the full notion of the e-Navigation concept. When considering the e-Navigation architecture, one should think in terms of information/data flow, application interactions, and user interfaces. It is therefore necessary to refine the figure into an information/data flow oriented graphical representation.

3 Overarching e-Navigation Architecture

The overarching e-Navigation architecture described in Fig. 2 included, in the horizontal direction, the shipboard and the shore-based parts connected through different links put into a hierarchical perspective (operational services and functional and physical links used by technical services), stressing the harmonization requirement which was the essence of the e-Navigation definition and highlighting the information/data flow in the e-Navigation architecture. In the vertical direction, a distinction between the information and data domains were represented, including the human/machine Interfaces that interconnect the two domains and provide information and data items to the human users in the required format [6].

Fig. 2 shows the principle of an information/data flow in the e-Navigation architecture while the structural details of both the technical shipboard and shore-based e-Navigation system architectures are not yet shown. This brings into focus the "operational service" level and the "Functional links used by Technical services" and the "Physical links used by Technical services". This is a further development as it highlights the fundamental distinction between information and data domains; explaining the relationship between the user requested information items; putting the concepts of Operational Services, Technical Services as well as Functional and Physical Links into a hierarchical perspective; identifying the place of the concept of "Maritime Service Portfolio"; and unfolding the relationship of shore-to-shore data exchange.

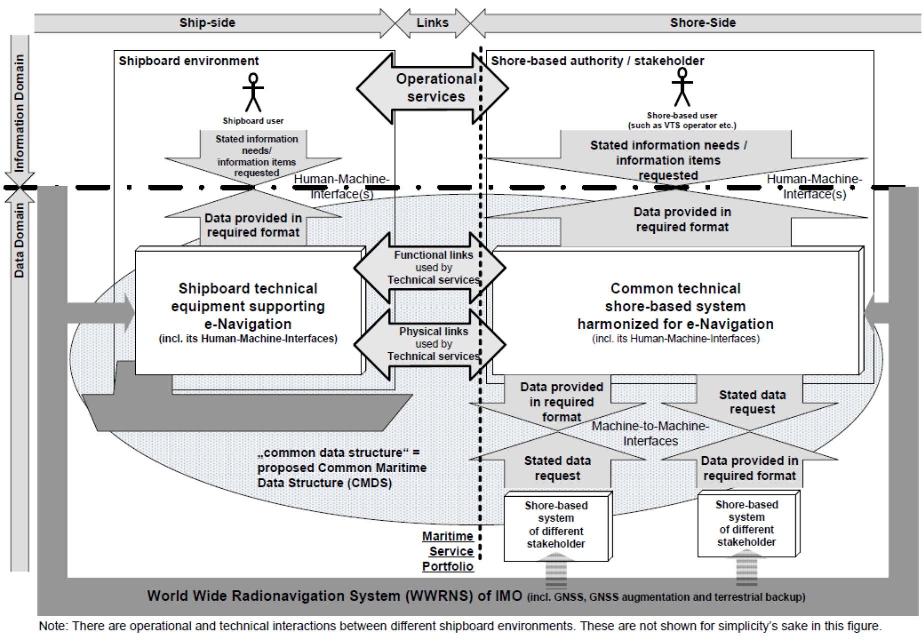

Fig. 2. Overarching e-Navigation architecture [3]

The above architecture also identified the concept of Maritime Service Portfolio (MSP) which defines and describes the set of operational and technical services and their level of service provided by a stakeholder in a given sea area, waterway, or port, as appropriate. This concept would be further developed in the future.

The Fig. 2 shows the complete overarching e-Navigation structure, explains the relationship of shore-to-shore data exchange and defines two additional important features:

1. the Common Maritime Data Structure (CMDS) that spans the whole of the horizontal axis (indicated by the shaded oval in the background), which serves an important function as it is a key to harmonization between the technical systems of stakeholders both shipboard and shore-based; and
2. the World Wide Radio Navigation System (WWRNS), which delivers in particular the position and time data to virtually all technical systems in e-Navigation. The degree of this dependency might differ for several shore-based systems (indicated by different arrow shading).

For simplicity of representation, the ship-to-ship interactions are not shown, although they are an integral part of the e-Navigation. The structural details of both the technical shipboard and common shore-based e-Navigation system architectures are not yet shown at this stage. Different figures would be required to be developed in the future in this respect.

4 Development of a Common Maritime Data Structure (CMDS)

The Common Maritime Data Structure (CMDS):

- should be based on user requirements;
- could represent any maritime entity and should be extended by the addition of new entities;
- should be accessible to any stakeholder or implementer;
- should be an abstract representation of parts of the maritime domain (i.e. it should represent the entities and its relationships but it should not represent processes);
- should not contain details on the physical representation of its entities; however, it could be used to guide the development of the necessary databases and interfaces; and
- should be flexible and extendable for meeting future requirements (i.e. new entities could be added by any stakeholder through a process known as registration).

Fig. 3 illustrates how the proposed CMDS would influence the components of the e-Navigation architecture when creating hardware and software used for e-Navigation purposes.

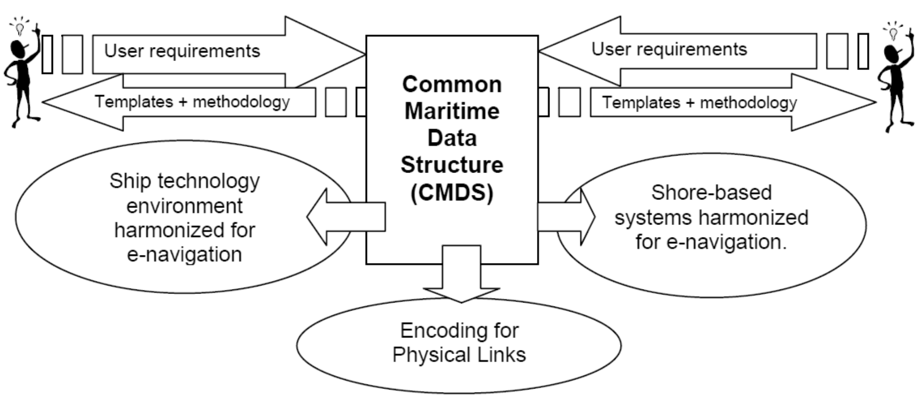

Fig. 3. Scope and impact of the CMDS [3]

5 Using the IHO's S-100 Registry for Storing Defined Data Objects

The S-100 standard developed by International Hydrographic Organization (IHO) could support a variety of hydrographic-related digital data sources, products and customers, including the use of imagery and gridded data, enhanced metadata specifications, unlimited encoding formats and a more flexible maintenance regime. The S-100 standard was fully aligned with mainstream international geospatial standards, in particular the ISO 19100 series of geographic standards, thereby enabling the easier integration of hydrographic data and applications into geospatial solutions.

The S-100 standard was designed to be extensible and future requirements such as 3-D, time-varying data (x, y, z, and time) and web-based services for acquiring, processing, analysing, accessing, and presenting hydrographic data could be easily added when required. The IHO's S-100 standard should be used as the baseline for creating a framework for data access and services under the scope of the International Convention for the Safety of Life at Sea (SOLAS).

IHO and IALA (International Association of Lighthouse Authorities) were exploring the possibilities of using the IHO's S-100 Registry, operated by IHO, for storing defined data objects. Fig. 4 provides a revised representation of the IHO's S-100 Registry.

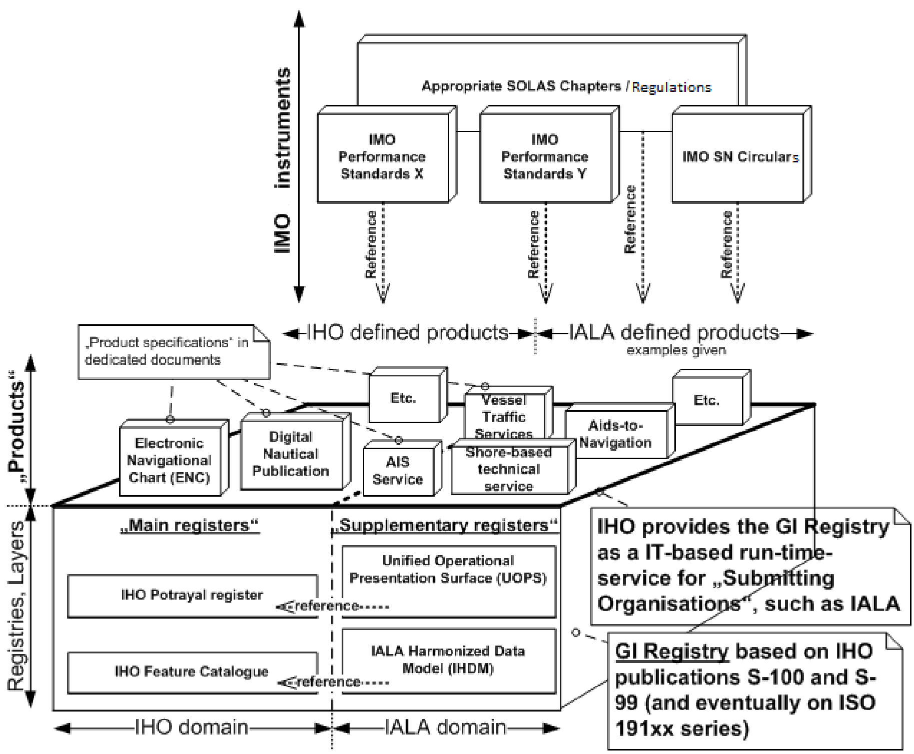

Fig. 4. Representation of the IHO's S-100 Registry [3]

The scheme illustrating the representation of the IHO's S-100 Registry was revised and modified during IMO Sub-Committee NAV57 in June 2011 (Fig. 5).

The IHO Registry (based on S-100/S-99) is capable of supporting additional recognized organizations, other than and in addition to IHO and IALA, such as IEC, ISO, etc. This is indicated by "recognised organization(s)".

The "references" introduced between the registries and layers of the "main register" and the "supplementary registries" are provided as examples, only, for simplicity's sake. There could be, by default, "references" between any registry of any international organization, provided they are of the same kind (i.e. features/attributes or portrayal elements).

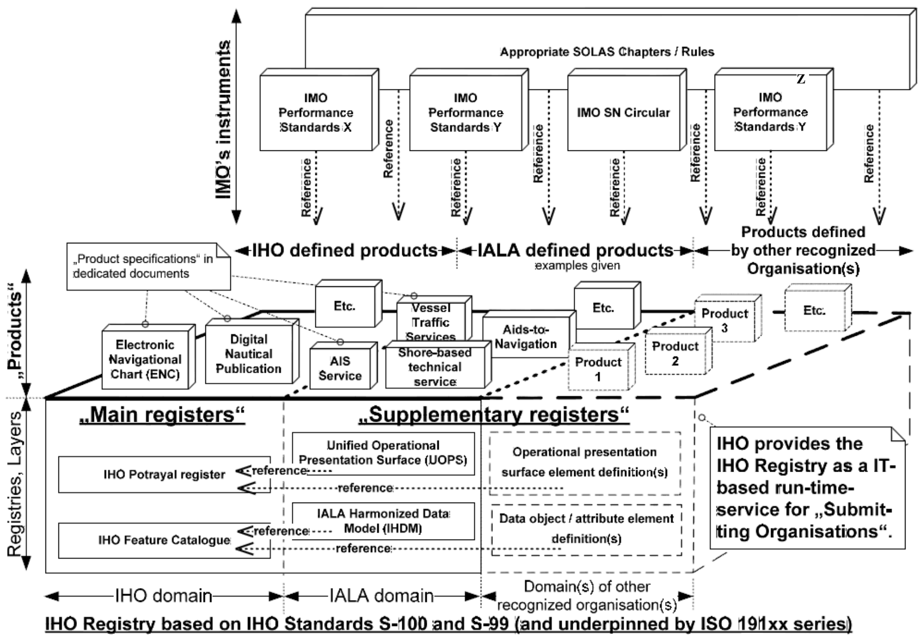

Fig. 5. Representation of the IHO's S-100 Registry, as revised at NAV57 (2011)

6 Development of Maritime Service Portfolios (MSPs)

An MSP defines and describes the set of operational and technical services and their level of service provided by a stakeholder in a given sea area, waterway, or port, as appropriate. Hence, a "Maritime Service Portfolio" might also be construed as a set of "products" provided by a stakeholder in a given sea area, waterway, or port, as appropriate.

The user needs with regard to the e-Navigation concept had identified and adopted different MSPs corresponding to needs for services and communication in different areas and for different operations, and it had been agreed that the areas could be divided into:

- harbour operations;
- operations in coastal and confined or restricted waters;
- transocean voyages;
- offshore operations; and
- operations in Arctic, Antarctic and remote areas.

Examples of such possible services might be local warnings, ice conditions, Electronic Navigational Chart (ENC) updates, real-time tidal information, etc. Integrated shipboard systems were a key shipboard platform that would fulfil the requirement for the "shipboard equipment supporting e-Navigation", and further development of systems such as Integrated Navigation System (INS) or Integrated Bridge System (IBS) might be examples to that end.

It is obvious that further development of MSPs to achieve harmonization, modernization, integration and simplification onboard and ashore is needed. The development of MSPs should be scalable and could be performed with the support of shore-side organizations, such as IALA or IHO.

Even though e-Navigation as a concept has been pushed by national and international authorities, it is widely understood that commercial industry and the technology that they develop has, and will have, a significant impact on the development of e-navigation. Key technological components to e-Navigation include, but are not limited to, ECDIS, GMDSS/radiocommunication, GNSS/DGNSS, AIS and radar/ARPA systems.

7 Development of Navigation Positioning Systems

Electronic positioning system is a prerequisite for the e-Navigation and position fixing using GNSS (Global Navigation Satellite System) is prevailing amongst commercial and leisure users. By the way radars and traditional Aids to Navigation (AtoN) will continue to be required, at least for redundancy and/or terrestrial backup to satellite systems, or in many military scenarios. Co-operation between complementary systems such as radar and AtoN should become stronger and stronger to assessing the data and improving reliability for more informed decisions.

The GNSS was considered as the primary system for navigation and positioning; however, the need was identified for having a non-space-based backup system. In this respect, several options or alternatives to facilitate resilience and backup were promoted, including, but not limited to, the use of AtoNs, radar, pilot service, VTS, e-Loran and INS.

In order to assess the requirements for resilient Position, Navigation and Timing (PNT) and suitable backup system, a proper analysis of the requirements for resilient PNT in terms of accuracy, validity, reliability and availability would be required. In particular, the requirements for timing should be carefully considered. In fact, maintaining a high precision of timing might not be necessary for e-Navigation into the foreseeable future. This might considerably simplify the backup arrangements needed for periods when GNSS performance was degraded.

The only foreseeable e-Navigation need for ultra-accurate timing could be for the transmission and reception of AIS messages. However, it was further noted that AIS already had a mode of operation that did not need accurate timing on board. If the performance degradation of AIS that results from using this mode was to be acceptable during periods of GNSS unavailability, there appeared to be no other onboard requirements for precision time in excess of that which could be given by existing cost effective technology.

8 ENC Availability

An Electronic Chart Display and Information System (ECDIS) is a computer-based navigation information system that complies with IMO regulations and can be used as an alternative to paper nautical charts.

An ECDIS system displays the information from electronic navigational charts (ENC) and integrates position information from the Global Positioning System (GPS) and other navigational sensors, such as radar and automatic identification systems (AIS). It may also display additional navigation-related information.

The following graph (Fig. 6) shows the steady increase in the number of ENCs produced and available for purchase over the last few years. This rate of increase is in line with the forecasts previously provided by IHO to the NAV Sub-Committee of IMO.

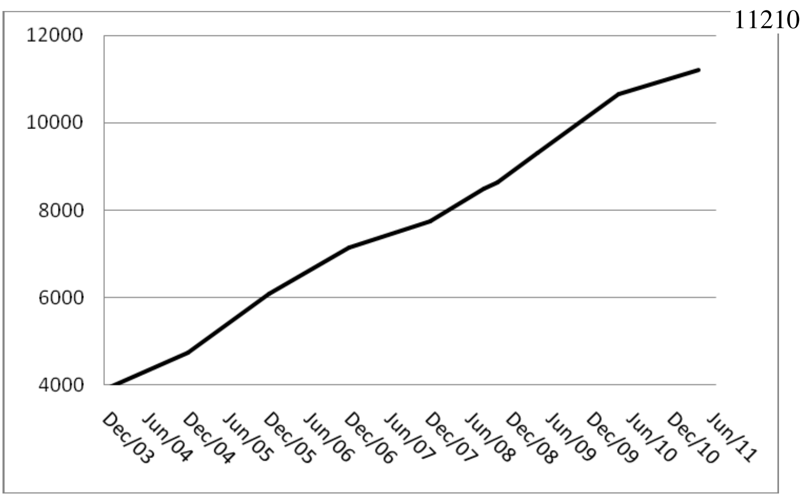

Fig. 6. ENC availability in the period 2003-2011 [4]

The following information summarizes the availability of ENCs in comparison to paper charts intended for international voyages and is based on available data as of the May 2011 (Table 1).

Table 1. Comparision of electronic charts (ENCs) with corresponding paper charts (SNCs) [4]

Comparison of ENCs with corresponding paper charts				
	May 2008	May 2009	May 2010	March 2011
Small scale ENCs (planning charts)	>90%	~100%	~100%	~100%
Medium scale ENCs (coastal charts)	60%	77%	84%	88%
Large scale ENCs (top 800 ports)	65%	84%	91%	94%

Of the 154 States with coastlines, there are now only six States, and Antarctica, where five or more ENCs remain to be produced in order to match corresponding paper chart coverage at medium scale. For the world's top 800 ports (by total tonnage), only eight coastal States have yet to produce ENCs that match the coverage provided by paper charts of those same ports. There remain ports outside the top 800 and some less frequently visited areas where ENC coverage is still missing.

9 The Concept of a Common Data Structure

IMO, IHO and IALA have raised the issue that some form of common data structure, representing the maritime domain (and including both ship and shore aspects), will be essential for e-Navigation.

In January 2010, IHO introduced a new data model to be known as S-100 - the Universal Hydrographic Data Model (UHDM). This international standard has been developed by the IHO over the last nine years in consultation with a wide range of stakeholders, including key ECDIS and navigation equipment manufactures. The purpose of S-100 is to provide a framework architecture for a contemporary standard for the exchange of hydrographic and related maritime data. S-100 is based on the ISO 19100 series of geographic standards and is fully compatible and interoperable with those standards. As the UHDM is aligned with ISO 19100 it will enable the exchange of hydrographic and other maritime data and information together with geospatial data from other domains. The use of data standards enables interoperability between geospatial data sets from different domains and could therefore be appropriate for many of the datasets envisaged for data exchange in e-Navigation.

S-100 is not limited to hydrographic data or hydrographic applications. It has been developed specifically to enable the widest possible range of users to use hydrographic data in conjunction with data from other maritime and marine domains. As well as traditional applications such as nautical charts and publications, applications based on S-100 already under development by non-IHO stakeholder groups include sea ice forecast reporting, recording UNCLOS boundaries, and marine information overlays. These are applications that obviously encompass various hydrographic, meteorological and oceanographic parameters that go well beyond the traditional navigation and hydrographic products provided by HO’s. S-100 is intended to be a fundamental enabler for hydrographic input to Marine Spatial Data Infrastructures (MSDI) as well other developing marine information infrastructures such as e-Navigation.

IALA is currently developing a proposed Universal Maritime Data Model (UMDM) for e-Navigation to meet requirements arising from the future implementation of e-Navigation. It is therefore important to harmonize efforts in data modelling, with the aim of creating and maintaining a robust and extendable maritime data structure. The common maritime information and data structure will require some form of overarching coordination to ensure the ongoing management and maintenance of the structure. There may be several management roles to be performed by such a coordinating body, (for example, the maintenance of a register). This management role may be able to be shared between relevant organisations.

The common data structure should contain data models like IALA's UMDM, IHO's UHDM and data models of other international stakeholders. The structure is a highly important element by which e-Navigation can modernize the operational environment of the maritime industry. Reporting should be standardized and in a format that supports the effective use ashore, such as a global voluntary single window network. Construction of the UMDM will be a collaborative effort among many parties involved in the maritime environments. By having each party bring their particular expertise, the UMDM will become the accepted standard model.

Implementation of IMO's e-Navigation strategy leads to a larger variety and higher volume of information and increased information exchange due to globalization. Consequently there is a need to handle information more effectively in a standardized way. The first step towards a common data structure is to define the meaning of each and every item in the data structure and the relationships among the items. This is done so that implementers of the data structure have common understanding of items. The means to do this is with a data model. At this stage, the data model, like the system architecture needs only to be described in the most general of terms. An example of how a UMDM could be implemented has been provided by the IHO with its S-100 model.

10 The IMO e-Navigation Concept and the IHO S-100 Data Standard

A significant challenge for e-Navigation is how to efficiently capture and subsequently transfer the many forms of non-hydrographic data and information in the e-Navigation domain in a relatively seamless, standardised and efficient way. At present, most maritime-related information is little more than textual-based messaging or verbal communication. This includes vessel radio reporting, the broadcast of Maritime Safety Information (MSI) through NAVTEX and SafetyNet, Vessel Traffic Services (VTS) and weather reports. Nautical charting services stand out as an exception.

The IHO has already developed standardised methods of codifying, encapsulating, and subsequently transferring and distributing hydrographic and charting data using its well-established S-57 data exchange standard which is also the base standard for electronic navigational charts (ENCs). But most other maritime data and information is neither digital nor standardised as yet.

Following on from S-57, the IHO has recently developed a contemporary digital data transfer standard that will support its 'next-generation' ENCs, digital nautical publications and supporting symbology, all of which will be part of e-Navigation in the future.

Most significantly and by design, the new standard, known as S-100, is compatible with the ISO 19100 series of geographic data standards. Because of this, increasing levels of interest have been shown by various would-be e-Navigation data providers to use S-100 and its supporting geospatial information (GI) registry as one mechanism for standardising the digital data capture of maritime information, especially where there are no other recognised underpinning data standards. Examples are:

- Sea Ice Coverage Overlays by the World Meteorological Organization (WMO),
- Extended continental shelf boundary claims data of the UN Department by the Administration of the Law of the Sea (UNDOALOS),
- Inland ENC requirements by the international Inland ENC Harmonization Group,
- Aids-to-Navigation (AtoN) metadata requirements by the International Association of Aids to Navigation and Lighthouse Authorities (IALA).

Any product specifications or standards that are developed using the S-100 standard will be adopted and maintained by the relevant contributing authority or organisation; the IHO has no controlling role - other than for its own hydrographic standards. These principles are explained in IHO publication S-99 - Operational Procedures for the Organization and Management of the S-100 GI Registry. Taking this into account, it is now recommended to the IMO that the IHO S-100 standard should be considered as the baseline data structure for maritime information in e-Navigation.

11 Conclusion

In computer science, a data structure is a particular way of storing and organizing data in a computer so that it can be used efficiently. Different kinds of data structures are suited to different kinds of applications, and some are highly specialized to specific tasks.

Data structures are used in almost every program or software system. Data structures provide a means to manage huge amounts of data efficiently, such as large databases and internet indexing services. Usually, efficient data structures are a key to designing efficient algorithms. Some formal design methods and programming languages emphasize data structures, rather than algorithms, as the key organizing factor in software design.

Data structures are generally based on the ability of a computer to fetch and store data at any place in its memory, specified by an address - a bit string that can be itself stored in memory and manipulated by the program. Thus the record and array data structures are based on computing the addresses of data items with arithmetic operations; while the linked data structures are based on storing addresses of data items within the structure itself. Many data structures use both principles, sometimes combined in non-trivial ways.

The implementation of a data structure usually requires writing a set of procedures that create and manipulate instances of that structure. The efficiency of a data structure cannot be analyzed separately from those operations. This observation motivates the theoretical concept of an abstract data type, a data structure that is defined indirectly by the operations that may be performed on it, and the mathematical properties of those operations (including their space and time cost).

It is envisioned that e-Navigation will be a 'living' concept that will evolve and adapt over a long time scale to support this objective. During this time information will change, technologies will change, political and commercial objectives will change, and tasks will change. However it is unlikely that the need for safe and efficient seaborne transport will change significantly.

It is very important especially for safety reason to establish common maritime data structure. The IHO S-100 standard should be considered as the baseline data structure for maritime information in e-Navigation.

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Analysis of Intelligent Transport Systems (ITS) in Public Transport of Upper Silesia

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Abstract. This article presents several examples of Intelligent Transport Systems (ITS) with special attention paid to systems supporting the development of public transport in the area of the Metropolitan Association of Upper Silesia (Polish Górnośląski Związek Metropolitarny - GZM). The GZM is an inter-commune association of a group of cities lying within the area of the Metropolitan Association of Upper Silesia and Zagłębie Dąbrowskie. Almost 2 million people live in the GZM area and the gross product in this area amounts to 8% of the gross domestic product.

Keywords: ITS, public transport, Park&Ride, bus lanes.

1 Metropolitan Association of Upper Silesia

The GZM is an inter-commune association including cities with the rights of districts situated in the area of the Silesian-Dąbrowa conurbation. On 8 June 2007, the Association was officially registered in the Register of Inter-Commune Associations under number 284.

The GZM includes: Bytom, Chorzów, Gliwice, Katowice, Mysłowice, Piekary Śląskie, Ruda Śląska, Siemianowice Śląskie, Świętochłowice, Tychy, Zabrze – situated in Upper Silesia, Dąbrowa Górnicza, Sosnowiec – situated in Zagłębie Dąbrowskie, and Jaworzno – part of the Chrzanów Area.

It is aimed at coordinating actions in the area of the GZM communes. GZM's registered office is situated in Katowice.

The first projects of joining cities were developed during the interwar period on the German side of Upper Silesia. The idea of the metropolization of the Upper Silesia and Zagłębie conurbation appeared again in discussions between members of local governments in the region in the first half of the 1990s. Such a solution was seen as an opportunity for more effective management and a way of strengthening weaker areas of the agglomeration. Presidents of cities decided to establish the association in Gliwice on 9 December 2005, and a declaration of the establishment of the GZM was signed in Świętochłowice.

J. Mikulski (Ed.): TST 2011, CCIS 239, pp. 164–171, 2011.

Fig. 1. Metropolitan Association of Upper Silesia [1]

1.1 GZM Tasks

The association's main tasks include:

- establishment of a common development strategy for cities belonging to the Association in accordance with the Spatial Planning and Development Act;
- implementation of tasks included in the common development strategy for cities belonging to the Association;
- acquisition of funds from domestic and foreign special purpose funds;
- management of roads entrusted to the Association by member communes;
- preparation of applications to acquire public funds from the European Union budget;
- activation of the labour market in the cities belonging to the Association;
- supporting innovative economic programmes raising the cities' competitiveness;
- expressing opinions concerning legislative and decision-making processes as regards issues in the area of the Association interest due to the tasks implemented by the Association.

The Association's activity should result in improved management of the agglomeration, enhancement of the economic strength and competitiveness of the GZM member-cities and in coordination of promotional activity and in emphasizing the importance of this region. The area of the association is inhabited by over 2 million people, the combined total budgets of the member cities amount to over 6 billion PLN and the gross product is approx. 8% of Poland's gross domestic product.

1.2 Public Transport

The public transport in the GZM area is well-developed - it includes buses, trams and trolleybuses. The public transport in the Upper Silesian Industrial Region consists of a dense, yet chaotic network of buses, trams and trolleybuses, together with railway lines with passenger trains. The network of tram tracks is ranked third in Europe as regards the length of the routes.

There exist altogether several hundred bus lines and several dozen tram lines. Several operators manage the public transport system. KZK GOP Katowice is one of the largest ones (buses and trams) - a municipal association of 23 communes managing the transport in the central part of the region from Gliwice to Sławków.

1.3 Road Transport

The road network is also well-developed in the GZM area. Drogowa Trasa Średnicowa (Central Highway) runs its course here (Katowice – Chorzów – Świętochłowice – Ruda Śląska; the Zabrze – Gliwice section is under construction) and also, among other things: A4 Motorway, A1 Motorway, S1 Expressway, S86 Expressway, national roads (DK) no. 11, 78, 79, 81, 86 and 94.

GZM cities also have numerous direct PKS (bus) connections with all regions of the country. Some of them are operated by PKS Katowice. These are lines to Lublin, Iwonicz, Ostrowiec Świętokrzyski, Zakopane, Rabka, Krynica and Ustrzyki Dolne.

Therefore, it must be noticed that the GZM is an area in which the introduction of ITS and other methods of improving the competitiveness of public transport is an action which is likely to be successful.

2 ITS

The application of ITS in the GZM area is one way of improving transport systems to increase their efficiency, effectiveness and safety. ITSs provide various tools, starting from advanced traffic control systems by means of traffic lights, traffic flow management systems in the street and road network and systems implementing priorities for emergency vehicles.

The attractiveness of ITS results from the fact that they create numerous opportunities to increase the availability, mobility and safety of the transport with the simultaneous reduction of the infrastructure construction costs, traffic congestion, traffic accidents, negative environmental impact and energy consumption. Owing to the integrated nature of solutions (e.g. individual traffic, public transport and transport of goods), ITSs condition the implementation of the sustainable development strategy.

A significant characteristic of ITS traffic management includes their openness, making it possible to integrate systems by various manufacturers to obtain a synergistic effect, both to shorten the implementation time of the systems and to obtain the highest possible traffic quality. Intelligent Transport Systems combined with other organizational and legal solutions should help to order passenger car traffic and to strengthen the position of the public transport.

2.1 Park and Ride System

“Park & Ride” is a car park intended for people who commute from the suburbs of big cities and use public transport. Drivers leave their cars in designated areas, change to public transport and continue their trip to the city centre in this way. The first car parks of this kind were established in Western Europe already in the 1960s (England).

This solution is rarely used in Poland, which is a serious mistake. In the 1990s, there was an attempt to implement a similar system in Cracow - the last of the car parks created at that time was closed in 2003. The main reason for the failure of the system was the location of car parks too close to the city centre, as a result of which they were used as target car parks and not as the changing ones. Poznań is having similar problems as there are no investors willing to establish car parks within the framework of Public-Private Partnership. However, according to the Poznań idea, Par&Ride car parks are to “intercept” the largest possible percentage of vehicles on their way to the city centre and to encourage drivers to use the public transport offer. To raise the attractiveness of such a solution, it is assumed that the driver of a car left at the P&R parking lot (together with an accompanying person) will be able to use - free of charge on the basis of the parking card (a proof entitling them to collect the car) - the City of Poznań public transport until they come back to the car park. The advantage of the system of modular car parks selected by the city is the lack of obstacles to parking LPG-fuelled vehicles. Additionally, at the time of increasing value of developed plots of land, modular car parks take up relatively little space and, depending on the needs, the number of modules used can be increased or decreased. Significant elements in favour of this solution also include: self-service system, lower electricity consumption than in the case of ground and underground car parks, prevention of third-party access to parked cars.

The "Park & Go” buffer car park construction is aimed at reducing the number of vehicles entering the inner city centre. The traveller should use such a car park and continue their trip on foot or by public transport. Just as in the case of enclosed car parks inside the central area as well as in the case of P&G car parks, the opening of each such facility should be connected with the elimination of approximately the same number of parking spaces on pavements or along kerbs in the surrounding area. Far-reaching limitations to the car traffic and absolute priority for pedestrians and the public transport are assumed inside the inner city centre. The same solutions - modular car parks - are planned for P&R and P&G areas.

Taking into account the specificity of the GZM area, several variants of this system should be considered. Car parks should be situated at the outskirts of the cities and at the outskirts of the agglomeration in the P&R system. This will make it possible to limit the number of vehicles entering the city centre and into the centre of the agglomeration. The application of such a solution will make it possible to limit the passenger car traffic in the GZM cities in a significant way. It must be remembered that the public transport must be correlated with the P&R and P&G systems. The passenger car volume in the GZM area is connected with one of the most serious problems of parking and traffic jams on access roads and streets in the cities nationwide and it is a significant problem for GZM inhabitants.

2.2 Variable Message Signs

Intelligent Transport Systems (ITS), based on integrated communications and information technologies, are commonly used to increase the effectiveness and safety of traffic control. Variable Message Signs can be mentioned among the specific solutions of ITS elements.

Various technologies can be used to create Variable Message Signs. However, the LED technology is most commonly used due to the new process of manufacturing high quality LEDs at affordable prices, even at the highest brightness thresholds using full-colour applications.

Variable Message Signs are based on the light emitting diode technology, the construction of the matrix makes it possible to display all colours in the RGB scale and any shapes - symbols, road signs and message signs. Such devices appear in Poland, but so far, they have informed drivers mostly about weather conditions and speed limits. However, their application can be broader:

- traffic control and management on individual lanes on multi-lane roads,
- directing to alternative roads,
- informing about current traffic conditions (traffic jams, accidents, etc.).

The use of Variable Message Signs in city information improves the traffic flow by central control and management of traffic directions. Informing about free parking spaces, roadworks performed in cities, diversions and other events has a direct influence on travelling safety and comfort. It also makes it possible to have a real influence on transport management in urban agglomerations.

LED information boards present in a legible way the possible traffic directions in the most dangerous places, generating an increased number of vehicles. Such places include, in particular: toll collection points in motorways, tunnels, flyovers, car parks.

Panel signs complete LED Variable Message Signs on dual carriage ways. They are particularly useful as regards traffic directions. Panel signs are used as signposts, for example, in situations when it is necessary to relieve heavy traffic congestion. In this case, a panel sign, after reversing the elements, will direct cars to an alternative route instead to a normally displayed route to a given city.

Panel variable message boards have numerous advantages. Owing to the application of the best reflective foils, their visibility is excellent under all conditions. Other advantages include low maintenance costs as far as power supply is concerned (low power consumption, solar batteries), a long operation period using optimal materials, fast wireless communication and wireless control. First of all, it is important that information from panel signs can be interpreted in an unambiguous way by drivers.

2.3 System of Collection of Fees for Entering the City Centre

In the process of a dynamic increase in the traffic intensity in urban areas, traffic jams become a more and more serious problem. They also result from the lack of possibility of extending the existing network of roads at a rate corresponding to the rate of the increase in the number of cars. In consequence, streets and crossroads have lower traffic capacity, pollution emissions into atmosphere become higher, the costs rise and the transport time becomes longer, a decrease in the labour efficiency occurs and the quality of life is lower.

There are systemic solutions which combine administrative actions with technological implementations. The System of Collection of Fees for Entering the City Centre is an example of such a solution. In a difficult situation of transport in the agglomeration, this seems to be the most effective method of solving problems. Such a system must ensure appropriate traffic capacity, it should be flexible to be extended, configured to be extended together with the development of the urban infrastructure, and first of all, it must be enforceable. Moreover, contemporary traffic requirements mean that urban fee collection systems may not be based on gates or subscription.

Gates slow down the traffic, while subscription or toll stickers are not always complied with by drivers. Therefore, automatic and electronic fee collection systems are introduced - they are capable of recognizing and classifying cars (e.g. using laser sensors), they connect by radio with sensors in vehicles, register the camera image presenting the number plate or use GPS transmission.

The experience of Swedes and Englishmen (fees for entering the centre of Stockholm and London) makes it possible to conclude that this is one of the best methods of reducing traffic in city centres. However, it is feared that the introduction of fees will lead companies to move away from city centres to the suburbs, which may considerably diminish the role of the city centre. Nevertheless, the reduction of traffic in the city centres of the Silesian agglomeration is very important, due to the limited number of parking spaces and considerably limited traffic capacity of streets.

2.4 Bus Lanes

There exist various opinions about bus lanes. As a rule, drivers do not think highly of this solution. It also turns out that they have become a reason for unpleasant incidents between drivers and the municipal police. Bus lanes should be perceived by drivers as tracks which cannot be used only by authorized vehicles. However, before this kind of perception is developed, Warsaw has decided to introduce automatic bus lane control.

London is a model for the introduction of a bus lane control system in the Polish capital city. In the second half of the 1990s, a method for counteracting the lowered competitiveness of the public transport compared to passenger cars. London developed the network of bus connections. Already at that time, 6.5 thousand buses carried 5.1 million passengers every day. Unfortunately, bus traffic was slowed down by cars repeatedly using the bus lanes. The city authorities decided to build a visual supervision system.

According to the estimates of the Warsaw Municipal Police, the ratio of the number of offences on bus lanes to the number of all moving vehicles ranges from 8 to 40% and the upper limit refers to situations of the lack of appropriate informative activity and the lower limit refers to situations of stabilization in bus only lanes and the lane is controlled by the local police and the municipal police.

The ARTR technology is used in lane monitoring – i.e., automatic recognition of number plates. There are two solutions. The first one is based on stationary camera points installed at support structures (e.g. on lamp posts along the bus lane). The system can be completed by several mobile points installed in special vehicles parked along the lane. The other solution uses mobile camera points installed at public transport buses.

Supervision systems can be extended to include additional functions, such as momentary speed and sectional speed measurements of public transport vehicles, an analysis of traffic intensity and structure on the bus lane or even identification of vehicles with hazardous materials or stolen cars.

2.5 Silesian Card of Public Services

The Silesian Card of Public Services project is aimed at implementing an information system facilitating the provision of public services via electronic means and supporting the public administration management. The main idea of the project involves the development of an integrated system of collecting and settling cashless operations for services provided by local government institutions together with an information system, making it possible to obtain data about the demand for individual services and the relations between them.

The Silesian Card of Public Services, as an electronic payment instrument, will make it possible to make electronic payments for public services. It will be possible to use the card as an inhabitant ID. It is also expected that the card will be an electronic signature certificate carrier. A dedicated application will make it possible to collect data necessary for efficient management of public institutions involved in the operation of the system. The Client's Portal will be an integral part of the project - an electronic platform which make online public services available and will integrate them. Integration of public services will consist in allowing system users to use the offer of institutions accepting the card from the Client Portal without the necessity of repeated logging in at various websites.

The project is mostly aimed at supporting the competitiveness of the central subregion, including the Silesian Province. The project will be implemented in 21 communes - the Project Partners - as regards the fees for services provided by the commune and official actions.

3 Summary

Several ways of using ITS in applications allowing for the improvement of operational parameters of public transport have been presented in the study. Due to the fact that the Upper Silesian Agglomeration is a location of many satellite cities clustered around the capital of the province, the problem of public transport and ITS systems is a complex issue. Numerous decision-making entities are not in favour of implementing such solutions. The examples of solutions are good solutions on their own, and, when combined, they make it possible to solve traffic problems. It may be concluded that a lot remains to be done in the GZM in the area of traffic management. Some solutions have not been used so far in any of Polish cities, e.g. the introduction of fees for a car's entry into the city centre. These are usually expensive solutions, but in the long run, they significantly improve the competitiveness of public transport.

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Vehicle Tracking Using the High Dynamic Range Technology

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Abstract. The capabilities of the vehicle tracking systems based on data acquisition from a single camera with a linear processing characteristic are limited by the range of light radiation acquired at a given moment. Taking into account the fact that different vehicles present on a single video frame can be either underexposed, and overexposed (especially in the case of a highly reflective surface in the sunlight), the possibilities of distinguishing between them are limited. The paper presents a method of vehicle tracking with simultaneous acquisition of video frames with different exposure parameters. Aside from changing a single camera exposure it is also possible to use a double-camera variant, especially for distant objects, for which the shift on both images acquired simultaneously is negligible. The proposed method uses a modified Track-Before-Detect technique with additional data fusion in order to obtain the High Definition Range images used for the tracking of vehicles represented on the images as the objects with varying brightness and size.

Keywords: HDR images, image analysis, vehicle tracking.

1 Introduction

Intelligent Transportation Systems (ITS) are used mainly for improving the traffic flow on the roads. The reduction of travel time, fuel consumption, carbon dioxide emission etc., as well as increase of the transport safety are possible utilising the ITS solutions [7]. The tracking technology applied for the vehicles is necessary for traffic control and monitoring. The typical road sensors used in urban areas are based on the inductive loop but some pressure (weight-in-motion) sensors may also be utilised. Unfortunately, usually a large number of them is necessary for the crossroad's measurements. Large systems use such sensors located densely under each lane of the road e.g. every 50 meters [7, 13]. Such sensors are suitable for high density traffic and weatherproof. Nevertheless, the most significant disadvantages of such sensors are large installation costs as well as the maintenance expenses. A typical inductive loop sensor should be replaced after 10 years due to its potential malfunctioning [7, 13] as well as the loop measurement unit.

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An alternative technique is based on the optical tracking using video cameras. Both near infra-red and visible light cameras are very cheap and even high resolution models are available in reasonable prices. Nevertheless, there are still some significant disadvantages of typical cameras. They are sensitive on weather conditions, necessary Video Processing Unit (VIP) is very sophisticated and expensive, their light measurements range is not adequate to the light conditions on the road. The first disadvantage depends on many conditions and can be considered as the main problem, since the middle and far infra-red cameras, which are less sensitive on weather conditions, are currently very expensive. The second problem, related to the VIPs, should be reduced in a few next years due to the electronic technology progress and expected reduction of costs. The last disadvantage is still a serious problem, since only a limited part of the light range is processed by the currently available cameras. Unfortunately there is only a small progress in high-dynamic range sensors for the road control purposes in the last years. Currently available cameras with adaptive exposure support only a part of the light range so some fragments of the acquired image are often underexposed (black) or overexposed (white). A combination of images acquired by two or more cameras working with different exposures allows the fusion into a single high-dynamic range (HDR) image. Since the cameras are cheap and support wide range of distance measurements, it can be especially important of non-urban areas where the road sensor infrastructure is usually much worse. Moreover using the proposed approach it is possible to extend the possibilities of currently available video systems with relatively low cost.

2 Spatio-Temporal Track-Before-Detect

Tracking systems are based on the detection, tracking and assignment scheme [1–3]. Generally, tracking is possible after the proper detection of the object and the influence of missed objects or false detections is reduced to some level by the tracking and assignment algorithms. Nevertheless, it is inconvenient for low Signal-to-Noise Ratio (SNR) cases. The detection is very sensitive to noise which is caused by the weather and light conditions, a long distance, size of an object, object's variability or background suppression.

Another approach for the tracking in such poor conditions is the Track-Before-Detect (TBD) scheme [2, 4, 12]. In this approach all possible trajectories are tested and if the cumulative object signal is high enough, the detection of the object is possible. A Bayesian approach for the TBD supports the raw data from the sensor instead of the binary detection used in the conventional approach. The accumulation of data over the multiple frames and sensors reduces the noise level what is essential in the TBD systems. In addition, conventional tracking systems use linear motion models, and the estimators such as Kalman filter [6]. However, the non-linear trajectories demand advanced approaches such as IMM (Interacting Multiple Models) what is important due to parallel utilisation of different models [2]. The TBD systems support non-linear trajectories by the Markov matrix transitions what is more convenient for the design of such systems.

Depending on the complexity of the trajectory some non-recurrent and recurrent TBD algorithms may be used. The recurrent version is faster for the computational point of view and needs less memory. The information update formula mixes input data and predicted positions. The motion update formula uses Markov matrix for the dispersion of probabilities (or likelihoods) between the current and future time steps. The new informations from measurements improve sharpness of the state space (probabilities or likelihoods). Depending on the value of the weight coefficient α the next prediction step is based mainly on the incoming data (α close to 0) or previous prediction (α close to 1). The basic algorithm can be described as [12]:

Initialisation:

$$P(k=0,s)=0 \tag{1}$$

For $k \geq 1$
Motion Update:

$$P^{-}(k,s)=\int_{S} q_k(s_k|s_{k-1})P(k-1,s_{k-1})ds_{k-1} \tag{2}$$

Information Update:

$$P(k,s)=\alpha P^{-}(k,s)+(1-\alpha)X(k,s) \tag{3}$$

EndFor

where:
s – particular space,
k – number of iteration,
X – input data,
$q_k(s_k|s_{k-1})$ - state transition (Markov matrix),
P^{-} – predicted TBD output,
P – TBD output,
α – weighting (smoothing) coefficient $\alpha \in (0;1)$.

Input data should be limited to a specified range, typically $\langle 0;1\rangle$ due to the accumulation of raw data by the TBD algorithm. The variable values of the tracked object signal are acceptable but the presence of some large values may significantly decrease the tracking performance in the cases when the tracked vehicle performs a maneuver. It is especially important for the recurrent TBD. Large values are undesirable because they affect the surrounding low-value measurements representing some other objects and should be suppressed.

Another problem is related to the data fusion from multiple sensors. The TBD algorithms have capability of data fusion from any kind of sensor but the information update formula should be modified for the alignment of the data range if the incoming data type or range differs. Moreover, a specific weight for each sensor should be used in such case.

3 HDR Imaging Measurements

The HDR measurements utilise a wide range of possible values that is convenient for the data storage without losing informations due to clipping or limited final representation of measured values. The High Dynamic Range Imaging (HDRI) based measurements can be obtained using a dedicated camera or multiple exposure images. The multiple exposure is especially important for the video based ITS solutions because it is usually possible to place a number of cameras (two or more) close to each other, especially for some distant measurements, without any complicated corrections related to the geometrical (perspective) projection. After the calibration of all cameras multiple measurements acquired at different expositions can be performed simultaneously with synchronisation. However, such calibration can be very complicated due to different perspective views for close distance measurements. The HDR Imaging may also be used for the driver assistance purposes [5], especially in night vision systems, often supported by some radar or infra-red sensors.

The techniques of combining multiple images at different exposures are related to one of the most relevant research trends in the image processing area. Another important aspect of research is the transformation methods of the obtained HDR images to Low Dynamic Range (LDR) ones due to many reasons from image representation to artistic aspects. During recent years many such transformation (tone mapping) algorithms have been developed [10]. An optimal mapping is very hard to find and each result is somehow unique, mostly due to some aesthetic reasons. The tone mapped images, further processed by the image processing and pattern recognition algorithms, may also be obtained using different tone mapping criteria, usually significantly differing depending on the specific application.

The HDR images (before the tone mapping) can be processed by the typical filtering algorithms and the obtained results may also be represented as the HDR images. The opposite classes of the objects (dark and bright, as well as any intermediate ones) should be tracked by the TBD algorithms but the large values should be suppressed [9]. A typical tracked object is represented on the image as the Gaussian blob shape with maximum value in the central point (representing e.g. brightness, correlation or probability).

The basic problem of the HDR tone mapping is related to the fact that the light intensity level in the environment can be significantly other than the output level that can be reproduced, as well as the available contrast range [11]. The primary goal of the tone mapping algorithms used in computer graphics is good visual match of the HDR scene and its tone mapped version visible on the image. The simplest way of conversion is the scaling, but it may lead to the loss of many details, which can be useful in further image processing or analysis. Many algorithms take into account some specific properties of the Human Visual System (HVS) such as e.g. visual adaptation that can be easily verified observing the same car with its headlights at night and in the strong sunlight. Another important elements are the background intensity, multi-scale adaptation and proper calibration.

For the tone mapping purposes several local and global operators have been proposed [10, 11] e.g. logarithmic mapping and its modifications, histogram adjustment methods, uniform rational quantisation, segmentation-based approach and many others. Another interesting approach for this problem is the usage of the frequency domain (including bilateral and trilateral filtering) and gradient domain reproduction. Nevertheless, the computational complexity of such operators is usually much higher than some typical global ones. A successful application of the HDR tone mapping for the detection and tracking purposes may require some specific operators, depending on the requirements of the algorithms applied for further analysis.

4 Proposed Approach and Results

Performing the tracking of the distant vehicles, often represented by several pixels only, in some situations the overexposed objects can cover some neighbouring ones on the images being the input data for the tracking algorithm. In order to illustrate such situation some experiments using the one-dimensional signals have been conducted (because of a better visualisation of the results in comparison to

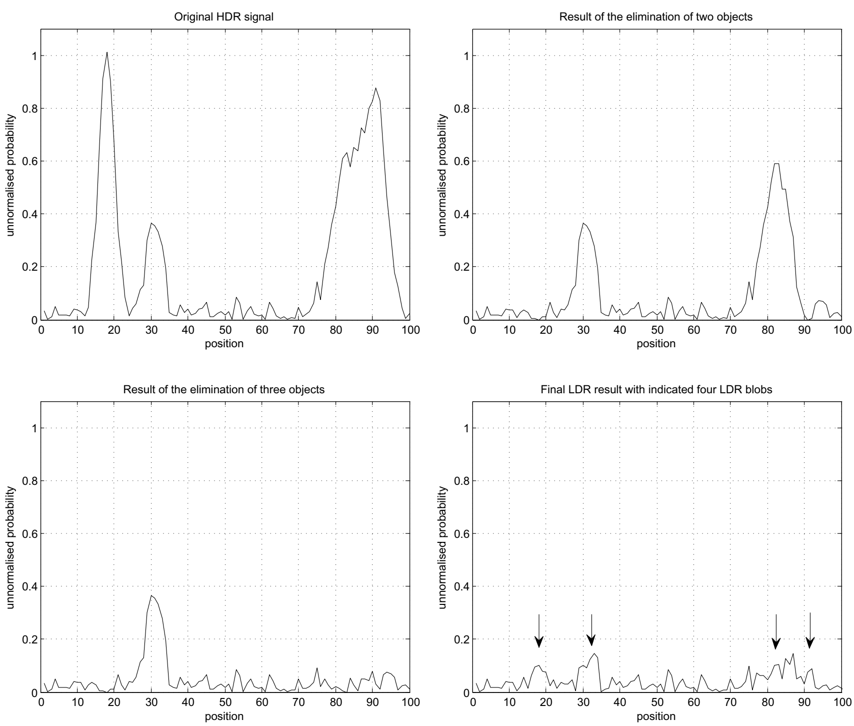

Fig. 1. Reduction of the dynamic range for the 1-D signal - HDR data, two intermediate results and the final LDR signal

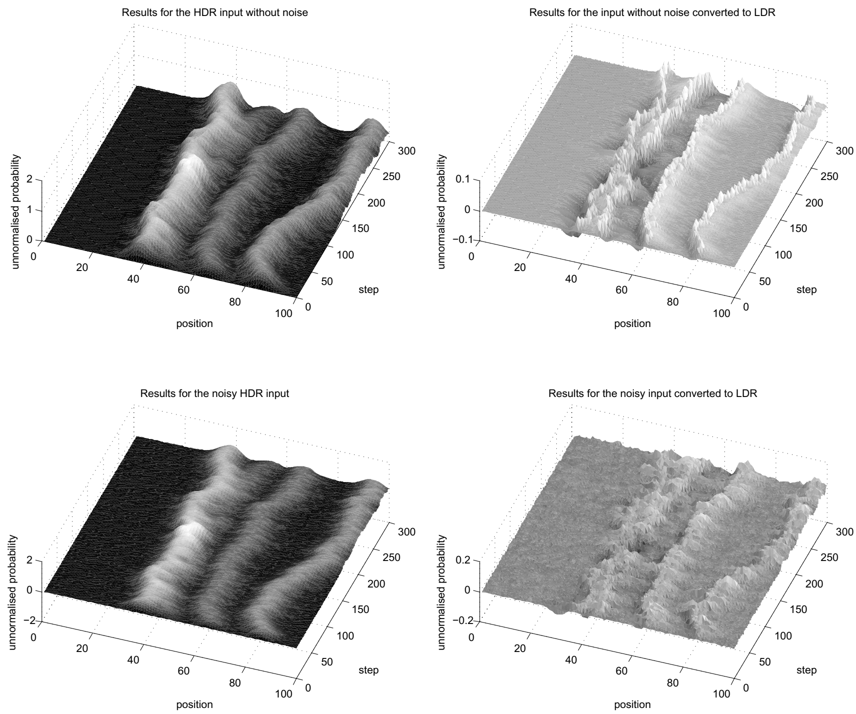

Fig. 2. Tracking results obtained for the input data with and without the noise using direct HDR input and the proposed conversion

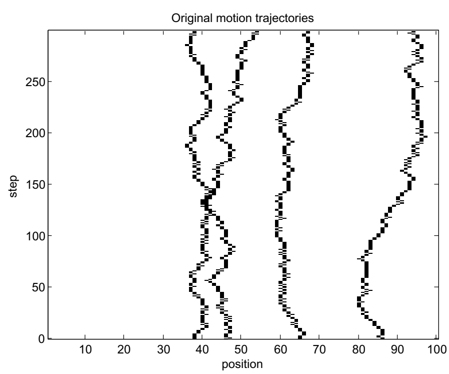

Fig. 3. Original motion trajectories used in both experiments

the 2-D case). Considering the fact, that in real applications the representations of some distant objects on consecutive frames are often disturbed by noise, the validation of the proposed approach has also been done for the noisy signals. The proposed algorithm of reduction some high peaks of the signal in order to allow proper tracking of some neighbouring objects represented by lower level signals is based on the assumption of the Gaussian blobs representing each object. Since such blobs, especially overexposed ones, are typically blurred, they may cover some other blobs, so they should be primarily detected and reduced to the lower dynamic range. After the detection of the maximum value the variance of the blob is estimated utilising the neighbouring values for the minimisation of the mean squared error. Next, the estimated blob is subtracted from the signal and replaced with a small peak. The process is repeated for some other objects until the threshold level of the signal is obtained (depending on the noise level). Such signal is the input data for the TBD algorithm described earlier. The illustration of the algorithm's idea is presented in Fig. 1, where the two neighbouring signals cover each other. After the elimination of two highest peaks the peak at the position 82 can be easily determined. The corresponding peaks in the final reduced dynamic range signal are indicated by arrows.

The results obtained by the TBD algorithm applied for the similar signal in the presence of noise and without it are illustrated in Fig. 2. In this experiment the amplitude and the position of each signal peak representing the moving objects have been randomly changed during 300 steps and the objects' exact trajectories are presented in Fig. 3. Obtained trajectories can be treated as an approximation of the distant vehicles on the multi-lane road observed from a perspective view. Analysing the obtained results, the advantage of the proposed approach over the direct usage of the HDR input data can be noticed, especially for the trajectories which are located close to each other. The direct application of the HDR input data causes the masking effect resulting in the joining of these trajectories into a single one. A separation of them is possible using the proposed conversion to the low dynamic range signal with an additional thresholding performed on the obtained results. It is easy to notice especially for the LDR signal without the noise, where the two motion trajectories located close to each other (on the left side) are well separated regardless of its common points between about 120-th and 130-th step as illustrated in Fig. 3.

5 Conclusions

The application of the HDR Imaging technologies for the traffic analysis related to the vehicles' tracking is an important area of research. Nevertheless, the direct usage of the acquired HDR data may result in some problems related with proper work of the tracking algorithm. The presence of some high blobs representing some objects may result in covering of some other objects, so their reduction is necessary for the proper tracking. Unfortunately, the most of the tone mapping algorithms used for the conversion of the HDR images to the low dynamic range ones are useful only for the computer graphic purposes. Although they are well correlated with human perception, they cannot be successfully applied for some other purposes, such as data preprocessing for the tracking purposes. The algorithm presented and verified in the paper leads to satisfactory tracking results and can be further extended towards real-time traffic monitoring applications.

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Problem of Railway Traffic Control Devices Disruption

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Abstract. The paper discusses general rules of electromagnetic compatibility between rolling stock and railway traffic control devices. It presents methods of laboratory and field measurement sensitivity to disruptions railway traffic control devices on the example of track occupation control devices. Exemplary analysis results of track circuits' sensitivity were presented.

Keywords: disruption, electromagnetic compatibility, railway traffic control devices.

1 Introduction

A prospect of opening of passenger rail market and introduction into the PKP network high-speed trains (over 160 km/h) is inextricably related with the use of modern rolling stock. From the electromagnetic compatibility point of view this rolling stock significantly differs from the traditional one (higher power, numerous presence of various systems and power processing and feeding devices). As a result, the issue of improvement of compatibility of the rolling stock with systems and devices of railways technical equipment, their complexity and direct influence on railway traffic safety should be treated thoroughly and as a high priority. Moreover, new measurement techniques and technologies and new areas of knowledge concerning compatibility of device operation should be sanctioned in regulations in force.

There should be specified railway traffic control systems and devices sensitive to disruptions, and elaborated requirements concerning broadly defined rolling stock electromagnetic compatibility with railway traffic control devices (rtc). These requirements legitimised in regulations in force. It will allow the infrastructure owner to achieve several objectives, such as:

- Limiting cases of rtc devices disrupted operation,
- Eliminating of financial losses due to cases of durable breakdown of rtc devices or their elements cused by disruptions,
- Eliminating of financial losses due to rtc devices disrupted operation,
- Eliminating of risks caused by rtc devices disrupted operation,
- Improvement of railway traffic safety,
- Eliminating of work interference related to rtc devices disrupted operation.

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Operation frequency analysis of railway traffic control devices.

Research data published in literature and gathered experiences indicate that track circuits and train sensors operating as track circuits are the most sensitive to disruptions.

Experiences gathered in the last few years (in different railway board) show that also axle counters are sensitive to disruptions, in particular caused by high-power locomotives.

Table 1 presents operation frequencies of track circuits, train sensors and axle counters applied in the network of Polish infrastructure owner PKP PLK S.A.

Table 1. List of operation frequencies for rtc devices

Track circuit type	Operation frequency [kHz]
Classic	0,05
Jointless linear and station track	1.58; 1.86; 2.17; 2.47; 2.8
Jointless point track	7; 8; 10; 12.15; 14.6; 16.8
Train sensors	10; 14.6; 19.0; 20.8; 23.4; 26.1; 28.7; 31.5; 34.6; 38.2
Axle counter	27; 42; 46; 48; 250; 1000; 1228

The frequencies listed above, or to be more precise, frequency bands will be considered further.

1.1 Operation Frequency Analysis of Traction Substations and Traction Stock

The PKP PLK S.A. network uses, above traction substations with 6 and 12 halfway rectifiers. Theoretically, at the traction substation output only harmonics resulting from rectifiers operating should appear, that is 300, 600 Hz (and harmonics of these frequencies). However, for various reasons (i.e. transformers or rectifiers non-symmetry) at the substation outlet appear harmonics of 50 and 100 Hz, all their harmonics, and harmonics resulting from super-positioning of basic substations harmonics and harmonics of 50 and 100 Hz. The 50 and 100 Hz harmonics levels depend on the quality of substation elements (transformers, rectifiers).

Filters (smoothing devices) used in traction substations are quite a different issue. This refers both to a filter type and their operation or non-operation. In the aspect of disruptions, two conditions of filter operation should be assumed that is: switched filters and disabled filters. In both cases the proportions between specific harmonics are different and depend on parameters of traction substation elements. Moreover, theoretical studies and research results until now gathered indicate that substations working with resonance filters, in comparison with substations equipped with gamma filters, are less stable in terms of operation disruption. There are several reasons for it. They are, among others derangement of resonance filters and non-suppression by these filters of 50 and 100 Hz frequencies.

Traction stock generates, above all, harmonic resulting from the converters operation. Converters of locomotives and electrical multiple units produced nowadays, work on frequency band from 30 to 300 Hz. Older type locomotives work with choppers on 33 1/3 Hz, 100 Hz and 300 Hz frequencies. Static converters usually work on frequencies of a few kHz.

In practice, every traction vehicle generates specific harmonics. Their repeatability appears only in some vehicle series using the same converter type.

Modern traction stock (traction vehicles, static converters, etc.) are usually equipped with filters that sufficiently suppress products of energy transformation in the stock. It is important to emphasise, that not all filters in the traction stock sufficiently suppress harmonics generated by converters. This refers, above all to static converters. Another issue is a manner of mass and earthing leading on the vehicle. Their inappropriate performance is often a cause of increase in disruption level, resulting from, among others entering of disruptions to traction networks (above all return network) beyond the installed filters.

In some cases of the use of high-power traction vehicles, an influence on sensors applied in axle counters appeared. A probable reason for this (European railways will conduct a research to explain this issue next year) are electromagnetic fields generated by rolling stock elements (traction engines, filter traction elements, etc.) or resonance in the return traction network.

2 Research Methodology

In order to provide electromagnetic compatibility between the rolling stock and railway traffic control devices, acceptable disruption parameters influencing rtc devices should be defined. In order to define acceptable disruption levels and a choice of assessment criteria for receivers of rtc devices, their features of sensibility to disruptions should be specified. The first one is defined on the basis of calculation of signal threshold values at which the receiver operates correctly. These parameters encompass: amplitude, frequency, impulse duration and impulse process time. Features of the rtc devices receiver's sensibility to disruptions are defined on the basis of disrupting signal parameters, similarly as in the case of defining sensibility and disruption parameters that may lead to improper operation of the receiver or its damage.

The issue of electromagnetic interferences may be omitted in the measurements, as the experience shows, that this type of disruptions have a negative influence at higher amplitudes of the signal. Disrupting influence in turn is significant at the continuous signal.

Research should be conducted in laboratory conditions, and for a comparison – in situ. Laboratory analysis was conducted for:

– Subassemblies of 50 Hz track circuits with isolated joints,
– Subassemblies o jointless track circuits,
– Receivers of train sensors.

Fig. 1, 2 and 3 show examples of specific measurement systems aimed at analysis of sensitivity and resistance to disruptions of track circuits in laboratory conditions.

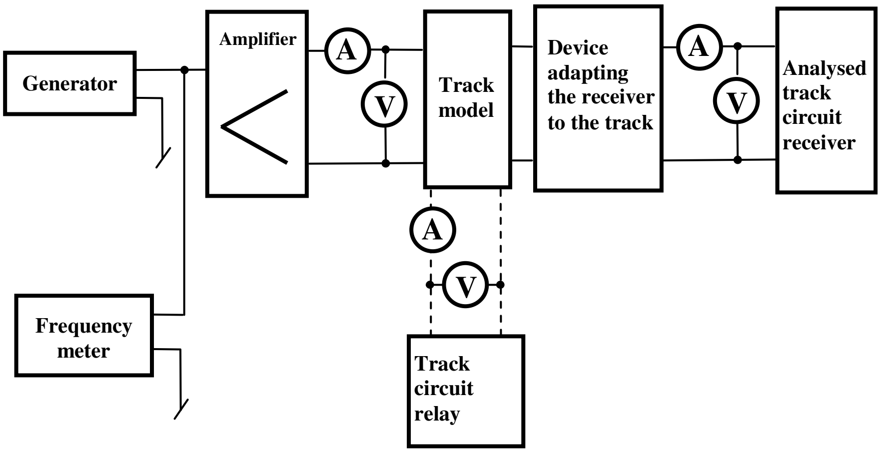
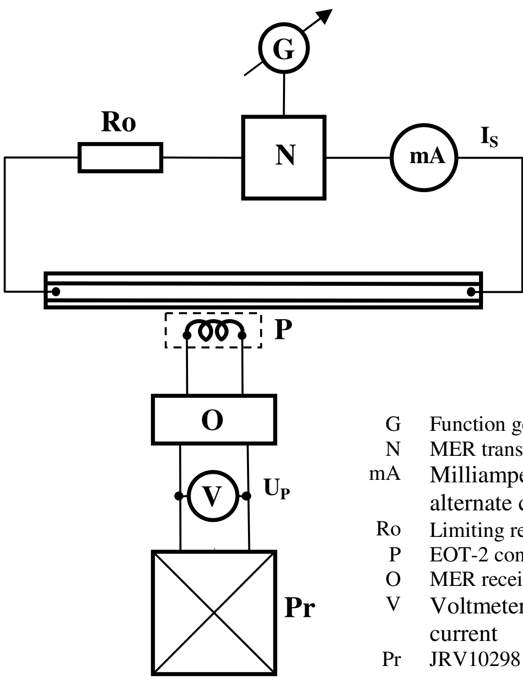


Fig. 1. Measurement system for laboratory analysis of track circuits with isolated joints



G	Function generator
N	MER transmitter
mA	Milliampere meter of 1.5 class alternate current
Ro	Limiting resistor 2Ω
P	EOT-2 converter
O	MER receiver
V	Voltmeter of 1.5 class alternate current
Pr	JRV10298 or JRB31114 relay

Fig. 2. Measurement system for laboratory analysis of current receivers sensitivity of jointless track circuits

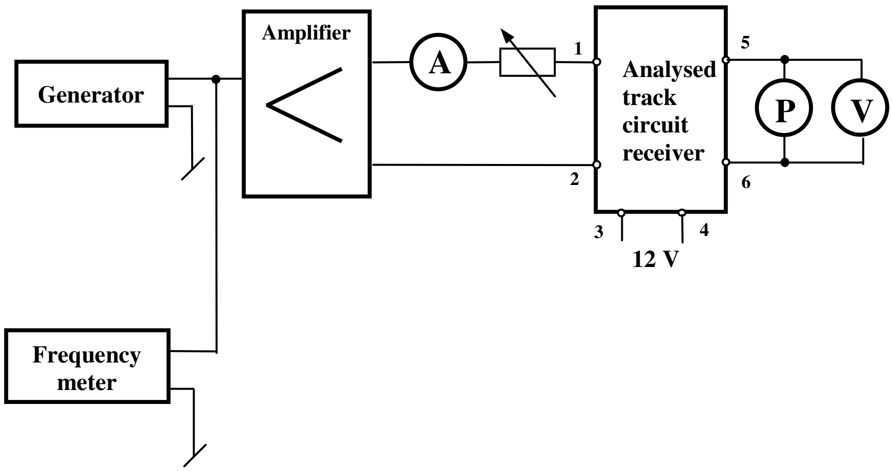


Fig. 3. Measurement system for laboratory analysis of voltage receivers' sensitivity of jointless track circuits

Field analysis should be performed according to the schemes presented in Fig. 4 and Fig. 5.

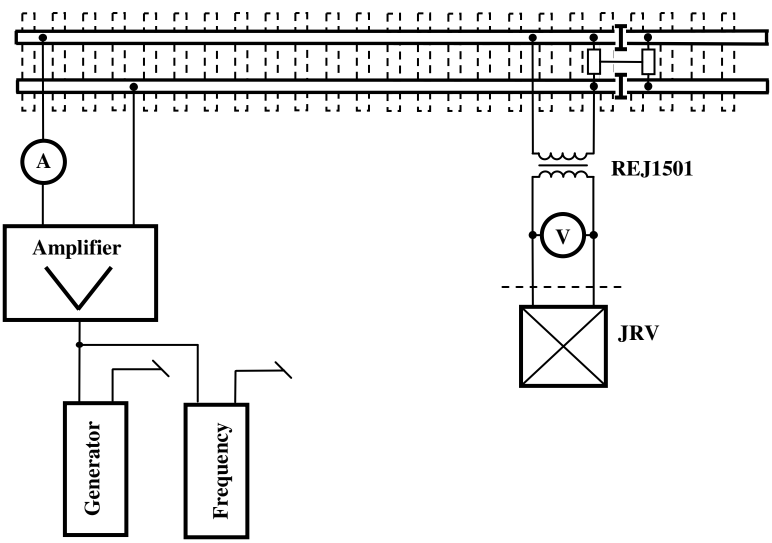


Fig. 4. Measurement system for field analysis of classic track circuit

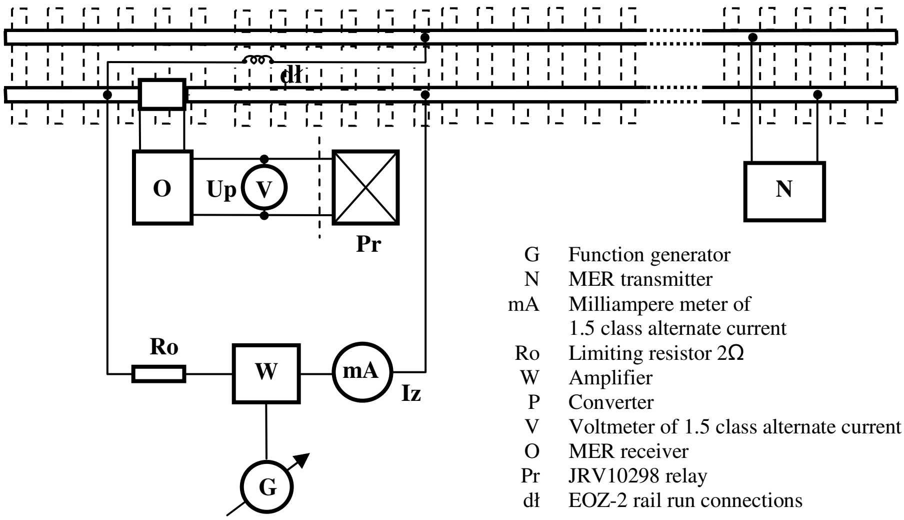


Fig. 5. Measurement system for field analysis of jointless track circuits

3 Acceptable Disruption Parameters

Depending on the effects of traction current influence, inappropriate operation of rtc devices can be defined as:

- **disrupting** – where safety conditions of railway traffic are maintained, but the disruption effects are, ie. lower railway throughput capacity, and unplanned stopping of trains (energy losses),
- **dangerous** – where safety conditions of railway traffic are not maintained (i.e. a track signalling device shows green light allowing driving, instead of red one). In any case, such a situation is unacceptable due to a potential danger of a disaster.

As all the rtc devices are located close to the tracks, and a part of them are directly connected to rails (the traction return network), they are exposed to a negative influence of traction currents.

Acceptable disruption parameters in rtc devices depend, above all on the applied device types. That is why, the devices of maximum resistance level should be used.

4 Defining of Reserve Coefficients

Features of receivers' sensitivity and characteristics of disturbance are a starting point of the disturbance assessment. Defining of disturbance acceptable parameters for a given rtc device type requires assuming adequate reserve coefficients. For track circuit receivers, being the most exposed to electric traction disruptions, acceptable disruption amplitudes should be defined for three cases:

a) free track circuit, zero working signal, the presence of disrupting signal;
b) free track circuit, the presence of disrupting signal, upon occupation of the track circuit, the receiver (transmitter) must slow down,
c) free track circuit, the presence of signal.

As a result the following terms were assumed:

A_R – amplitude of track circuit working signal;
A_p – amplitude of track transmitter attraction (induction);
A_o – amplitude of track transmitter slowdown (de-induction);
A_z – amplitude of disruptions.
$A_R : A_z = S$ – working signal to disruptions ratio.

For the cases of track circuits conditioned mentioned previously, the acceptable amplitudes of disruptions will be as follows:

– $A_z < A_P$ that is $A_z \cdot S_1 < A_P$
– S1 – coefficient of an interval of track circuit signal causing induction from disturbances of track transmitter,
– $Az < Ao$ that is $Az \cdot S2 < A0$
– S2 – coefficient of an interval of track circuit signal causing de-induction from disturbances of track transmitter,
– $AP - Az > Ao$
– $Az < AP - A0$ that is $Az \cdot S3 < AP - A0$
– S3 – coefficient of an interval between disruptions and working signal excess over induction signal.

The following values of reserve coefficients were assumed: S_1=1,2; S_2=1,1; S_3=1,1.

5 Calculating of Acceptable Parameters of Disruptions

Defining of acceptable parameters of disruptions require taking into account of track circuit sensitivity, reserve coefficients and current distribution on rails. The following issues should be considered:

a) Jointless track circuits with galvanic coupling of the receiver with the track;
b) Jointless track circuits with induction coupling of the receiver with the track;
c) Single-rail track circuits with isolated joints;
d) Two-rail track circuits with isolated joints;

For example, for track circuits from point a) calculations for the case presented in Fig. 6. were performed. The presence of asymmetry in railways was assumed due to, i.e. a rail break (marked by R_1 and R_2 resistors). For the values indicated in the picture, a maximum value of current flowing through the receiver was presented.

The results are shown in Table 2. The obtained maximum value of current in the receiver (49,1%) can be defined as 50% of the total current in the railways. It means, that in the calculations of acceptable parameters, the acceptable (in this case) disruptive current (resulting from the receiver's sensitivity) should be multiplied by 2.

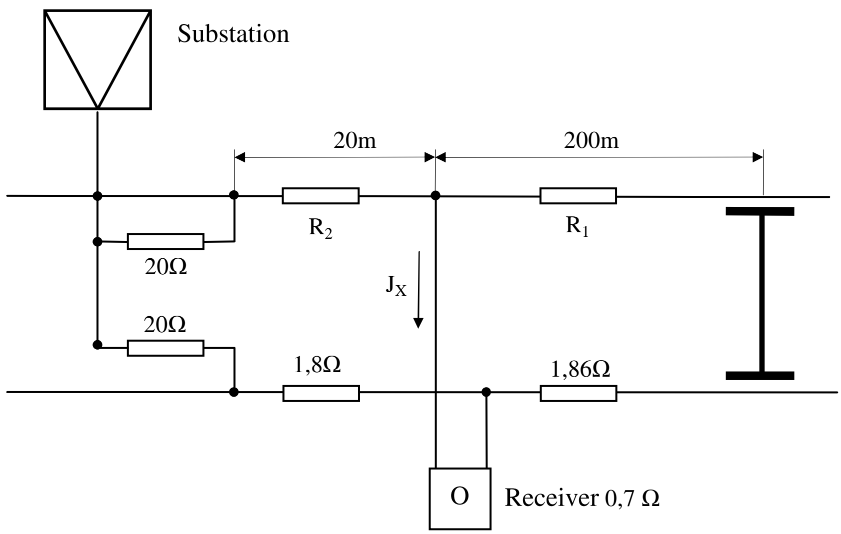


Fig. 6. Movement situation to calculate disruptions in a jointless track circuit with voltage reception

Table 2. Current flowing through the receiver for different resistance values from Fig. 6

R_1 [at R_2=18,6Ω] [Ω]	1,8	5	10	18	100k	
I_x [%]	0	3.3	7	13.1	49	
R_2 [at R_1=1,8Ω] [Ω]	18,6	30	50	150	180	100k
I_x [%]	0	11.3	22.3	38.1	39.8	49.1

6 Examples of Analyses Results

Fig. 7-10 presents examples of laboratory and filed analyses results.

Fig. 7 and Fig. 8 present features of jointless track circuit receivers working on 2800 Hz frequency. Picture 7 refers to a new type receiver, whereas Fig. 8 to an older one (year of production: 1991). The features of the new receiver are regular and

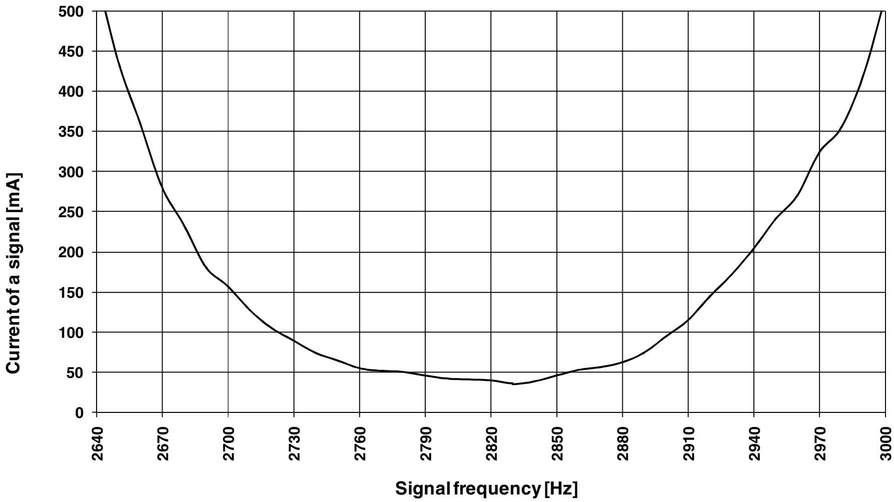


Fig. 7. Sensitivity features of MER111404/5 receiver in frequency function

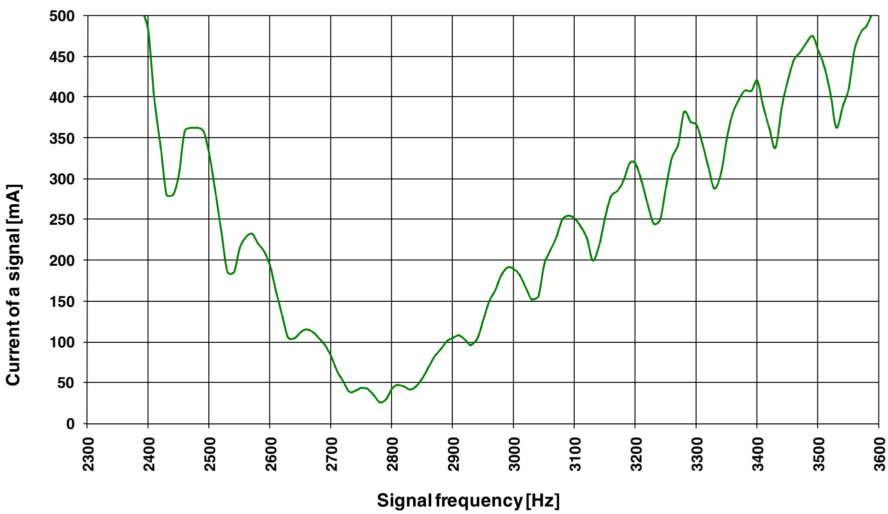


Fig. 8. Sensitivity features of MER111401/4 receiver in frequency function

symmetric with respect to the centre frequency, whereas the older receiver does not reveal these characteristics. Thus it can be assumed that railway traffic control devices should be retired after 20 years. A longer operation period leads to the loss of initial properties of their specific elements (although still working safely).

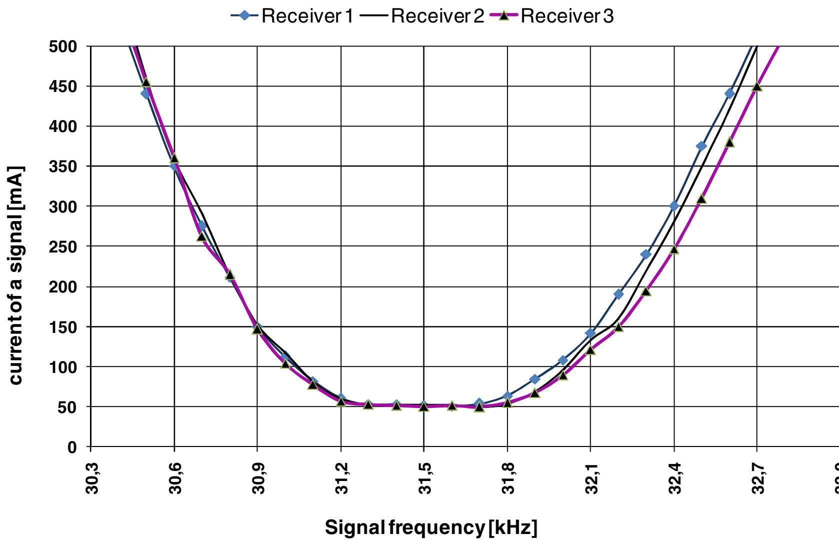


Fig. 9. Sensitivity features of a jointless track circuit receiver of current type

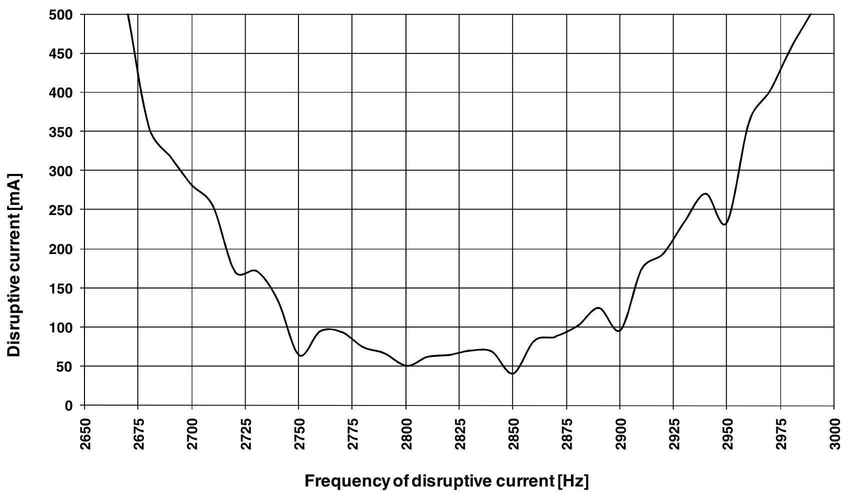


Fig. 10. Sensitivity features of a jointless track circuit receiver on a disruptive continuous signal

Fig. 9 presents features of jointless track circuit receivers operating as train sensors. The characteristics measured for three receivers are identical. It is a proof of their perfect technical condition.

Fig. 10 shows sensitivity features of jointless track circuit receivers measured on the railway. The characteristics measured in laboratory conditions are identical.

It appeared that the applied measurement systems give identical results and thus measurements may be conducted in laboratory conditions. This may significantly reduce their cost and time required for their performance.

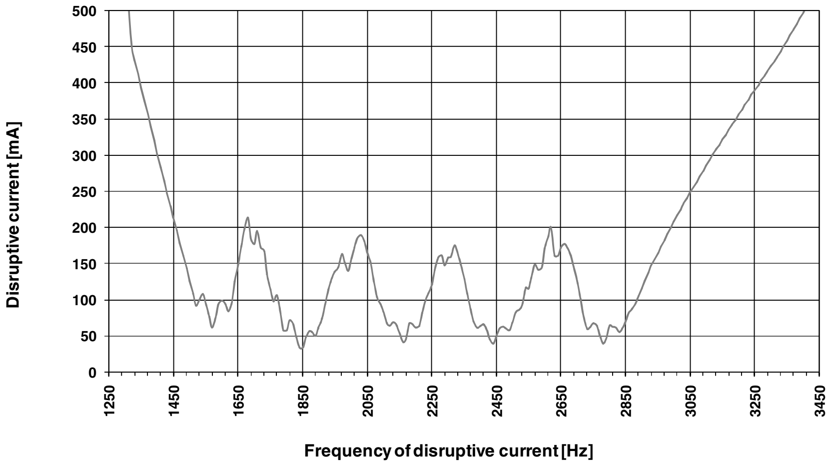


Fig. 11. Values of acceptable parameters of disturbances for old-type current jointless track circuit receivers

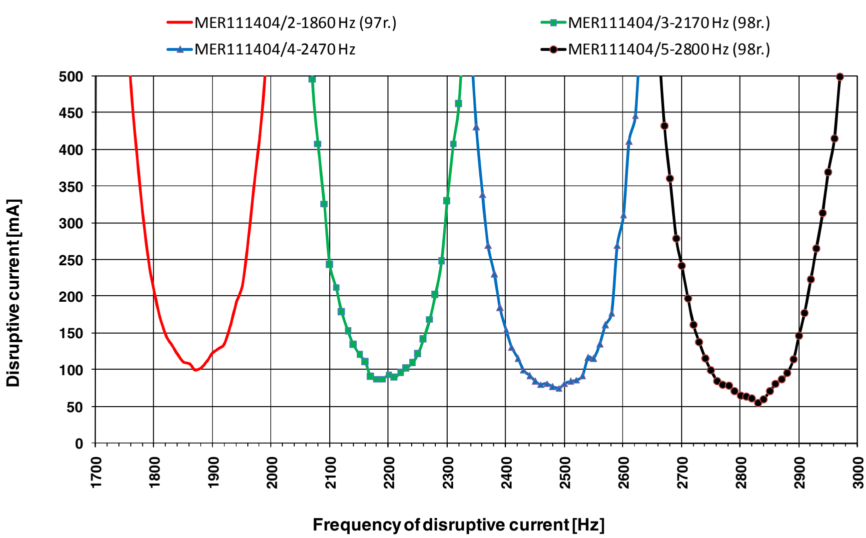


Fig. 12. Values of acceptable parameters of disturbances for new-type current jointless track circuit receivers

Fig. 11 and Fig. 12 showing values of acceptable parameters of disturbances for jointless track circuit receivers, indicate that old-type receivers present very irregular features (compare with Fig. 8), whereas new-type receivers have regular characteristics. Moreover, acceptable values of disruptive currents ARE twice as much higher for new-type receivers. This fact leads to an obvious conclusion that old-type receivers should be retired.

7 Conclusion

On the basis of the performed analyses and research, it can be assumed that:

- By means of the adopted methods of laboratory and field analyses of sensitivity features of track circuit receivers, the analogous results were obtained. It allows conducting only laboratory analyses, which will reduce costs and time needed for their performance.
- Old-type railway receivers of jointless track circuits should be retired due to parameter non-compliance and significantly higher sensitivity to disruptions.
- The obtained values of acceptable parameters of disruptions should be applied to define maximum disruption levels generated by the rolling stock (including traction vehicles) to the traction network.

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Implementation of DYSONAPP System as a Method of Increasing Traffic Safety on Rail-Road Level and Pedestrian Crossings

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Abstract. Paper concerns implementation of DYSONAPP™ system as a method of increasing traffic safety on rail-road level crossing and pedestrian crossings. This solution is dedicated for non guarded railway level crossings (without barriers or light signals). System, similarly to road signs of variable message (VMS), warns in a visual and audible way the road users (drivers and pedestrians) on approaching train. The innovation of the system appears in a technical solutions, but also in assignment to road safety equipment, that makes possible its purchasing and installation by local governments interested in increasing safety, not only by railway infrastructure owners.

Keywords: non-guarded crossing, safety, level crossing, traffic safety, vms, variable message sign.

1 Introduction

The demand on increasing safety on non-guarded rail-road crossings (level crossings) becomes more and more important due to traffic growth, especially on roads that cross secondary or low density railway lines. That are the places, where the exposure factor based on traffic volumes on the rail line and crossing roadway (vehicles per day x trains per day) is not sufficient to make implementation of barriers or light signals as mandatory by appropriate administration.

DYSONAPP has been developed by House of Solutions International Sp. z o.o. for Krakowskie Zakłady Automatyki S.A. (KZA S.A.) that produce and market the system in Poland. The background of the concept dates back to beginning of 21th century, when the first discussions on increasing safety on non-guarded rail-road crossing took place. The following years have shown rapid improvement of LED display technology, video-processing using network cameras for outdoor surveillance, mobile object detection systems and wireless communication. Simultaneous reduction of prices of this equipment made possible the development of the cost effective and smart solution. Thus, there became a space for a solution based on telematic application.

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2 Accidents on Non-guarded Level Crossings in Poland

There have been 13 084 rail-road level crossings in 2010 in Poland, including non-public, internal roads[1].

They have been divided on following categories, as in Table 1.

Table 1. Categories of rail-road level crossings in 2010 in Poland

Category	Equipment	Number	Percentage
A (activated by human)	Barriers, road warning lights	2710	20,71
B (activated automaticaly)	Barriers, road warning lights	665	5,08
C (activated automaticaly)	Road warning lights	1324	10,12
D (non-guarded)	Road sign (cross, stop)	8381	64,06
E (pedestrian crossings)	None	n.a.	n.a.
F (normally closed)	Barriers	4	0,03

There have been 354 accidents[2] recorded on non-guarded rail-road level crossings (cat. D) between January 2009 and March 2011 i.e. during 27 months. That gives the average 1 accident per 55 hours, countrywide.

Table 2. Categories of roads with non-guarded crossing

Category	Owner	Non-guarded crossings	Accidents (I.2009-III.2011)
State roads	State	28	7
Province roads	Local government	108	22
County roads	Local government	1036	118
Community roads	Local government	6025	195
Other	Private	531	6

As shown on Table 2, majority of accidents takes place on county and community roads, where the most of non-guarded crossings is located. Especially dangerous seem to be according this statistics non-guarded crossings on roads of higher categories, most probably due to traffic density and average vehicle speed.

The percentage of accidents on non-guarded crossings among total number of accidents on all crossings fluctuates in recent years around 70%.

Statistics show, that majority of accidents takes place on non-guarded crossings, that represent also majority of crossings in Poland. Those crossings are equipped with road signs B-20 Stop and G-3 or G-4 Crossbuck (St. Andrew cross). According to statistics, these signs are not sufficient to assure safety on crossings.

Installation of classical signaling devices at the crossing is associated with high investment costs. That requires also changing the category of crossing (onto A, B or C).

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[1] Source: PKP Polskie Linie Kolejowe S.A. `www.pkp.com.pl`

[2] Source: Polish Railway Transport Authority.

Lack of proper exposure factor that makes investment in expensive system mandatory, usually leads to discussion, which organization (rail or road administrator, infrastructure owner, local government) would bear such a cost. The result is (apart from a few exceptions) the remaining status quo.

3 Innovative Solution for Non-guarded Crossings

As mentioned above, requirement specification for classical signaling system for level crossing resulted in high investment cost or difficulties in appropriate budgeting them by possible investors.

DYSONAPP system has been developed in the way to avoid these dilemmas and limitations:

- invented as a road safety system, not as railway signaling system (that simplifies the requirements for architecture, safety, components, software etc).
- neither connected with the existing railway infrastructure nor the signaling systems.
- placed roadside, at the border of the railway land.

As a variable message sign (VMS), DYSONAPP can be a scope of investment by local governments, cities, towns or communes, that plan increasing traffic safety, in a similar way as they do installing speed cameras. That applies especially to places with high risk of accidents.

DYSONAPP does not alter the category of level crossing, existing traffic road signs are not changed. B-20 and G-3 or G-4 are still a formal information for drivers, which can be important in case of system failure. System operation only supports the driver with information showing images from cameras directed along the railway line and - in the case of train detection - displays sign B-1 No entry. It stimulates the driver's perception and temporarily dominates over the B-20 Stop sign. In case of internal failure detection, system displays the A-30 Other danger and adequate inscription, if possible, or turns off the screens.

4 System Operation

System consists of units connected by radio transmission, that may be powered by standard electrical network or independently by photovoltaic modules.

Fig. 1 shows main system elements – detection and warning unit (1), warning unit (2) and optional remote detection units (3).

Detection and warning unit is equipped with cameras and mobile object detectors – that is laser distance and velocity meters or Doppler-type radars. They constitute the detection subsystem. There are also warning devices, that can consist of LED screens or standard traffic lights, if simplified version. When there is no train on track in the visible neighbourhood, LED screens show current video pictures of two directions along the tracks. In case of train detection, video stream is replaced by static picture of traffic sign B-1 No entry and inscription Train Approaches. The warning is being hold by defined period of time after detection is off.

There are several options of the warning devices – there can be:

- two LED displays on both sides of the crossing showing video or warning (traffic sign),
- one LED display on both sides of the crossing showing warning (traffic sign) only, remaining black without train detection,
- traffic signal lamps on both sides of the crossing showing blinking yellow or constant red,
- other configuration – on special customer's demand.
- acoustical signals (bells, horns) similar as used in classical level crossing systems.

In case of curved railway line close to crossing or side obstacles like forest or buildings, remote detection units are to be used. They are located along the track in a place, from where is enough time between detection and warning activation. Distant detection units are independently supplied form photovoltaic panels and communicate with central unit by means of radio transmission (cableless).

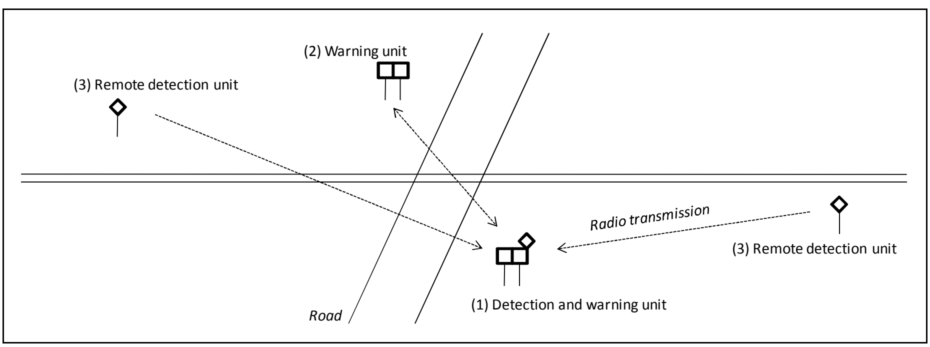

Fig. 1. Main system elements

5 System Structure

All units base on similar functional structure, as on Fig. 2. Some units (like remote detection unit (3)) are used as options, when necessary. Others are used in each configuration.

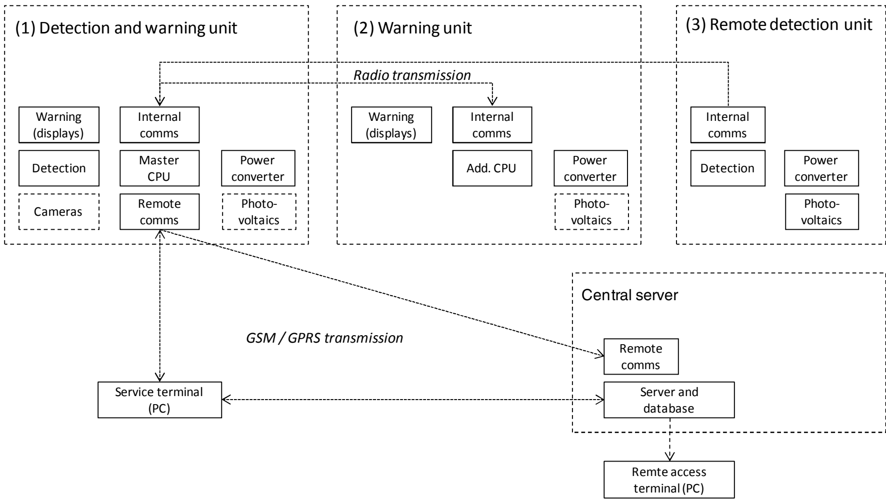

Fig. 2. System structure

Warning devices are used in each configuration on both sides of the crossing. The only possible exclusion is single acoustical warning in case of pedestrian crossings.

Detection devices (sensors, cameras) are mounted only in detection and warning unit (1) on one side of the crossing. Warning unit (2) on the opposite side receives the information to activate warning from unit (1).

System, however operating independently, is connected remotely to central server. Server contains a database of statuses of all installed systems and enables the remote diagnostic access as well as download of video files. There are also terminals (PC) for remote access and service access, used by qualified staff.

6 Operation Modes

System has following modes of operation, excluding processes of programming, setting parameters and diagnostic access:

- *Waiting mode* – no rolling stock is being detected, warning is not active.
- *Detection mode* – rolling stock has been detected, its approaching is confirmed, warning is active.
- *Failure mode* – the failure of an element has been detected, warning devices indicate impossibility of warning (A-30 sign is being displayed or displays remain black, in case of lights – red one blinks or both lamps are off), system administrator is being informed about the failure and its type by e-mail or sms.

On a double railway line, in case of detection of a train approaching from one direction, and subsequent detection of a train approaching from the other direction, warning is being switched into opposite direction and upheld, until the other train passes the crossing.

Detection of failure leads the warning devices to display failure warning or, in case of serious defect, turning off the screens.

Information displayed during active modes is shown on Fig. 3.

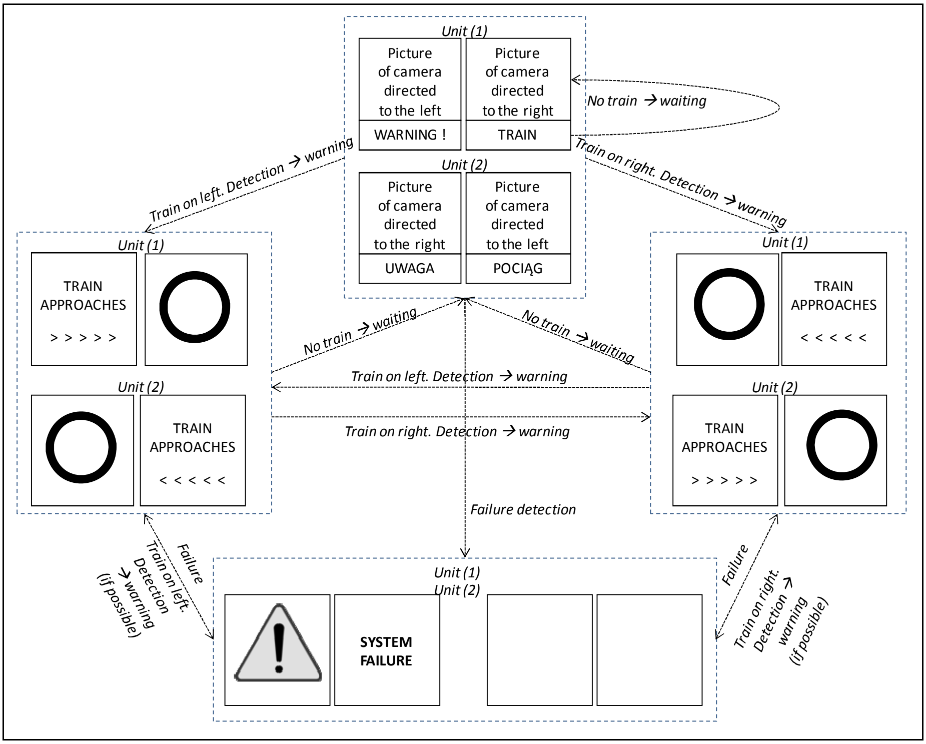

Fig. 3. Operation modes and displayed information

7 System Flexibility

Video stream is being recorded by up to 3 cameras. Two of them faces opposite directions of tracks, the third one records current situation on the crossing itself. In case of any accident, video-recording archive from all the cameras can be analysed.

On customer demand, depending on local needs, system may be used as a flexible telematic device by authorized railway personnel, municipal traffic control rooms, police or other services. Then it provides additional services as continuous videostreaming, remote video surveillance, speed or other statistical data etc.

The example of pictures recorded by cameras, including current status of display is shown on Fig. 4.

Fig. 4. Example pictures recorded by cameras and concurrent warning message

Brightness of display emission is harmonized to external conditions. During night, dawn, twilight or heavy clouds brightness is being reduced automatically, to avoid dazzling. During a day, brightness is being maximized, to assure proper perception even in full sunlight.

Acoustical warning levels may differ depending on day hours, average noise level etc. According to geographical conditions, more than one system can operate using the same remote detection units placed externally to neighbour linked crossings, along the line.

Also, in certain geographical cases, for safety reasons, the additional use of protective horizontal barriers protecting the vehicles against direct impact on the supporting structure of the system is recommended.

Power supply, control electronic elements, cameras and detectors are placed at an appropriate height to prevent theft or vandalism. There are additional sensors, that generate remote alarms when the equipment boxes are being opened.

8 Conclusion

There is a continuously growing demand for economical, modern technology-based solutions to increase safety on roads, especially on non-guarded rail-road level crossings. As the road traffic volume will increase in predictable future, the risk of accidents on these crossings will grow, too. Therefore, each trial to solve this problem in a classical or unique and modern way has to be considered as reasonable and worth trying.

System DYSONAPP, presented in this paper has a chance to fill the gap of growing demand on systems that increase safety on non-guarded crossings and reduced budgets of railway infrastructure administration and local governments responsible for road safety. It presents an unique combination of modern technology applied and formal assignment to road signaling system as a variable message sign, that makes possible cost effective proposal comparing to classical systems.

Architecture and Basic Assumptions of RSMAD

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Abstract. The study presents the architecture of Radio System for Monitoring and Acquisition of Data from Traffic Enforcement Cameras (in short RSMAD) which is used for transmission (using GSM, UMTS or TETRA networks, and through the Internet), archiving and exploring image data of traffic offenses. The paper also presents selected basic assumptions of the RSMAD system, which are relevant to the function implemented by the system. The study also discusses some aspects concerning the cryptographic security structure of the RSMAD system.

Keywords: GSM/UMTS, RSMAD, traffic enforcement camera, VPN.

1 Introduction

The Radio System for Monitoring and Acquisition of Data from Traffic Enforcement Cameras is an innovative and integrated ICT system used primarily for transmission, archiving and exploring the data concerning traffic offenses. Furthermore, the system will be able to perform other duties with greater relevance to the road safety. RSMAD is designed for the police and it is supposed to cover the whole area of the country [1]. The RSMAD system aims to improve the work of the police and other authorities empowered to control the traffic in the field of supervision and maintenance of portable and stationary traffic enforcement cameras (in short TEC), supplied by various manufacturers and distributed through the country. Above all, the implementation of the RSMAD system is to improve the road safety by reducing the number of offenses and accidents.

2 Functional Assumptions of RSMAD

The RSMAD system provides the possibility of concurrent use of shared data resources by multiple users. In this context, RSMAD have features of transactional system. The Data Acquisition Center (in short DAC, Fig. 1 – 3) is the central point of the system, which is automatically supplied with image data from multiple sources of information distributed over wide areas [2], [3]. The data transmission is realized through a variety of telecommunications systems, including radio communications

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and using any transmission technology. RSMAD allows also speeding up remote configuration of TECs based on the graphical user interface. Access to the system resources will be possible only for authorized users (Fig. 3).

The main features of the system are: complexity, integration of data and procedures, functional and structural flexibility, openness to different techniques and technologies, and security of transmission. The basic functional assumptions of the RSMAD system are as follows:

- ***the system's compatibility with TECs and software from different manufacturers*** – the structure and functionality of the system enable the co-operation with TECs of various parameters and performance provided by independent producers, compliance will be ensured only by adjusting the functional software modules,
- ***the possibility of a simple connection to a new traffic enforcement camera system (in short TES)*** – the system is equipped with a feature which allows the system administrator a simple connection of new TECs, without interference in the source code of the application,
- ***monitoring and reporting the system status*** – system administrators have a possibility to monitor the current state of the system and to detect possible malfunctions in its operation,
- ***the possibility of remote configuration of traffic enforcement cameras*** – depending on the type of devices a remote management of TECs and configuration of their parameters is possible,
- ***configuration of data processing and transmitting modules*** – the functioning of data processing modules, and modules transmitting blocks to the DAC is configurable,
- ***flexibility and system development*** – the system architecture enables its further development, flexible and easy maintenance,
- ***direct access to system parameters configuration*** – manual configuration of selected devices and modules is possible through a virtual network VPN *(Virtual Private Network)* and via remote video transmission system known as VNC *(Virtual Network Computing)*,
- ***security of information*** – the data transmission (both utility and maintenance) is realized via encrypted links,
- ***integration with external systems*** – the system provides integration with public telecommunications networks, primarily mobile and landline and a CDVaD system *(Central Database of Vehicles and Drivers, in Polish: CEPiK)* for reading data.

3 The Architecture of RSMAD

The RSMAD's architecture is distributed (Fig. 1 and Fig. 3). This means that from the perspective of end users, the system creates an impression of a centralized system [2], [3].

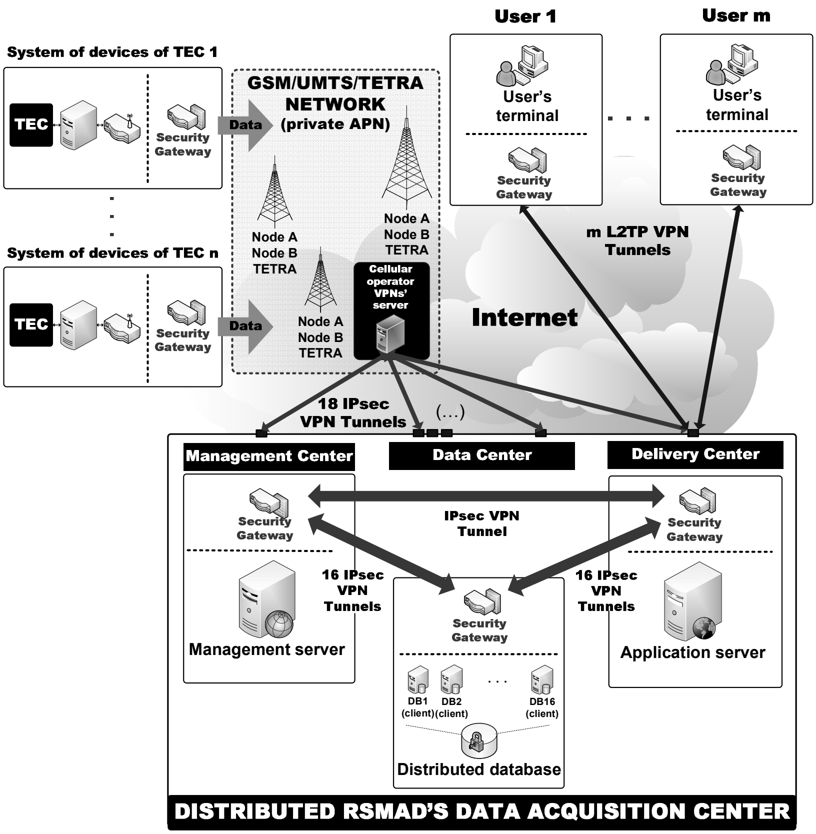

Fig. 1. Simplified architecture of RSMAD

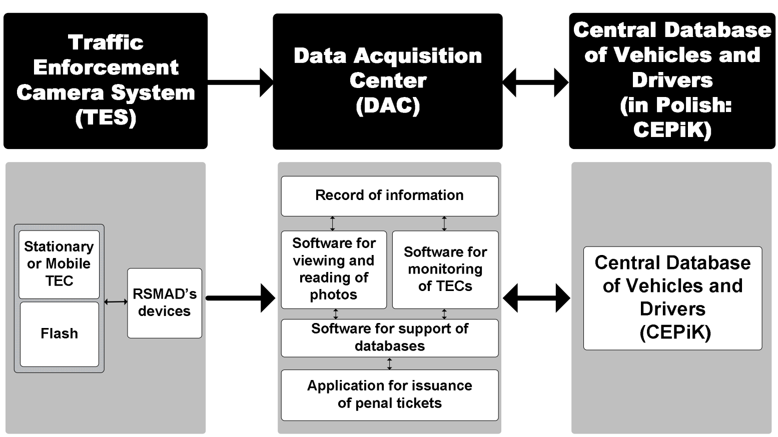

Fig. 2. Conceptual block diagram of RSMAD

RSMAD is equipped with features which allow it to communicate with the database of the CDVaD (Fig. 1 and Fig. 2). Fast and reliable access to data stored in the registration numbers database of CDVaD enables effective finding of traffic offenders, through immediate identification of the vehicle, its owner and driver. Integration with the CDVaD system is realized via secure web services.

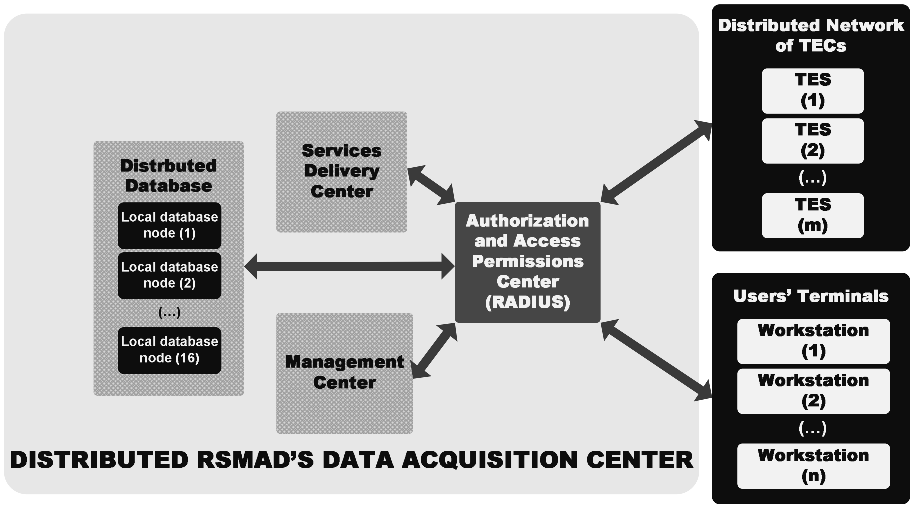

Fig. 3. Simplified scheme of users' authorization in RSMAD

The source of image data in the system are adequately equipped TECs with installed software and dedicated communications modules. The data transmission will be implemented through network-based systems: GSM/UMTS and TETRA. Transfer blocks containing image data of traffic offenses are formed and secured at the level of TES and then sent by radio to the DAC, which is composed of: the Management Center (in short MC), the Services Delivery Center (in short SDC) and the Data Center (in short DC). A detailed structure of DAC is shown in Fig. 1 and 3.

As it is shown in Fig. 3, access of authorized persons to RSMAD's database is executed using appropriate client applications.

The specificity of the RSMAD system, current regionalization of police work and other services, forces the architecture of the system to consider also these conditions. Therefore, the distributed database system is used in RSMAD. Thus, RSMAD's DC will consist of several local database servers with data processors (creating the so-called database nodes network) and the global node. The RSMAD system database is the base with so-called horizontal fragmentation due to the regionalization of the system mentioned before. This allows the storage of data from different regions on the local servers in the headquarters of various provinces or other regions. That is why the backup process will not be centralized and the responsibility for it will be born by individual field units. This allows the dispersal of reporting mechanisms on many smaller centers, which significantly influences the processing of data.

4 Selected Aspects of RSMAD's Security

Communication between TECs [3], [4] and the DAC is implemented basing on the IPsec *(IP Security Protocol)* VPNs solution and a private subnet known as APN *(Access Point Network)*. In particular, the transmission of data via IPsec VPN tunnels is implemented between the network of the GSM/UMTS networks' operator and: MC, SDC, and all DC nodes.

The IPsec protocol is implemented in a way ensuring the broadcast: confidentiality, authentication, integrity, non-repudiation and protection against attacks by repetition [5]. The security of connections is provided by the appropriate encryption algorithm and using a cryptographic hash function. However, the ability of easy migration to other solutions is preserved. The use of these algorithms in the IPsec protocol brings very tangible benefits: on the one hand it ensures a sufficiently high level of security; on the other hand, it ensures proper system performance [5].

In the RSMAD system the following areas of information security have been defined [5], [6]:

– ***ICT network security*** – all elements of the RSMAD teleinformatic network are protected,
– ***the protection of access to transmitted data*** – all the data transmitted, stored and processed in the RSMAD system is under the cryptographic protection; transfer blocks are sent in an encrypted form, and digitally signed[1],
– ***the authorization of access to system resources*** – access to the RSMAD system resources is based on a strict control of access to each of the areas of its activities (Fig. 3),
– ***firewalls[2] and advanced gateway security with control mechanisms of virus detection and intrusion prevention*** – the RSMAD system firewall and security gateways ensure the control of access to network devices (commonly referred to as hosts) and the confidentiality of data transmitted in networks,
– ***verification of data*** – the RSMAD system is provided with cryptographic protection of data in relation to their non-repudiation and integrity,
– ***security of data stored in RSMAD*** – the RSMAD system is equipped with technical and technological resources which will ensure the increase of the reliability and availability of the system.

It is also important that implementing an extensive cryptographic security structure in the RSMAD system does not hamper or in extreme cases entirely prevents users from fulfilling their duties under normal conditions. Therefore, it is important to define the policy and the security architecture ensuring, as far as possible, reaching a compromise between optimizing the efficiency of the system and reaching the required level of security. However, in order to ensure secure transmission of data

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[1] ***digital signature*** – a cryptographic transformation of data which enables the recipient to verify the authenticity and integrity of data and ensures the protection of the sender against forgery.

[2] ***firewall*** – the term referring to a specific software or hardware with appropriate software deployed, which aims to protect systems and networks from attacks of intruders.

between applications and network services, basing on a SOAP[3] mechanism *(Simple Object Access Protocol)* the secured HTTPS *(Hypertext Protocol Secure)* is used. Each call to the network service is also associated with the calling party authorization.

5 Conclusion

This study was entirely devoted to discussion of the architecture, assumptions, functional and safety issues in the ICT system of RSMAD, mainly in terms of the system. Because of a very wide range of topics only the most important aspects were presented in the paper.

The running of a system demonstrator, which primary objective is to demonstrate that the proposed scheme can successfully operate in real conditions, is also planned in the project. The concept RSMAD demonstrator's architecture will be based on main and target concept of RSMAD in each of its areas: the system, network and application.

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[3] ***SOAP*** – protocol which enables the exchange of data and communication regardless of technology used in XML *(Extensible Markup Language)*.

The Significance of ITS Applications for the New Mobility Culture in the Cities

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Abstract. Negative influence of the transportation on urban environment is a real fact in the case of a number of cities. Its background is in the increase in urban density and in the mobility of the inhabitants primarily due to the growth in individual motoring. Also the analysis of the task and workload split in transportation confirms the domination of the road transportation. Other challenges due to the transportation activities are: permanent congestion, deteriorating quality of air in the cities and the growth in the number of accidents. All of the above require reflection and call for changes. The changed approach to mobility in the cities has been termed the new mobility culture. Important position on the way to sustainable mobility has been taken by the activities related to the applications of intelligent transportation systems. The identification of the related issues to be solved as well as the options and potential solutions in the context of the new mobility culture have been discussed in the present paper. New mobility culture is at the same time a way to a better and more environmentally friendly transportation in the cities. It allows a wide spectrum of actions.

Keywords: urban transportation, ITS applications, mobility.

1 Introduction

Transportation in the cities causes a range of detrimental effects. A source of a large part thereof is the rapidly developing individual motoring as well as the domination of road transportation in the domain of urban transportation. Such a situation makes it necessary to undertake the actions leading to balancing the social, economic and environmental goals of transportation related activities in the cities.

The sustainable transportation allows maintaining the degree of mobility of citizens which was already achieved and leads to the improvement in the transportation availability of cities and their functionally diversified areas. These effects are achieved with the maintained criteria of environmental protection, improvement to the quality of life of the citizens, enhanced economic effectiveness of the projects related to urban transportation and with the principle of equal access to the transportation services for all the transportation users.

The concept of urban transportation implementing the above listed principles has been termed the New Mobility Culture. The activities and undertakings implementing

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the intelligent transportation systems to solve the sustainable mobility issues are of particular importance on the way to its introduction. This topic is a subject of discussion in the present paper.

2 New Mobility Culture as the Factor of Development Balancing in the Cities

The need for a sustainable development of urban transportation makes one reflect and – by posing difficult challenges – raises the awareness of the need for changes. This is particularly true in the situation when:

– negative influence of the transportation on the natural environment is a real fact (deterioration of the air condition, noise, increased number of accidents),
– traffic density in the cities and the mobility of the citizens constantly increase, mainly due to the rapid development of individual motoring,
– the investigation of the distribution of transportation tasks proves the domination of road transportation.

The change of approach to mobility in the cities and its understanding – different to the traditional one – has been given a name of New Mobility Culture [4]. According to the Green Paper: 'Towards a New Culture for Urban Mobility' (2007), the New Mobility Culture is a search for such solutions to the problems of transportation, which are characterised by [2]:

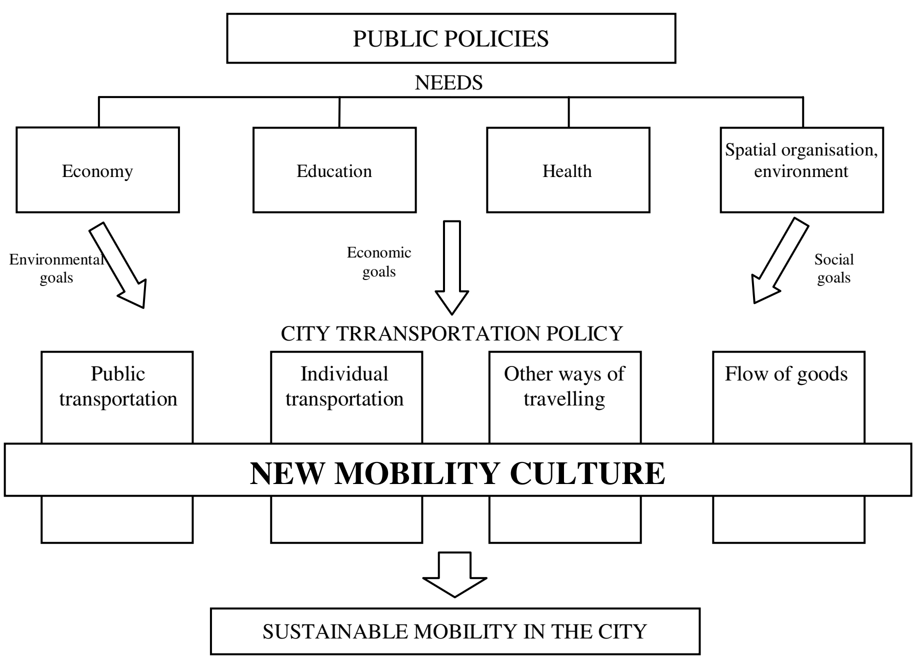

Fig. 1. The concept of New Mobility Culture in the city as an instrument of balancing the social, economic and environmental goals

- innovative technologies, suitable for the needs,
- the use of ITS applications,
- pro-environmental nature and high degree of safety of the transportation as well as by implementation of economic incentives and putting in practice appropriate legal regulations.

Table 1. The features of an urban transportation system operating and developing in agreement with the sustainable mobility principles [5]

A feature of an urban transportation system with sustainable mobility principles	Activity directions in specific value areas of urban transportation system	The expected results of value increase in the urban transportation system
1	2	3
1. Right organisation of the urban transportation	– Changes of the transportation behaviour of the transportation users, changes in the infrastructure of urban transportation and in the means of transportation (in accordance with the sustainable development principles)	– Reduction of CO_2 emissions – Reduction in air pollution – Reduction of transportation-related noise levels – Decrease of the number of accidents
	– Reduction of congestion in urban traffic	– Better perception of the city, which becomes more competitive as compared to other territorial administration units – Improvement to traffic quality in the city, including better smoothness
	– Taking into account identified social needs	– Improvement in the availability of urban transportation and the quality of service – Integration of transportation activities with the public policies (education, health, social policy)
	– Ensuring the improvement in social and economic coherence	– Socio-economic development of the city – Improved attractiveness of the city for a range of social and economic activities

Table 1. (*continued*)

2. Creating conditions for making rational choices by the transportation users as to the way of travelling and to the flow of goods	– Intra and inter branch integration in passenger transportation – Development of intermodal transportation in the freight transportation sector	– The improvement of the economic situation of the city inhabitants and of the businesses operating on its territory – Improvement in the effectiveness of spatial management (new areas for diversified activities and the improvement in the relations between different business activities)
3. Creative influence of mobility in the city on the complementarity if solutions in long range transportation	– Construction of functionally diverse interchange centres, integrated stops and logistic centres – Ensuring efficient and effective service for branch and inter-branch nodes and contact sites for relocation systems	– Reduction of the costs of transportation – Achieving high priority for the time factor – Creation of a journey as a stream of efficient, effective and safe continuation of the previous journey (similarly as in freight transportation)

The New Mobility Culture (cf. Fig. 1) concentrates the activities leading to the balancing of the transportation in the cities. At the same time the implementation of social (the improvement to the quality of life of the citizens and other users of transportation), economic (the support for the economic growth) and of environmental goals (protection of the natural environment) takes place.

The concept stresses the need for combining a number of different activities, various ways of relocating and types of means of transportation utilised. This has been assumed a principle in approaching the sustainable transportation topics. Reaching the sustainable mobility requires a development of a long term plan of operation and development of urban transportation. The result of such a plan is a final shape of the transportation system, which is aligned with the sustainable mobility principles. Table 1 presents the key features of a transportation system operating and developing in accordance with the above mentioned principles, lists the necessary activities and the expected results.

In order to achieve the integration of social, economic and environmental goals of urban transportation, to form a well organised transportation system allowing a rational choice of the way of travelling or of transporting goods providing complementary solutions in long-range transportation by balancing the mobility in the cities, it is necessary to name the key problems of the mobility and the instruments that need to be used in solving these problems.

3 Sustainable Mobility – The Challenges for the Contemporary Urban Transportation

The current section is dedicated to the discussion of the challenges of the contemporary urban transportation on its way to sustainable mobility. These challenges will define the direction of the activities undertaken within the urban transportation system. In the indicated areas, the implementation of certain specific tasks will require using advanced ITS technologies. The stream of interrelations of sustainable mobility in the cities and of the ITS applications is presented in Figure 2.

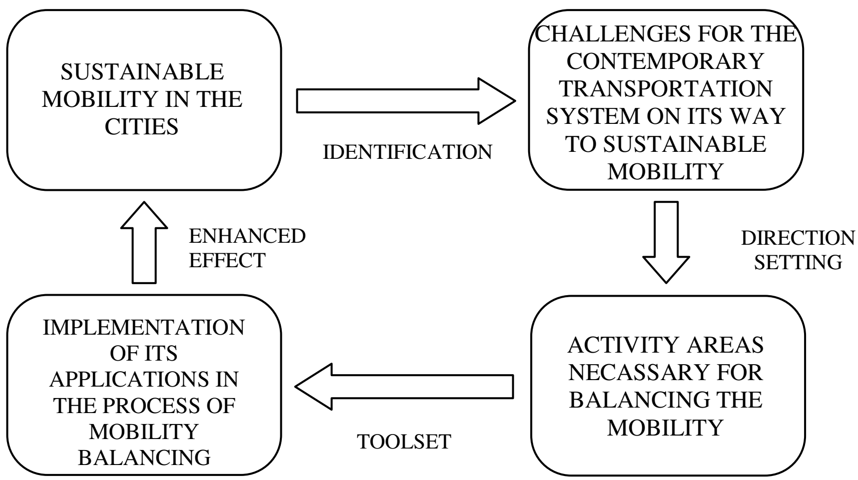

Fig. 2. ITS application as one of the instruments of balancing the mobility in the cities

In general, the challenges for the urban transportation systems should contribute to defining the effective operating framework for the transportation users, operators as well as the decision makers, to the introduction of new technologies optimised in time and space and to the development of the proper infrastructure. The challenges concern [3], [8]:

– reduction of the energy consumption by the urban transportation (quantitative aspect) and more environmentally friendly energy consumption (qualitative aspect),
– better utilisation of the urban transportation infrastructure and the improvement to the traffic quality,
– limiting the negative influence on the natural environment and on its most important resources,

- the need for considerable modifications to the transportation technologies, which should be characterised by:
  - the use – in all possible and justified cases – the most efficient means of transportation and the combinations thereof,
  - utilising road transportation only at final sections of the trip or goods flow; the transportation operating in such a way must also be pro-environmental;
  - increased support of the transportation systems by the information technologies, allowing simpler and more reliable transportation,
  - the improvement in the power efficiency of the vehicles used in the cities in all types of transportation,
  - increasing share of integrated service for passenger and goods transportation;
- the improvement in the availability of the public transportation and non-motorised individual transportation (pedestrian and bicycle traffic) as well as the improvement to the quality thereof;
- the increase in safety and reliability in urban transportation,
- introduction of demand management and spatial organisation supporting the limitation of traffic,
- innovation in urban transportation, generating modern (efficient, effective, environmentally friendly and safe) solutions in people and goods transportation, remaining consistent with the sustainable mobility principles defining the mobility standards in the cities and utilising the advanced ITS technologies.

The challenges defined in this way at the same time determine the areas of necessary changes to the transportation systems in the cities and their surroundings. Fig. 3 illustrates the system of systemic challenges and change areas. The change areas are, among others, the infrastructure and vehicle base of urban transportation, the use of ITS technologies, the mobility management domain and related behaviour of the subjects operating on the supply and demand sides of the urban transportation services market, legal regulations and the development of economic incentives stimulating the process of balancing the mobility in the cities.

The identified change areas allow defining the activities to be undertaken to achieve the sustainable mobility condition in the cities.

The new mobility culture in the cities means balancing their socio-economic development, generating certain qualitative and quantitative transportation needs, defining the level of access to the urban areas from the outside and the degree of internal coherence, while caring about the improvement to the quality of life of the inhabitants and other groups of transportation users and about the environment. The development of urban transportation systems consistent with the above principles introduces a number of changes to the current state. The ITS application will be of great significance for the course of changes specified in Table 2.

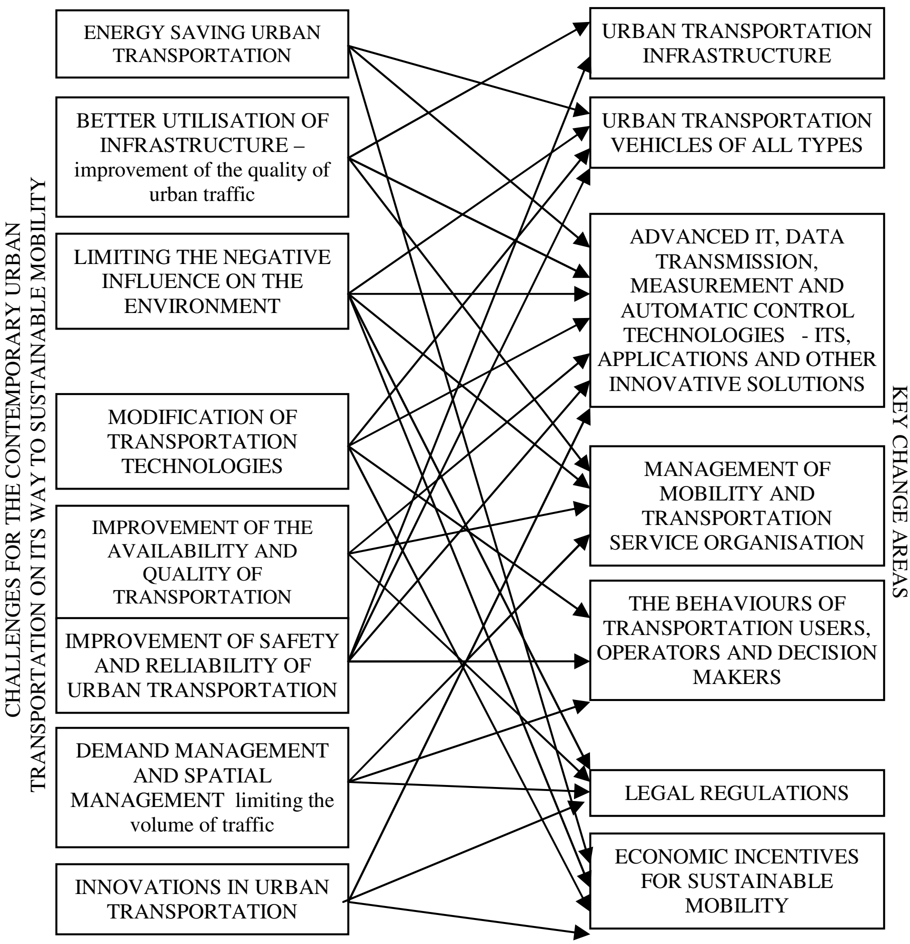

Fig. 3. The challenges of the contemporary urban transportation versus necessary change areas in the activities leading to the sustainable mobility [3], [4], [8]

Table 2. The list of changes in the specific areas of urban transportation system resulting from the challenges for the contemporary urban transportation in the process of forming the sustainable mobility in the cities [1], [3], [4], [8]

Area of changes to the urban transportation systems, necessary in the mobility balancing process	List of changes in a specific area of the urban transportation system
1	2
1. Urban transportation infrastructure	– the development of infrastructure for pedestrian and bicycle traffic – infrastructure modernisation aimed at the improvement in safety and reliability of traffic – building a new infrastructure for the distribution of alternative fuels and supporting new drive systems in motor vehicles – making the use of the urban transportation infrastructure more flexible and with a widened scope
2. Vehicles of all kinds of urban transportation	– modernising the design and the equipment in the vehicles as to increase the traffic safety – improvement in the power effectiveness of the vehicles in urban transportation – further development of the vehicles with alternative power systems (independent of petroleum oil); gradual elimination of conventionally powered vehicles from the cities – use of more robust, lighter and more specialized passenger vehicles – introduction of alternative drive systems and fuels in the urban transportation fleet (buses, taxis, supply vans)
3. Advanced IT, automated control, measurement and data transmission technologies - ITS applications and other innovative solutions	– support for the transportation infrastructure to improve its utilisation and to extend the capacity of information and communication systems; – the development of ITS technology applications in the basic operating areas of urban transportation; – the development of information systems improving the mobility in the cities, enhancing the process of providing information to all participants of urban traffic and of traffic management; – the development of ITS technologies in the domain of traffic safety; – creation of intelligent mobility systems in the cities – implementation of the innovative solutions limiting the negative effects of transportation activity in the cities – further development of intelligent car design – implementation of innovative and less costly solutions in collective urban transportation (e.g. fast, high priority bus transportation, flexible transportation of people, etc.)

Table 2. (*continued*)

4. Mobility management and the organisation of transportation service	– creating the conditions for implementing a co-modality of passenger cars and public transportation (Park-and-Ride) – optimisation of use of private passenger cars (Car-Sharing, Car-Pooling) – the improvement in the availability of urban transportation for the people with physical impairment – the development of virtual mobility eliminating a substantial part of mobility needs, – influencing the transportation users by propagating the means of travelling alternative to passenger cars, – integration of city transportation policy with other public policies (economy, spatial organisation, education, health) – including logistic topics in the transportation policy domain of the cities – improvement in the city cargo logistics, – construction of the public transportation offer in such a way that the needs of the citizens and other users related to basic mobility are met, provision of an easy access to the services with high effectiveness – creation of new standards and benchmarks in transportation systems
5. The behaviour of transportation users, the operators and decision makers (behavioural factors)	– promotion of the travel by public transportation, on foot or by bicycle – promotion of pro-environmental style of driving (to be a part of the driver training programmes) – promotion of life styles less dependent on motor vehicles – incentivisation of applying new standards of individual mobility – intensification of various (in its form and content) education and information campaigns for the traffic safety targeted on urban population – improvement in qualifications, competences and skills of urban transportation personnel
6. Legal regulations	– utilisation of opportunities created by the EU regulations (e.g. rights and obligations of various users of transportation) – the development of urban infrastructure design standards in the domain of transportation safety and protection in the cities – working out the guidelines and general rules for division of the urban space into zones to prevent the formation of mobility barriers for people and goods – the support for the pro-environmental transportation by means of a proper public procurement system – extension of road fees and toll system and making the relevant taxation system more fair and uniform

Table 2. (*continued*)

7. Economic stimulation of sustainable mobility	– relating the fees (e.g. parking fees) to the size of public space available to transportation – introduction of new, environmentally friendly transportation technologies to the market by means of offering financial incentives – financial support for the project of enhancement of the competence of public offices personnel in design and implementation of mobility plans

4 The Use of ITS Application in the Activities Targeted at New Mobility Culture in the Cities

The process of definition of general directions of future activity directions in urban transportation targeted at achieving the sustainable mobility condition, of the areas of their allocation and of the postulated changes in specific areas leads to the conclusion that advanced ITS technologies are one of the necessary conditions of reaching the goals of sustainable mobility in the cities. Therefore, it should be assumed that without a widespread application of ITS the reaching of a high level of sustainability in mobility is currently not possible.

Due to its widespread applications, ITS currently contribute to:

– preparing the urban transportation systems for the achievement of future objectives and tasks,
– positive thinking about the possibilities of reaching the vision of future urban transportation, the attributes of which will be sustainable mobility in the city and environmentally and people friendly urban transportation.

In the process of reaching the sustainable mobility in the cities the intelligent transportation systems are of primary importance as they perform the functions related to traffic management, infrastructure management and information systems. The systems may relate to either both subsystems of urban transportation – public collective transportation and individual transportation (integrated management systems) or alternatively to any single one of them.

The implementation of ITS applications in traffic management systems, infrastructure management systems, and in information systems generates a number of advantages for different groups of users of the urban transportation. This is possible due to a harmonised implementation of social, economic and environmental goals, i.e. due to the characteristic feature of sustainable mobility. The following advantages may, among others, be named [4], [7], and [8]:

– as related to the infrastructure:
  - better utilisation of the urban transportation infrastructure,
  - improvement in the effectiveness of use of the transportation infrastructure and means by different groups of transportation users,
  - the possibility of more effective planning of trip routes (trip times, number of interchanges) or delivery of goods,

– as related to urban transportation vehicles:
  - reduction of the harmful emissions,
  - improvement in the selected operating parameters of public transportation vehicles, resulting in better transportation capacity,
– as related to the delivery of transportation services and to the individual transportation:
  - simplification of the service processes in passenger and freight transportation and the improvement in the reliability of urban transportation,
  - increase in the number of trips using several different means of public transportation,
  - reduction of delivery times in freight transportation within the territory of a specific city,
  - reduction of the number of congestion sites within the city transportation network and the improvement of the traffic smoothness,
  - fulfilling some of the needs related to the access to services without generating additional mobility.

ITS applications in urban transportation allow creating the innovative mobility standards [9]. An example of a mobility standard in passenger transportation is presented in Fig. 4.

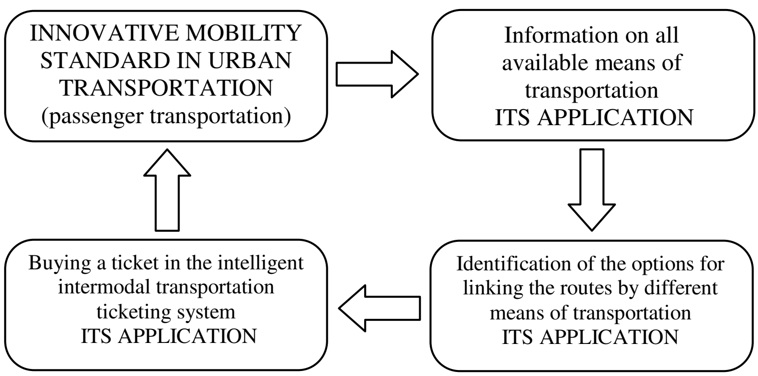

Fig. 4. Innovative mobility standard in urban passenger transportation

In urban transportation and within the innovative mobility standard ITS applications are the basic tool used at each stage of the transportation process.

On the way to more environmentally friendly and better transportation in the cities, meeting the requirements of the sustainable mobility, a wide spectrum of activities may be applied. Also the actions involving the use of intelligent transportation systems may concern all the component elements of the urban transformation and may come in high numbers. These facts put a focus on the leading role of the innovative solutions such as ITS in the process of achieving the sustainable mobility in the cities.

5 Conclusions

The review of the relations between the process of providing the sustainability of mobility in the cities and its most fundamental tools being ITS applications makes it clear that the local authorities have a wide range of options for the activities aimed at achieving the goals of the new mobility culture. In addition, these activities are supported by the European Union. The tangible support is the financial means available for the activities targeted at achieving the sustainable mobility in the cities. These means are included in the Structural Funds and in the Cohesion Fund and may be used to support innovative solutions developed in the member states of the Union. The proof may be, among others, the results of the CIVITAS initiative within CARAVEL project implemented in 2005-2009 in four European cities: Burgos, Genoa, Kraków and Stuttgart [6].

In relation to the new mobility culture it has to be stressed that the relevant tasks in the Polish cities are highly specific. In these cases, the overall process of reaching the sustainability in mobility is superimposed on the processes of re-building and development of transportation systems (carried out for more than two decades now) and on the process of qualitative and quantitative matching of the transportation potential of individual cities with the identified and dynamically changing needs. As it may be mentioned, a large number of Polish cities concentrate currently on the construction of efficient and effective urban transportation systems, while the activities targeted on sustainable mobility are the components thereof yet not necessarily of the highest priority.

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Effect of Aggressive Driving on Formation of Congestion

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Abstract. In this paper we consider the effect of aggressive driving on the formation of congestion. Many studies have shown that aggressive motorists, who drive too fast and too close to the vehicle in front, or timid motorists, who leave a too big gap, send a "wave of deceleration" backwards, down the road and the traffic grinds to a halt. Such behaviour leads to the stop-start traffic jams which infuriate many motorists. Aggressive drivers, who do not leave enough space the car in front of them, and timid drivers who need a big gap between themselves and the cars surrounding them, gum up the works for everybody else. The researchers concluded that, on the whole, timid drivers create more problems than aggressive ones but on the other hand the timid driving belongs to forms of aggressive behaviour of drivers. And these traffic jams are not merely frustrating for motorists – they also lead to increased fuel consumption, more emissions and more accidents. An important issue is finding when a driver becomes aggressive. In Slovakia, we conducted a questionnaire survey among drivers and our contribution will describe the results of this research focused on the impact of aggressive behaviour on the possible fluidity of traffic flow.

Keywords: aggressive driving, congestion, traffic flow theory, questionnaire survey.

1 Introduction to Traffic Flow Theory

The generalized relationships between speed, density and flow rate are shown in Fig. 1, with these parameters defined as follows [2]:

- ✓ **Flow Rate M** – the equivalent hourly rate (vehicles per hour) at which vehicles pass over a given point or section of a lane or roadway during a given time interval of less than one hour.
- ✓ **Speed V**– defined as a rate of motion expressed as a distance per unit of time, generally as kilometer per hour (km/h). In characterizing the speed of a traffic stream, a representative value must be used, because a broad distribution of individual speeds is observable in the traffic stream. The curves in Fig. 1 utilize "average travel speed", which is computed by dividing the length of the highway segment under consideration by the average travel time of the vehicles traversing it.

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✓ **Density H** – the number of vehicles occupying a given length of a lane or roadway at a particular instant. For the curves shown in Fig. 1 the density is averaged over time and is usually expressed as vehicles per hour (vehicle/h).

✓ The principles of macroscopic models are relations between the essential characteristics of a traffic flow – intensity, density (quantitative characteristics) and speed (a qualitative characteristic). For a complete description only two of these characteristics are sufficient, the third one can be calculated according to a continuity equation (see equation 1):

$$M = HV \tag{1}$$

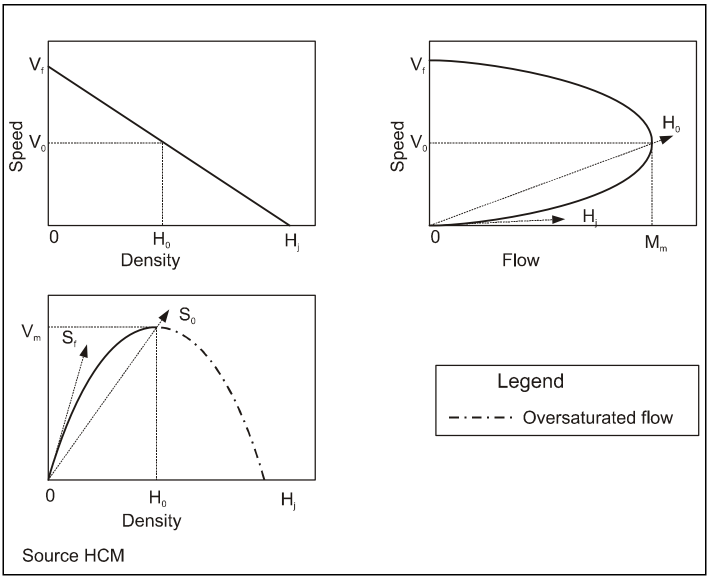

Fig. 1. Generalized relationship among speed, density and flow rate on uninterupted – flow facilities

The form of these curves depends on the prevailing traffic and roadway conditions on the segment under study. Moreover, while the diagrams in Fig. 1 show continuous curves, in reality there are likely discontinuities, with part of these curves not present. The curves illustrate the following significant points.

✓ A zero flow rate occurs under two different conditions. One is when there are no vehicles on the facility – the density is zero, and flow rate is zero. The second is when the density becomes so high that all vehicles must stop – the speed is zero, and the flow rate is zero, because there is no movement and vehicles cannot pass a point on the roadway.

✓ Between these two extreme points, the dynamics of traffic flow produce a maximizing effect. As the flow increases from zero, the density also increases,

> since more vehicles are on the roadway. When this happens, the speed declines because of the interaction of vehicles. This decline is negligible at low and medium densities and flow rates. As the density further increases, these generalized curves suggest that the speed decreases significantly just before the capacity is achieved, with the capacity being defined as the product of density and speed resulting in the maximum flow rate. This condition is shown as the optimum speed V_o (often called the critical speed), the optimum density M_o (sometimes referred to as the critical density), and the maximum flow V_m.

An efficient freeway operation depends on the balance between the capacity and the demand. In the simplest terms, the highway congestion results when the traffic demand approaches or exceeds the available capacity of the highway system. As the vehicle demand approaches the highway capacity, the traffic flow begins to deteriorate. The flow is interrupted by spots of turbulence and shock waves, which disrupt efficiency. Then, the traffic flow begins to break down rapidly, followed by further deterioration of operational efficiency. The result of this spiralling inefficiency can be observed during every weekday commute in almost every metropolitan area: Drivers push their way onto already crowded freeways to join thousands of others already caught in seemingly endless traffic jams. Unfortunately, by joining the already impeded traffic flow, drivers become part of the problem, creating even greater inefficiencies: more stop-and-go traffic conditions, longer delays, and greater potential for accidents [1].

2 The Effect of Speed Change on the Formation of Congestion

Only the change of speed causes formation of congestion on the roads, as it was already described in the previous section.

A cause of congestion is clearly that nobody is able to stick to the specified speed consistently.

The cause is the slowing down – if a driver starts slowing down in the column, the driver in the car behind him slowing down a little more, because if he slows down to a lesser extent, he would crash into the vehicle which is in front of him and behind the steering wheel it is virtually impossible to slow down just as it was done in the car ahead and a "shock wave" is sent in the stream behind.

The next driver thus slows again a little more like the others and etc.

Then the effect of snow ball is followed, until they finally stop in the column.

A foreign study shows that the largest throughput can be achieved if everyone is driving with a constant speed ranging from 70 to 80 km/h.

Besides a high density on the communications, the congestion is caused by aggressive driving. Aggressive drivers are slowing down in the last-minute, thereby causing deceleration of the traffic flow. We attempted to test drivers and to detect situations that bring about aggression.

3 Aggression on the Roads

Aggression on our roads is a very serious phenomenon. The severity stems mainly from a loss and the consequences, which are results of aggressive behaviour on the road, in physical, health, social and psychological terms [5]. In connection with the developing transport the number of aggressive drivers on the road increases. However, in this department there is a lack of sufficient technical information available in motoring advanced countries. Fig. 2 presents the share of main causes of fatal traffic accidents [6]. The first place takes the speeding, which is the expression of driver's aggression; the style of driving and breaking the basic rules rank next.

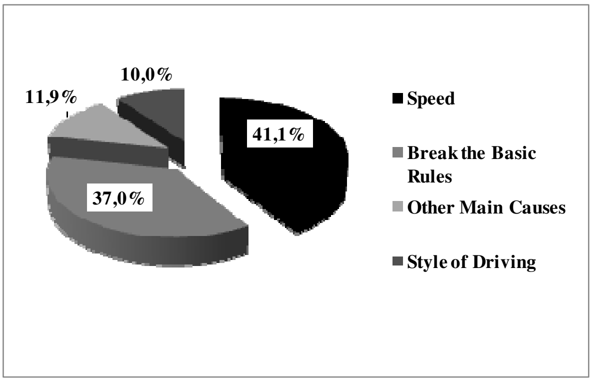

Fig. 2. The share of main causes of fatal accidents

If we want to examine whether the concept of aggressive, reckless driving can be found in the legislation of the Slovak Republic relating to the road traffic, it would be futile, as this term is often used by the police and public, but is not precisely defined.

Aggressive driving on the roads, however, applies to any driver and it is not sanctioned to such extent so that the drivers would think it over and would drive with respect to all road users.

4 The Questionnaire of Aggressive Driver´s Behaviour in SR

Abroad, the questionnaire is used to carry out a survey to detect potential aggressive drivers or to diagnose drivers who already had a driving license [3].

This knowledge showed that the survey carried out in Slovakia should be focused on anger, which is the main part and occurs most often at aggressive drivers. This anger should be at least divided (with examples from practice) to 5 scales, which should be precisely defined.

While developing the questionnaire the Slovak Autoturist Club (SATC) was contacted. On the first page of the questionnaire there are 27 situations that commonly occur on Slovak roads. For each of the questions there is a scale of 5 degrees with divisions of anger, which the respondent feels at that concrete traffic situation (degrees – no anger, 1st level of anger, 2nd level of anger, 3rd level of anger, 4th level of danger – the worst one). On the second side of the Questionnaire there is a classification of the length of perceived anger and on the third the most annoying situations in order. In addition, there are additional questions such as the number of years of driving, sex, year of birth, education and district of residence. At the end of the form explanations are given, what is the meaning of other 5-point anger scales.

The Questionnaire was carried out during two weeks from 26.07.2010 to 08.08.2010. The respondents drew it up electronically and sent to the specified email address. The on-going questionnaire has also been filled out manually and the respondents were approached in neighbourhood shopping centres, gas stations, as well as nearby the university. Percentages between electronically and manually filled in questionnaires were about 55% and 45%.

335 respondents, of which there were 203 men and 132 women, participated in the Questionnaire. Subsequently, respondents were divided into age and sex categories. Fig. 3 shows that the numbers of respondents in different age groups are balanced. The only blip can be observed in the age group 60 years and older, which is due to the fact that the majority of these people responded to the survey only in a printed form and the survey was concentrating mainly on the age groups of 25-29 years and 30-39 years, because of police resources showing that these drivers cause the majority of accidents.

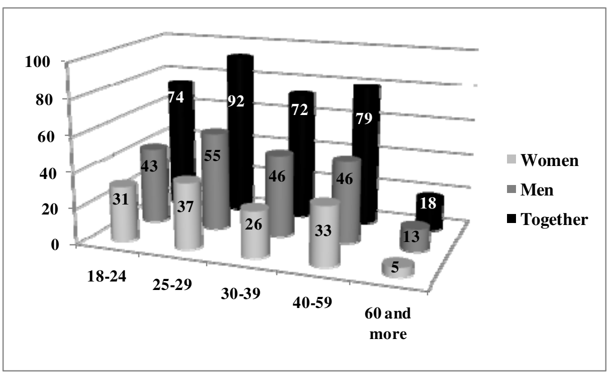

Fig. 3. The partition of respondents by age and sex

The Questionnaire was treated from different perspectives, but the most important was to determine which of the traffic situations was the most annoying for respondents. The average, which determined the respondents' level of anger, was calculated from the respondents' answers on various traffic situations. These averages were divided according to their values and it was determined which of these situations were the most annoying or least moderate. Fig. 4 shows traffic situations, which are able to "put out" most on the roads.

Traffic situation		Average value
1.	Someone is reversing in front of you without looking back	3,27
2.	Someone increase the vehicle speed when you are trying overtake him	3,10
3.	Someone is pushing on the front of your car after overtaking	3,04
4.	Someone is pushing on the back of your car (eg. wants to force the release of the lane)	3,00

Fig. 4. The most annoying traffic situations

The last item was related to the anger length and they could be selected from 5 options (only briefly, a while, a longer while, long enough, for a long while – according to the scale of the Questionnaire). Fig. 5 shows the length of women's anger, which is divided into specific age categories. As it can be seen from the figure, the largest number of women (45 women) of different ages indicated (on the traffic situation from the questionnaire) that they could be angry for "a longer while". The longer while was defined in the questionnaire within the time period of 10 to 30 minutes inclusive. If it is based on the individual ages, the number of women in 25-29 and 40-59 age group ("a longer while duration of anger") was 14, followed by women in 18 to 24 age group with 12 persons, the 30 to 39 group was the penultimate women´s group with the number of 4 and the last group of women over 60 with a value of 1. In the case of women ages 18 to 24, 25 to 29 and 40 to 59 it was also the highest number of responses among all the offered options.

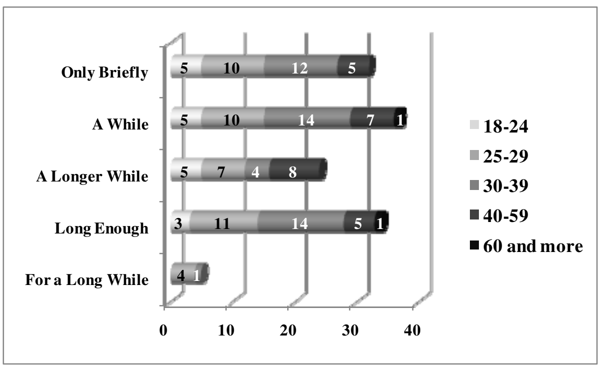

Fig. 5. Length of Anger – Women

A comparison is shown in Fig. 6. Most men identified (with the number of 80) that they are angry in such traffic situations also "a longer while". When a comparison is made between the numbers of women in "a longer while" response and at the same response in men´s group, we see that men are distributed in the different age groups more proportionately (not taking into account the age group of 60 and more). The largest number of responses – 28 – is for men in the age category of 25 – 29, which is followed by men in the age category of 30 to 39 with 20 responses, then men 18 to 24 years have 19 votes and the last (except for the age group of 60 and above - 0) are men 40 to 59 – number of "votes" 13.

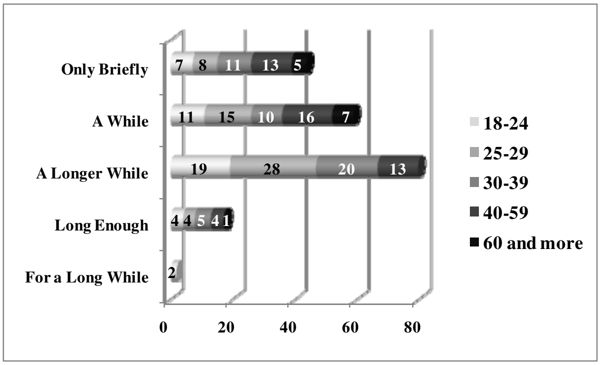

Fig. 6. Length of Anger - Men

If we think about it, we know that only two seconds of inattention can cause an accident. And when it is compared with 10 to 30 minutes duration of anger, during which the driver is more distracted while driving and experiencing negative emotions compared to a peaceful state, which can be classified as inattention, it is worth consideration!

5 Results of the Questionnaire

The questionnaire revealed that:

- In the Slovak Republic the aggression between drivers on the road clearly increases and this phenomenon will certainly continue in the future.
- Women, who are generally considered more peaceful, demonstrated something opposite by responding aggressively to most of the mentioned traffic situations, although they participated in a questionnaire at a lower rate.
- Similarly, both men and women can be angry in the traffic situations and anger takes approximately from 10 to 30 minutes.

6 Conclusion

Safety is the exemption from accidents and losses of human lives. It also deals with property protection, regulation, management and transport technology development. The analysis of accidents indicates that 95% of transport/traffic accidents are caused by the human factor failure (wrong evaluation of the situation, participant's skills/abilities etc.). One of the most frequent errors of drivers is a wrong decision in a critical situation. The decision process is very complicated since the driver has to evaluate the arisen situation correctly within fractions of a second [3].

The questionnaire showed a lot of important data, that nervousness and aggression on the roads are clearly rising. Drivers should be aware that their own aggression creates problems to themselves, for example currently in Slovakia there are different penalties for improper gestures, for speeding and they begin to concern the safe distance from other vehicles. However, frequently the fines are a negligible sum not only for foreign drivers. The essential idea is the awareness of drivers that they do not drive on the roads alone and should also be considerate to other road users.

Slovakia needs a system based on qualified and specialized institutions. We need the solutions that will help to decrease aggressiveness gradually or to fully eliminate it. “Legislation should include such sanctions that when breaking certain rules the drivers should take lessons of defensive drive or therapy where they will try to learn how to control their bursts of aggressiveness” [4].

During the next year we will develop, according to this questionnaire, a model of a traffic drivers’ behaviour with a focus on aggression using weights of importance on which basis it would be possible to determine whether the driver’s behaviour has an aggressive nature or, on the contrary, non-aggressive nature.

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Effect of Fractional Orders in Differential Equation Describing Damping in the Measuring Transducer

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Abstract. The paper presents the way to write differential equations of measuring transducers by means of fractional orders. The impact on the dynamics of the transducer with fractional orders for part of the equation responsible for the damping is presented. Examples of the frequency characteristics for different orders of the equation are also given.

Keywords: fractional calculus, measuring transducer, dynamic systems, discrete transmittance.

1 Introduction

In the classical approach to modelling, the performance of measuring transducers as well as their dynamics are described by means of differential equations [1], [2], [3] and [5]. Usually it is enough to use ordinary second order equations in the form of:

$$A_i \frac{d^{(i)}y}{dt^{(i)}} + A_{m-1}\frac{d^{(i-1)}y}{dt^{(i-1)}} + \ldots + A_0 y(t) = B_j \frac{d^{(j)}f(x)}{dt^{(j-1)}} + B_{m-1}\frac{d^{(j-1)}f(x)}{dt^{(j-1)}} + \ldots + B_0 f(x) \tag{1}$$

The development of the fractional order integral derivative created new possibilities of modeling measurement transducer dynamics and, generally speaking, of all systems whose dynamics can be expressed in a differential form, not only those of integer order differentials.

In the case of the derivative of an integral the known operators of differentiation and integration are combined into a single D^n operator [6], [7] and [9], where n is a positive integer in the case of differentiation, a negative integer for integration and a neutral operator for $n = 0$, which can be written down as:

$$D^n f(t) = \begin{cases} \dfrac{d^n f(t)}{dt^n} & for \quad n > 0 \\ f(t) & for \quad n = 0 \\ \displaystyle\int_{t_0}^{t}\left[\int_{t_0}^{\tau_1}\ldots\left[\int_{t_0}^{\tau_{-n-1}} f(\tau_{-n})d\tau_{-n}\right]\ldots d\tau_2\right]d\tau_1 & for \quad n < 0 \end{cases} \tag{2}$$

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Because the dynamics of the systems considered is described exclusively by derivatives, further formulas will refer to the positive fractional order derivatives.

For fractional orders, a derivative is defined as:

$$ {}_{t_0}D_t^{(v)} f(t) = \lim_{\substack{h \to 0 \\ t - t_0 = kh}} \left[\frac{1}{h^v} \sum_{i=0}^{k} a_i^{(v)} f(t - hi) \right] \tag{3} $$

where:

t_0, t - terminals of fractional differentiation or integration;

v - order of a derivative integer,

or in an equivalent matrix form:

$$ {}_{t_0}D_t^{(v)} f(t) = \lim_{\substack{h \to 0 \\ t - t_0 = kh}} \left[\frac{1}{h^v} \sum_{i=0}^{k} a_i^{(v)} f(t - hi) \right] \begin{bmatrix} f(t) \\ f(t-h) \\ \dots \\ f(t-kh) \end{bmatrix} \tag{4} $$

where:

$$ a_i^{(v)} = \begin{cases} 1 & for \quad i = 0 \\ (-1)^i \dfrac{v(v-1)(v-2)\dots(v-i+1)}{i!} & for \quad i = 1, 2, 3, \dots \end{cases} \tag{5} $$

is defined as a reverse difference of a discrete function, and h the $f(t)$ function increment specified in the $[t_0, t]$ interval:

$$ h = \frac{t - t_0}{k} \tag{6} $$

2 Fractional Order Equation for Transducer Dynamics

The dynamics of visco-elastic materials is better described by a fractional order integral derivative than by a classical integer order notation [9]. This fact encourages one to attempt modelling of a transducer containing the elements of this by means of the dynamics equation including a fractional order equation.

Measuring transducers containing elements storing kinetic energy, potential energy and elements causing energy losses are modelled by means of the second order differential equation:

$$ A_2 \frac{d^2}{dt^2} y(t) + A_1 \frac{d}{dt} y(t) + A_0 y = B_2 \frac{d^2}{dt^2} x(t) + B_1 \frac{d}{dt} x(t) + B_0 x(t) \tag{7} $$

A representative of this class of transducers is a transducer with a seismic mass depicted in [2], [3], [6] and [7], whose dynamics is described by the following equation:

$$\frac{d^2}{dt^2}y(t)+2\zeta\omega_0\frac{d}{dt}y(t)+\omega_0^2 y(t)=2\zeta\omega_0\frac{d}{dt}x(t)+\omega_0^2 x(t) \tag{8}$$

where: ω_0 – is the natural pulsation, ζ – the degree of damping.
Taking into account the relative displacement of seismic mass $w(t)$:

$$w(t)=y(t)-x(t) \tag{9}$$

equation (9) assumes the following form:

$$\frac{d^2}{dt^2}w(t)+2\zeta\omega_0\frac{d}{dt}w(t)+\omega_0^2 w(t)=-\frac{d^2}{dt^2}x(t) \tag{10}$$

Assuming that the dynamics of the element responsible for damping is better described by a fractional derivative, equation (10) is written down as:

$$\frac{d^2}{dt^2}w(t)+2\zeta\omega_0\frac{d^{(\nu_1)}}{dt^{(\nu_1)}}w(t)+\omega_0^2 w(t)=-\frac{d^2}{dt^2}x(t) \tag{11}$$

Generalizing equation (11) to equation (7) and taking into account the fact that integer order derivatives in the derivative of an integral are a particular case of fractional derivatives we can write down:

$$A_2\frac{d^{(\nu_2)}}{dt^{(\nu_2)}}y(t)+A_1\frac{d^{(\nu_1)}}{dt^{(\nu_1)}}y(t)+A_0\frac{d^{(\nu_0)}}{dt^{(\nu_0)}}y=B_2\frac{d^{(\mu_2)}}{dt^{(\mu_2)}}x(t)+B_1\frac{d^{(\mu_1)}}{dt^{(\mu_1)}}x(t)+B_0\frac{d^{(\mu_0)}}{dt^{(\mu_0)}}x(t) \tag{12}$$

Bearing in mind definition (2), formula (12) can be expressed as:

$$\begin{bmatrix}A_2 & A_1 & A_0\end{bmatrix}\begin{bmatrix}D_t^{(\nu_2)}\ y(t)\\ D_t^{(\nu_1)}\ y(t)\\ D_t^{(\nu_0)}\ y(t)\end{bmatrix}=\begin{bmatrix}B_2 & B_1 & B_0\end{bmatrix}\begin{bmatrix}D_t^{(u_2)}\ x(t)\\ D_t^{(u_1)}\ x(t)\\ D_t^{(u_0)}\ x(t)\end{bmatrix} \tag{13}$$

where, taking (4) into account:

$$\begin{bmatrix}D_t^{(\nu_2)}\ y(t)\\ D_t^{(\nu_1)}\ y(t)\\ D_t^{(\nu_0)}\ y(t)\end{bmatrix}=\begin{bmatrix}\frac{1}{h^{\nu_2}} & 0 & 0\\ 0 & \frac{1}{h^{\nu_1}} & 0\\ 0 & 0 & \frac{1}{h^{\nu_0}}\end{bmatrix}\begin{bmatrix}a_0^{(\nu_2)} & a_1^{(\nu_2)} & a_2^{(\nu_2)}\\ a_0^{(\nu_1)} & a_1^{(\nu_1)} & a_2^{(\nu_1)}\\ a_0^{(\nu_0)} & a_1^{(\nu_0)} & a_2^{(\nu_0)}\end{bmatrix}\begin{bmatrix}y(2h)\\ y(h)\\ y(0h)\end{bmatrix} \tag{14}$$

and:

$$\begin{bmatrix} D_t^{(u_2)}\,x(t) \\ D_t^{(u_1)}\,x(t) \\ D_t^{(u_0)}\,x(t) \end{bmatrix} = \begin{bmatrix} \frac{1}{h^{u_2}} & 0 & 0 \\ 0 & \frac{1}{h^{u_1}} & 0 \\ 0 & 0 & \frac{1}{h^{u_0}} \end{bmatrix} \begin{bmatrix} a_0^{(u_2)} & a_1^{(u_2)} & a_2^{(u_2)} \\ a_0^{(u_1)} & a_1^{(u_1)} & a_2^{(u_1)} \\ a_0^{(u_0)} & a_1^{(u_0)} & a_2^{(u_0)} \end{bmatrix} \begin{bmatrix} x(2h) \\ x(h) \\ x(0h) \end{bmatrix} \tag{15}$$

Introducing variables a_2, a_1, a_0 :

$$\begin{bmatrix} A_2 & A_1 & A_0 \end{bmatrix} \begin{bmatrix} \frac{1}{h^{v_2}} & 0 & 0 \\ 0 & \frac{1}{h^{v_1}} & 0 \\ 0 & 0 & \frac{1}{h^{v_0}} \end{bmatrix} \begin{bmatrix} a_0^{(v_2)} & a_1^{(v_2)} & a_2^{(v_2)} \\ a_0^{(v_1)} & a_1^{(v_1)} & a_2^{(v_1)} \\ a_0^{(v_0)} & a_1^{(v_0)} & a_2^{(v_0)} \end{bmatrix} \begin{bmatrix} y(2h) \\ y(h) \\ y(0h) \end{bmatrix} = \begin{bmatrix} a_2 & a_1 & a_0 \end{bmatrix} \begin{bmatrix} y(2h) \\ y(h) \\ y(0h) \end{bmatrix} \tag{16}$$

and b_2, b_1, b_0 :

$$\begin{bmatrix} B_2 & B_1 & B_0 \end{bmatrix} \begin{bmatrix} \frac{1}{h^{u_2}} & 0 & 0 \\ 0 & \frac{1}{h^{u_1}} & 0 \\ 0 & 0 & \frac{1}{h^{u_0}} \end{bmatrix} \begin{bmatrix} a_0^{(u_2)} & a_1^{(u_2)} & a_2^{(u_2)} \\ a_0^{(u_1)} & a_1^{(u_1)} & a_2^{(u_1)} \\ a_0^{(u_0)} & a_1^{(u_0)} & a_2^{(u_0)} \end{bmatrix} \begin{bmatrix} x(2h) \\ x(h) \\ x(0h) \end{bmatrix} = \begin{bmatrix} b_2 & b_1 & b_0 \end{bmatrix} \begin{bmatrix} x(2h) \\ x(h) \\ x(0h) \end{bmatrix} \tag{17}$$

we obtain:

$$\begin{bmatrix} a_2 & a_1 & a_0 \end{bmatrix} \begin{bmatrix} y(2h) \\ y(h) \\ y(0h) \end{bmatrix} = \begin{bmatrix} b_2 & b_1 & b_0 \end{bmatrix} \begin{bmatrix} x(2h) \\ x(h) \\ x(0h) \end{bmatrix} \tag{18}$$

3 Example of a Measuring Transducer with a Fractional Order in Dynamics Equation

In the Matlab environment [11], a measurement transducer of continuous transmittance was modelled:

$$G(s) = \frac{-s^2}{s^2 + 10s + 50} \tag{19}$$

Its amplitude and phase characteristics are depicted in Fig. 1:

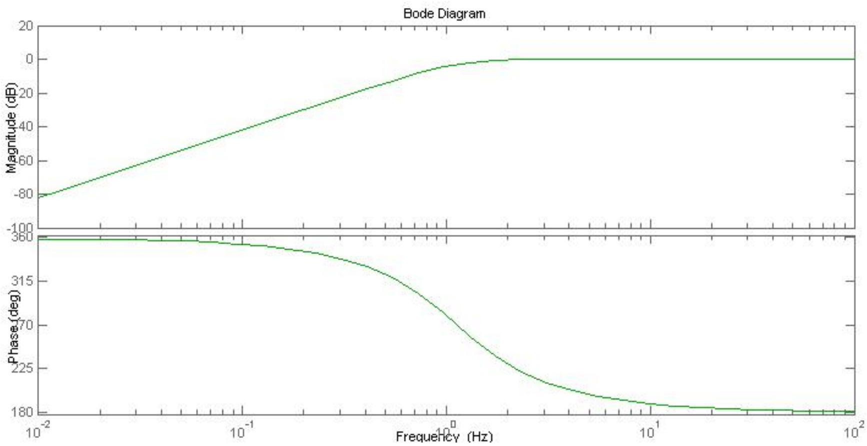

Fig. 1. Amplitude and phase characteristics for a transducer model

and a step response – in Fig. 2:

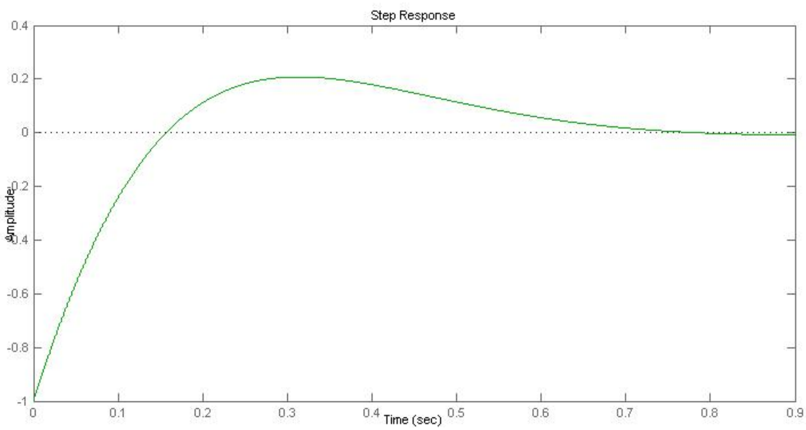

Fig. 2. Transducer model's step response

As the reverse difference used in fractional calculus refers to a discrete function, the function available in Matlab was applied to transform the continuous transmittance (19) into a discrete transmittance for the sampling time $T_s = 10^{-4} s$ obtaining:

$$G(z) = \frac{-z^2 + 2z - 1}{z^2 - 1.999z + 0.999} \tag{20}$$

Fig. 3 depicts amplitude and phase characteristics of an integral derivative model obtained with the use of equations from (12) to (20) for the integer order derivatives.

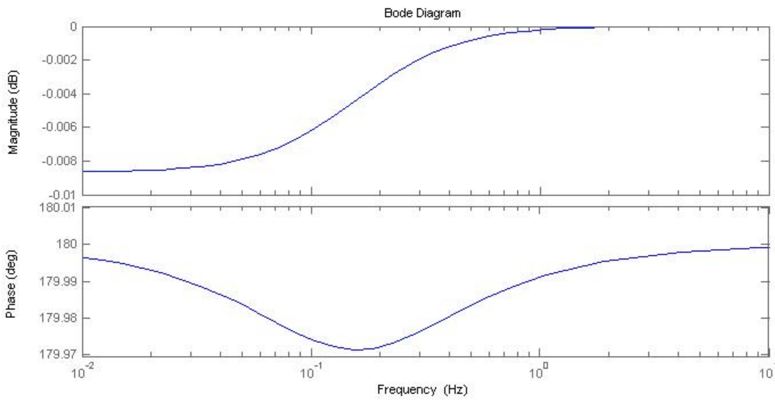

Fig. 3. Amplitude and phase characteristics of a transducer's integral derivative model

Fig. 4 compares how amplitude and phase characteristics of the transducer's integral derivative model change depending on the value of the order of a derivative ν_1 standing next to coefficient A_1 responsible for the value of damping (looking at formula (12)). These values were changed within the range from 0.2 to 1.8 with a step of 0.2. The remaining values of the order of derivatives are integers, identical with those from the "classical" notation (8).

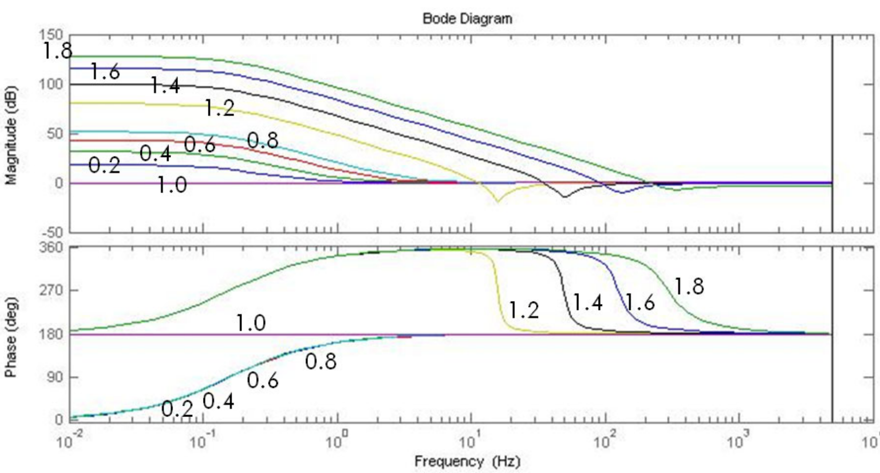

Fig. 4. Amplitude and phase characteristics of a transducer's integral derivative model depending on the value of the fractional order

4 Conclusion

While comparing amplitude and phase characteristics of a transducer model written down in the form of a classical equation (8) and an integral derivative model (20) it can be stated that the range of changes as regards both the amplitude and the phase in the comparable interval of frequencies in the case of an integral derivative model is rather small (Fig. 3).

Fig. 4 presents the effect of changes in the value of the derivative order on the amplitude and phase characteristics of an integral derivative model. It can be noticed that the amplitude is higher subject to the changes in the derivative order value regardless of the fact whether the order value increases or decreases. In the case of the phase characteristics the growing order value entails a growing phase shift in relation to the order value equal 1. Decreasing the order causes a respective decrease in the phase shift.

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Perspectives of Telematics Implementation in Tri-city Transport Systems Management and Planning

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Abstract. In 2010 the City of Gdynia applied for match funding of the project "Implementation of the Integrated Traffic Management System TRISTAR in the Tri-City" under the Infrastructure and Environment Operational Programme. This year the project has been placed on a list approved by the Ministry of Infrastructure. Tri-City proceeds with a tender for the implementation of the system. The key elements included in the TRISTAR system architecture will be implemented under the project. They will enable the implementation of further elements of the system. The paper presents the characteristics and the expected effects of the implementation of new components, which will include a multi-level model of transportation systems, an automated incident detection system, weigh-in-motion and bus lanes /HOV lanes control with the use of ITS. Public consultation of the studies and projects will be done using an internet platform including e.g. simulations developed using the multi-level model.

Keywords: intelligent transportation systems, transport management, transport planning, city logistics.

1 Introduction

The functioning of the urban transport system should be based on solutions that allow meeting the needs of all groups of users including residents, business entities and institutions. According to the concept of city logistics the above should consist of optimizing the flow of people, goods and information streams as well as minimizing the adverse impact of transport on the environment. The transport management in urban areas should be based on two basic assumptions to achieve the mentioned objectives. First, it is necessary to diagnose the operating problems of the urban transport system and to select the appropriate solutions for transport infrastructure and organization. Secondly, it requires the right tools to carry out these tasks, enabling control and monitoring of selected aspects of transport in cities to connect different planes of actions operationally and technically. The logistics management in urban transport operations should consist of two main pillars – infrastructural and organizational activities. According to the assumption made, the solutions of transport telematics (Intelligent Transportation Systems) will allow for the practical implementation of planned activities, while combining the two pillars of the system.

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The transport carried out in urban areas is characterized by a simultaneous occurrence of multiple modes and the variety of needs of different user groups. Cities are areas of concentration of economic and social activities that are strictly conditional on the effectiveness of the functioning of the transport system, including the passenger and freight transport. The intensification of the demand for transport causes problems due to a high concentration of transport activity in specific areas, the emergence of congestion, the different modes competition for limited resources of the infrastructure and the adverse impact of transport on the environment. In view of these problems, there is a need of systemic management of the transport structure in cities, so that the transport could carry out its tasks with full efficiency, while reducing the adverse effects. Using the tools of city logistics is therefore a response to the need to streamline the flow of people and goods within urban areas. These tools allow the optimization of flows in order to reduce the transport congestion [1]. The above definition includes several elements highlighting the role of planning, control, optimization, and monitoring of transport. Innovations in the field of transport telematics may play a special role in these processes. In practical terms it is defined as a combination of solutions, communications and control systems [2]. Observation of already implemented telematic solutions lets to obtain benefits such as reduced traffic congestion, enhanced safety, increased transport efficiency, lower environmental impact, increased comfort of users, improving the economic performance of the transport process participants as well as reducing the degradation and better use of transport infrastructure and environment.

2 Use of Telematics to Achieve a Sustainable Transport System

The need for implementation of measures to reduce the negative effects of automotive development and to increase the quality of transport service under conditions of variable demand is the main reason for the introduction of intelligent transport management systems in many cities in developed and developing countries. Gdansk, Gdynia and Sopot have also taken action to implement the ITS measures. In 2006, the mayors of Gdansk, Gdynia and Sopot signed an agreement to undertake joint activities aimed at preparing an application for external funding for the implementation of the system, which formed the basis for the start of cooperation of cities in order to achieve this objective. The detailed concept of the TRISTAR system was developed on the basis of the agreement in 2007. A pilot project was started up in the same year, in Gdynia on junctions of Morska street. The SCATS and RAPID (beginning of system of priority for public transport vehicles) systems have been started up within the pilot project. The Tri-City has prepared and submitted an application for funding to implement the TRISTAR system from the European Union under the Infrastructure and Environment Operational Programme. This year the project has received funding and the local government will announce a tender for its implementation.

The TRISTAR will comprise such functional sub-systems as an integrated road traffic management system, an integrated public (passenger) transport management system, an integrated goods traffic management system (logistic centres), an integrated rescue management system (integrated rescue system), an integrated transportation information system. Under funding from the European Union, two the most important components are foreseen to be implemented in the first stage of the TRISTAR system introduction – the urban traffic management system and the public transport management system. However, each of the systems includes the most important unit of other sub-systems (e.g. road safety sub-system, transportation information system) [3]. The implementation of the basic and most important elements of the system, which are detection systems, communication systems, data collection and processing systems as well as the construction of Traffic and Public Transport Management Centres will enable the application of new solutions that will contribute to the development of sustainable urban transport system of the Tri-City Agglomeration cities.

The analysis of the Tri-City Agglomeration transportation systems identified a number of transportation problems and one of them is that the public transport is not prioritised in traffic. It is a reason of increasing travel times and making public transport less attractive compared to the use of private cars. As local surveys show, the travel time is one of the most important factors why people choose to use a car instead of the public transport [4]. The Pomorskie region's spatial policy includes a sustainable transportation policy designed to reduce the demand for the passenger car and increase the use of public transportation inter alia by ITS solutions. The modal share reduction of cars is aimed at the expansion of public transport services and at promotion of cycling and walking. The urban traffic would be managed by means of traffic signals with the priority to the public transport. The Tri-City Agglomeration with its maritime economy businesses and sea ports carries a lot of freight transportation leading to a substantial traffic of heavy freight vehicles in the city. With the growth of traffic in the area, including the establishment of the Pomorskie Logistic Centre, the telematics will have to be introduced into the goods traffic management [5].

The reasons described above have prompted the city of Gdynia to plan further action in the mobility management. Under the CIVITAS II Plus programme Gdynia together with the cities of Achen (DE), Palma (ES) and Koprivnica (HR) have applied for funding for the project under which the city plans to introduce among other things a multi-level model of transportation systems, an automated incident detection system, weigh-in-motion and bus lanes /HOV lanes control with the use of ITS. During the proposal development phase, the consortium partners recognised that a sustainable urban transport planning is the underlying basis for most of transport related measures in cities. Building on this strategic level of innovative, clean and energy efficient vehicles and transport systems is the core policy field of the CIVITAS Initiative. Information and communications technologies offer services to enhance transport systems in cities. Possible solutions are presented below in the paper.

2.1 Multi-level Model of Transportation Systems

The planning of transport networks is a fairly complicated process, because for its construction and expansion important decisions are needed. The building of efficient transport networks requires solving complex optimization problems in transportation. The results of analysis carried out using various tools, which include various types of forecasting software, are used to facilitate the process of planning decisions making. Forecasting is based on scientific analysis, to formulate opinions about the future state of the studied phenomenon on the basis of knowledge about its current course [6]. In the case of transportation systems the forecasting mostly concerns the prediction estimation of the future (medium or long term) traffic volume or volume of passenger travel or freight for the existing or planned transport network. The need for use of traffic models to forecast and test transport networks is obvious due to the inability to survey the events and relationships occurring in the transport networks in an empirical way.

The following assumptions for the concept of developing a system for forecasting and traffic analysis in Gdynia have been made; according to these assumptions the system of traffic forecasting and analysing should:

- cover the area of Gdynia, but to be fed with the data from the regional and the national model
- have a hierarchical structure consisting of layers of different management levels
- enable the efficient exchange of information and data between layers of management
- enable the provision of data to various tasks arising from the process of functioning of the transport systems and facilities, which will facilitate optimal decision-making
- provide the data for the planning work, feasibility studies of transport facilities, projects of changes in the traffic arrangement plans, taking into account geometric solutions at intersections and interchanges and advanced traffic control
- set up the data and information for updating Gdynia's Sustainable Urban Transport Plan (SUTP) and provide detailed analyses and verification of effects on the mobility management initiated by SUTP proposals and measures
- provide simulation tools to convince communities of proposed solutions.

The above assumptions cannot be achieved with a single traffic model. This will be possible, however, by building an integrated, multi-level model of traffic forecasting and analysing (Fig. 1). The approach will be a multi-level and multi-layer model based on the idea adopted by the Department of Planning and Transportation of the City of London [7]. The levels are determined by the type of administrative area and the layers are determined by the kind of transport analysis or transport management.

The strategic level includes the provision of data to develop a transport policy, the implementation of planning studies and network studies. A macroscopic model (based on the VISUM programme [8]) will be applied at the strategic level. The model requires disaggregation of districts within the area of the City of Gdynia together with detailed road networks and elaboration of transport lines and running of public transport within the city. The model will be used to collect the data for a mezoscopic model, complying with the planned routes located in the vicinity of the city.

The tactical level includes the provision of data to develop a decision-making papers (network and corridor studies, feasibility studies), development projects of traffic arrangement, traffic control and evaluation of planning solutions effectiveness as well as for traffic management purpose. The object of research will be the transport network, a string of roads or streets, and the segment of public transport line in this case. The mezoscopic model (based on the SATURN programme [9]) will be applied at the tactical level. This model will be used to analyse the scenarios of traffic arrangement modifications as well as to estimate the efficiency measures of planned modifications. The model will derive the results from the macroscopic model within the scope of demand modelling with a parallel division into particular modes of transport. This will enable calibration taking into account the road network within the Pomorskie Voivodeship (results from the macroscopic model). The macroscopic and the mezoscopic models will provide the basis for the elaboration of a microscopic model (simulations).

Area	**Level of management**	**Strategic**	**Tactical**	**Operational**
	Object	Transport network	Transport network/ streets and PT lines	Street, PT line, set of junctions, junction
	Model type	Macroscopic	Mezoscopic	Microscopic
Region	Tool	VISUM		
City		VISUM	SATURN	
Cordon		VISUM	SATURN	
Local			SATURN	VISSIM, DRACULA

Fig. 1. Use of traffic modelling tools depending on the level of management and area

The operational level includes the provision of data to develop specific projects of traffic arrangement, traffic control programs, projects of transportation services for the selected objects and primarily to visualize the operation of transport facilities. The object of research will be a section of road or street, section of the public transport line or junction. The microscopic model (based on the VISSIM programme [8] or DRACULA programme [9]) will be applied at the operational level. This model will allow for verification and demonstration of results obtained from the macro and mezoscopic models and will provide an important input for the community projects and the planned internet platform. After the implementation of TRISTAR system in Gdynia the models will be supplied with the information on traffic parameters in real-time.

2.2 Automated Incident Detection

Currently, there is no incident detection system in the City of Gdynia or in the region. Such systems are innovative in Poland and are only beginning to be implemented on motorways [10], [11], but there is no such system on urban streets in Poland yet. However, there is the first research on the detection of incidents on urban roads, where in addition to detection a link with traffic signal is included. Algorithms based on Bayesian networks are applied in research [12]. In mid-2012, the Traffic Management Centre is planned to be set up within the TRISTAR system. It will be the starting point for better traffic safety which would then be further developed. The incident detection system has been included within the planned TRISTAR system in several chosen areas: on streets with a higher speed limit and on sections between junctions but it has not been foreseen for the city's arteries – within the junctions. The planned pilot project can be implemented regardless of the TRISTAR system, but if TRISTAR is implemented the incident detection system will extend and complete the TRISTAR system. It is planned to equip junctions with video camera-based detection systems. The main objectives of this measure are: to install a pilot automated traffic incident detection system at two traffic hot spots in Gdynia, to shorten the time of road accident detection by 50%, to shorten the time of the rescue operation by 20%, to decrease the number of fatalities in road accidents by 20%, to improve traffic conditions due to shortening the time of rescue operation.

A feasibility study on the automated incident detection study for the pilot project will be conducted at first. The geographical location of the pilot project will be determined based on the statistical analysis of location, type and gravity of road incidents. Also, research standpoints for simulation of road incidents detection are planned. Verification of algorithms of road incidents detection based on computer simulation and recommendation of algorithms for implementation will take place. After the implementation of TRISTAR system in Gdynia the models will be supplied with the information on traffic parameters in real-time. The data will be collected before and after the implementing of the system at junctions to find out whether the objectives of the measure have been reached. The following indicators have been chosen: detection rate, false alarm rate, time for detection of road accidents, time needed for rescue operations, number of fatalities in road accidents. In the case of successful operation of the system it will be recommended for implementation on a larger number of junctions.

2.3 Weigh-in-Motion and Enforcement

The cost of damages to the road surface and bridge repair works was estimated at 14 million PLN (above 3 million Euros) in 2010. The road surface is mainly damaged by trucks travelling between the harbor and other parts of the city. The trucks obviously not only contribute to road surface damages and high annual cost of their maintenance but also to a high level of noise, significantly reducing the quality of life of the city's inhabitants. Currently, there is no weight pre-selection system in the City of Gdynia or in the region. Such systems are innovative in Poland and are only beginning to be implemented in a few cities (e.g. Wroclaw).

The first in Gdynia and the region and one of the first in Poland weight pre-selection system is to be implemented on all entry roads to the City. The system will enable weigh-in-motion of the vehicles and immediate transfer of information about the vehicle that exceeded the permissible load with its registration number to the Traffic Management Centre. This information will also be transferred to the Road Traffic Inspection that will be able to impose fines. The data will be collected before and after implementation of the system on incoming roads to the city to find out whether the measure objectives have been reached.

The cost of road maintenance will be calculated after the system implementation and compared with costs of road maintenance before the system implementation. The following indicators have been chosen: road maintenance costs and the number of overweight trucks. The main objectives of this measure are to:

- prepare a feasibility study for access restriction of heavy and overloaded vehicles
- introduce a weigh-in-motion system at entry points to the city
- cut the road maintenance costs due to overweight trucks on controlled roads by 15%
- reduce the number of overweight trucks on city roads (by 90% on controlled roads) to decrease the environmental and noise pollution and to increase the road safety
- share the experiences with Polish cities.

2.4 Dedicated Bus Lanes/ HOV Lanes Control with the Use of ITS

During rush hours (in the morning and in the afternoon) there is considerable congestion on two main arterial roads in Gdynia. On Morska Street bus trips often take 15-20 minutes longer than usually. Research by the Public Transport Authority in Gdynia conducted in 2010 revealed that PT vehicles are: 30% on time, 21% delayed by 2 -3 minutes, 40% delayed by 4-9 minutes, 8% delayed by 10 minutes and more, about 1% ahead of schedule. Currently, there are no bus lanes on the above-mentioned arteries. Car users, the largest group among road users, are rather sceptical about the introduction of dedicated bus lanes/ HOV lanes and have to be persuaded to comply with traffic regulations. As regards HOV vehicles, entitled drivers might also have to be persuaded to make use their rights to use these lanes. The TRISTAR system does include giving priority for PT at crossroads with traffic lights and installing VMS with passenger information at bus stops. Introducing bus lanes and controlling their right use will increase the competitiveness of PT. The planned pilot project can be implemented regardless of the TRISTAR system, but if TRISTAR is implemented the HOV lanes/ bus lanes will extend and complete TRISTAR.

The concept of HOV lanes/ bus lanes for the city centre and two incoming roads into the city centre – a section of Morska Street and Zwyciestwa Street – will be elaborated. For the other potential dedicated lanes the implementation conditions will be developed through a study. The study will evaluate possibilities of completion of dedicated bus lanes, their location, advantages, costs, the impact on the traffic flow and the necessary reorganisation of traffic. This element, available also for taxi and other privileged vehicles, will provide an important and decisive tool for the further reconstruction and modernisation of main streets in Gdynia, improving competitiveness of public transport. The main objectives of this measure are:

- introduction of dedicated bus and high occupancy vehicle (HOV) lanes along major arterial roads and an increase in the share of PT in the modal split with a target of 85% PT and 15% HOVs on the dedicated lanes
- improvement to the quality and punctuality of PT travel and service
- assuring that PT is more competitive to individual transport (due to shorter journey trips) and a decrease of the number of car trips and cars to achieve 10% less congestion

3 Conclusion

The dependence on a car during recent decades has been the reason that the urban transport system based on the car use less and less meets the needs of users, by generating a lot of adverse effects. The existing simple solutions for increasing the supply of road transport infrastructure and subordinating to it ways of urban space use are becoming less acceptable. It is associated with the growing congestion, uncontrolled sprawling of cities as well as the economic and social constraints, especially where the scale of these problems is directly proportional to the role played by transport. Therefore new solutions are necessary to improve the relationship between the transport and cities, with a focus on ending the current stalemate. In the current situation activities integrating solutions for urban planning, transport planning and mobility management are more often considered. Common part is the most efficient use of public transport and the consequent reduction of needs to use cars. Information and communications technologies offer services to enhance transport systems in cities.

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Analysis of the Suitability of Selected Data Transmission Systems in RSMAD

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Abstract. This paper analyses the suitability of the selected radio communication systems currently used for data transmission, or usable in the future, in Radio System for Monitoring and Acquisition of Data from Traffic Enforcement Cameras (in short RSMAD). The paper also presents the advantages and disadvantages of each system, paying particular attention to features that directly affect the suitability of the solution in the RSMAD system. An analysis of safety and a review and evaluation of effectiveness of mechanisms for cryptographic data protection, in chosen data transmission systems used in the RSMAD system are also an important element of this work. Analyses were performed for systems such as: GSM (GPRS, EDGE), UMTS (HSPA/HSPA+), LTE, TETRA/TETRA-TEDS and WiMAX.

Keywords: GSM, UMTS, RSMAD, traffic enforcement camera.

1 Introduction

The Radio System for Monitoring and Acquisition of Data from Traffic Enforcement Cameras (in short RSMAD), from the viewpoint of its functions, is an integrated computerized system. For the data transmission the system uses mostly commercially available radio transmission technologies (described further in later sections of this paper) [1]. Currently, the RSMAD system is primarily used for the acquisition and exploration of data containing the information on traffic offenses, coming from traffic enforcement cameras (in short TEC). The purpose of the construction of this system is a measurable improvement in the road safety as well as a considerable improvement in the work of public services responsible for traffic control.

In general, the RSMAD system refers to the transmission of data, collected in TECs, to a specially designed Data Acquisition Center (abbreviated as DAC), in the form of secured transport blocks via various types of radio networks [2, 3]. In the RSMAD system the data transmission takes place now mainly through mobile networks: GPRS *(General Packet Radio Service)*, EDGE *(Enhanced Data rates for GSM Evolution)* and HSDPA/HSPA+ *(High-Speed Packet Access)* [3]. An intensive research associated with the use of TETRA *(Terrestrial Trunked Radio)* is also being carried out. In the future, a use of web based systems: LTE *(Long Term Evolution)*

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and LTHE technology *(Long Term Evolution HSPA)* as well as WiMAX (*Worldwide Interoperability for Microwave Access*) will also be possible [1].

It should be noted, that a major problem in systems with a distributed structure (also with RSMAD as a classic representative), in addition using public networks for data transmission, are the issues of effective cryptographic protection of data against unauthorized access. The structure of the cryptographic security of the system was discussed in more detail in papers [2] and [5].

2 Security Analysis of Selected Radio Systems in Terms of Their Usefulness to RSMAD

Telecommunications networks using the wireless transmission medium are particularly vulnerable to intruders. Wireless data transmission means that unauthorized persons may have a potentially easy access to the transmitted data. This is especially important problem in networks with serious gaps in the structure of security and those in which the methods of cryptographic protection of data are confidential (systems designed contrary to the Kerckhoffs principle [5]). Due to the great openness of the RSMAD system, to the various techniques and technologies of data transmission and taking into consideration the serious vulnerabilities in some systems security (particularly GSM and TETRA), each layer of the RSMAD system uses independent cryptographic data protection mechanisms [5]. Table 1 shows a comparison of safety, of chosen radio systems, which meaning is or may be in the future, relevant from the RSMAD system point of view.

Nationwide range of the RSMAD system determines the need to use different data transmission systems, including those which are less secure (such as GSM and TETRA (Table 1)), which suitability is determined by the considerations other than security. The results of the analysis are presented in Table 2.

In summary, it has to be noted that definitely the highest level of security is provided by the networks based on systems: WiMAX, UMTS, LTE and TETRA-TEDS. In turn, the systems most vulnerable to attacks by intruders are: GSM (very vulnerable) and TETRA (partially vulnerable) [1, 5]. Nevertheless, despite significant vulnerabilities of the GSM system, its well developed infrastructure directly determines its very high suitability for the data transmission in the RSMAD system. Thus, the use of this system for secure data transmission in telecommunication systems (including RSMAD), requires the efficient operation of all mechanisms for cryptographic protection of data in each layer of the system. In view of the resistance to different types of threats and the level of maturity of the system, the UMTS system is by far the best in this respect, which from RSMAD's point of view seems to be an optimal solution. The importance of TETRA-TEDS and WiMAX systems, despite very high resistance of these systems to popular types of attacks is likely to remain limited in the future. This is mainly due to total absence or negligible degree of development of necessary infrastructure.

Table 1. Comparison of safety of selected radio systems

Data protection mechanisms	Name of the system				
	GSM (GPRS/ EDGE)	UMTS (HSPA/HSPA+)	TETRA	TETRA-TEDS[1]	WiMAX/ LTE
Monitoring of data integrity	–	+	–	–/+[2]	+
Authentication of mobile stations through the network	+	+	+	+	+
Network authentication by mobile stations	–	+	+	+	+
Encryption	+	+	+	+	+
Using temporary numbers / IDs	+	+	+	+	+
Checking terminals	+	+	+	+	+

Table 2. Comparison of resistance of tested radio transmission systems of data for certain types of attacks

Threat	Name of the system				
	GSM (GPRS, EDGE)	UMTS (HSPA/HSPA+)	TETRA	TEDS	WiMAX/ LTE
Session hijacking	no resistance	resistant	resistant	resistant	resistant
Use of the substituted base	no resistance	resistant	resistant	resistant	resistant
SIM/USIM/TSIM Card Cloning	no resistance	resistant	resistant	resistant	resistant
Locating the mobile station	no resistance	resistant	resistant	resistant	resistant
The attack on the authentication service	no resistance[3]	resistant	resistant	resistant	resistant
Modification of the transmitted data	no resistance[4]	partly resistant	no resistance[5]	partly resistant	resistant

[1] TETRA-TEDS *(TETRA Enhanced Data Services)* – development of TETRA standard.
[2] It is possible to implement mechanisms to verify the integrity of data transmitted via the network of framework of this system.
[3] This is mainly due to the weakness of the COMP128 algorithm.
[4] Because of the lack of mechanisms to verify data integrity.
[5] Lack of data integrity control mechanisms.

3 Analysis of Transmission Parameters of Selected Radio Systems in Terms of Their Usefulness to RSMAD

Table 3 shows a comparison of data transmission speeds offered by various popular systems for radio transmission of data which meaning is or might be important in the future for RSMAD. The table includes also the important advantages and disadvantages of these systems which at the moment determine the level of their usefulness to the RSMAD system.

Table 3. Comparison of data transmission speeds offered by various popular systems for the radio data transmission

Name of the system	$R_{DL,MAX}$ *	$R_{UL,MAX}$ **	Key advantages	Important disadvantages
GSM (HSCSD[6])	28.8 [kbps]	14.4 [kbps]	▪ highly developed infrastructure	▪ low transmission speeds
GPRS	80 [kbps]	40 [kbps]	▪ highly developed infrastructure	▪ average transmission speeds
EDGE	236.8 [kbps]	118.4 [kbps]	▪ highly developed infrastructure	▪ average transmission speeds
TETRA	2.4 – 28.8 [kbps]	2.4 – 28.8 [kbps]	▪ service reliability	▪ very low transmission speeds ▪ very small coverage
TEDS	538 [kbps]	538 [kbps]	▪ comparatively high performance ▪ high level of security	▪ lack of existing implementations of the system in our country ▪ high cost of implementation
UMTS	384 [kbps]	128 [kbps]	▪ average transmission speed	▪ usually only available in larger cities
HSPA	**HSDPA**: 14.4 [Mbps] **HSDPA+**: 56.0 [Mbps]	**HSUPA**: 5.76 [Mbps]	▪ very high transmission speeds	▪ relatively limited coverage
WIMAX	39.9 [Mbps]	17.3 [Mbps]	▪ very high transmission speeds and performance of the system	▪ high costs of infrastructure construction ▪ high price of terminals
WIMAX II	300 [Mbps]	300 [Mbps]	▪ very high transmission speeds and performance of the system	▪ lack of existing implementations ▪ doubts about the future of this technology due to high costs
LTE	100 [Mbps]	50 [Mbps]	▪ very high transmission speeds and performance of the system	▪ lack of existing, fully functional implementations

* $R_{UL,MAX}$ – maximum theoretical data rate of uplink
** $R_{DL,MAX}$ – maximum theoretical transmission speed in the link down

[6] HSCSD *(High Speed Circuit Switched Data)* – the technology used in the GSM network for data transfer in switching channels mode.

Systems dedicated to high-performance broadband data transmission, such as: HSPA/HSPA+, WiMAX and LTE, feature the highest degree of usefulness. Not less important aspect, determining the suitability of the technology to transmit data in the RSMAD system, except for the offered transmission speeds, is the coverage area. Solutions based on GSM (GPRS, EDGE) and UMTS (with particular emphasis on its development in the form of HSPA/HSPA+ technology) systems excel in this respect [1].

At the moment, only the GSM system (and its subsystems: GPRS and EDGE), in conjunction with the constantly developing UMTS network (along with the mechanisms of HSPA/HSPA+), are able to satisfy these requirements. There is no doubt that in the future these fourth-generation systems (e.g.: LTE-Advanced or WiMAX II), typically dedicated to the broadband data transmission, will provide an excellent medium for the delivery of services that require an increasing rate, while maintaining high safety standards [1]. Unfortunately, these networks are not likely to reach full functionality soon and for that they may not be used in the RSMAD system for a long time. The future of solutions based on WiMAX systems family (including WiMAX Mobile), despite their many advantages, is still uncertain due to various circumstances, including formal and legal frameworks for the allocation of frequencies. Both GPRS and EDGE subsystems as well as the UMTS system, and its extension in the form of HSPA, can effectively implement the service of data acquisition from TECs especially that under the service the transmission of images does not have to be carried out in real time or even close to real. Thus, the defining of the maximum transmission delay as an important parameter is not required because in practice it is limited only by the formal and legal considerations related to the maximum time between registration of the offense and the notification of this fact to the offender.

Table 4 presents the comparison of the most important systems, from the standpoint of RSMAD, used for the radio transmission of data. Bearing in mind primarily the degree of coverage, the GSM system is the best in this respect. Not much worse in this respect is UMTS which infrastructure is developing very dynamically. It should be noted that it often happens that the ranges of GSM and UMTS networks overlap each other, so depending on network load in a given area, the terminal can use a network offering at the time a higher quality of connection.

In the case of RSMAD it is extremely important that it is a developmental system, which tends to consider the suitability of these systems also for mobile video data transmission in the future. It seems that it may be possible only in the areas of large cities covered by the HSPA network. Certainly, great opportunities will also be offered by the emerging LTE and mobile versions of WiMAX. The latter technology faced in recent years many barriers for development (mainly the high cost of implementation) but the parameters of the services offered in the second version of this system result in treating it as a serious alternative to the LTE system. The transmission of large amounts of data in the form of a moving image, however, raises certain problems, particularly in the case of the need of transmission in real time.

Table 4. Multicriteria comparison of selected data transmission systems, important from the standpoint of RSMAD

Type of the comparative criterion	GSM	UMTS	TETRA	TEDS	WiMAX
Existing infrastructure	Excellent	Good	Insufficient	No	Insufficient
Security level of services	Medium	High	Medium	High	Very high
Coverage	Very good	Medium (mainly in urban area)	Very poor	No	Poor
Expected prospects for further development	No	Medium	Negligible	Negligible	Very high
The possibility of using for mass data transmission	Sufficient	Very good	Poor	Good	Excellent

4 Conclusion

In conclusion, it should be noted that from the standpoint of the RSMAD system and having regard to all of the results of the analysis, the largest usefulness is presented by the cellular systems: GSM (GPRS, EDGE) and UMTS (HSPA/HSPA+). In the future, a significant increase in the importance of the LTE system, which will gradually displace older solutions, is possible. There are also no clear grounds totally disqualifying any of the contemplated transfer technology in the RSMAD system. It should be emphasized that, in the TETRA system, it is extremely important to use the multislot transmission. The WiMAX system, despite its many important advantages, does not seem to constitute a real threat to GSM and UMTS, as a key transmission technology in the RSMAD system [1], [2].

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Applying Military Telematic Solutions for Logistics Purposes

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Abstract. The technological progress which is observed nowadays, especially in informatics and telematics, let mankind to develop new, up-to-date technology solutions which can be used in many areas including logistics. The article presents current and future possibilities of applying hi-tech constructions in logistics security, transportation or coping with results of disasters. Hi-tech robots and devices "armed" in artificial intelligence can not only support human activities. Smart machines can even replace a human factor in the most dangerous activities. Telematic solutions can support driving vehicles, manage and lead trucks convoys or trains, automatically react to situations on the roads. Sophisticated instruments may be equipped now with a wide range of detectors. Other robots stuffed with movement indicators, recognition equipment, and a code identifier can automatically run depots, load and unload cargo vehicles or protect storage areas. In the paper the authors present transfer opportunities of technologies developed for military purposes for logistics use.

Keywords: automated logistics control systems, telematic systems, hi-tech control, surveillance and security equipment, Unmanned Aerial Vehicle UAV, Unmanned Ground Vehicle UGV, Autonomous Underwater Vehicle AUV.

1 Introduction

Technical progress is an unavoidable process which influences all spheres of human activities. At present new developments and achievements in the field of electronics, informatics and telematics are very quickly adopted and employed for logistic solutions.

The development of modern technologies introduced some new sophisticated constructions which did not exist before. Especially one can see the progress in development of telematic applications as robotic devices which can support large spectrum of activities of human beings. Robots can be applied in environments which are hostile or hazardous for a man. Some of them are projects prepared for military purposes. The intelligent machines designed for use on the modern battlefields have been prepared and tested in extremely hostile environmental conditions, with

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maximum strains and at an extremely high damage risk factor. The “war” developments are then adapted to the civilian purposes and not infrequently they are very suitable for logistics use due to a fact that especially the logistic sustainment plays a crucial role in all kinds of military combat operations. There exist some current examples of transferring results of research on military exploitation of devices to logistic applications. The military industry is one of the biggest and one of the most developed branches of the modern business, which invests large amounts of money in research. On the other hand governments spend vast fortunes on new sophisticated combat machines. Some of the constructions and developments are implemented to the exploitation by the soldiers and are not accessible for a long period of time for civilian use, but later on such as radar, Internet or GPS system are transferred for non-military use. Other solutions are not accepted by military decision makers and industries try to get back their investments and adapt the projects to a regular market. Furthermore other designs can have “dual use” for both military and civilian applications at the same time. There are many examples of such technology transfer. One of the newest solutions primarily designed for combat are unmanned vehicles. Started with aerial designs in the twenties, nowadays ground and underwater vehicles support soldiers of many armies all over the world. After some “crash tests” on battlefields, the industry sensed new dimensions of employing their products in industrial spheres including logistic purposes. The current concepts and capacities of UAVs, UGVs and AUVs use for logistic matters focus mainly on the safety and protection, transportation or use of unmanned vehicles to cope with effects of both natural and man-made disasters or effects of all kinds of accidents which can damage or destroy natural environment. The robots are extremely useful in situations where and when an intervention could put human lives in danger. Every day the number of intelligent appliances supporting or replacing a man increases and they will be used very intensively in the future, but they can only support human activity, reduce costs and increase effectiveness of actions but robots will be still long not capable of fully replacing a man due to the complexity of the present world.

2 Watching over from the Sky – UAVs

One type of devices which comes from the military know-how is the UAV which can be used particularly in the logistics security, monitoring surveillance and transportation. The abbreviation “UAV” stands for “Unmanned Aerial Vehicle” which is “…a power driven aircraft, other than a model aircraft, that is operated without a flight crew member on board”[1].

So called “drones” had been developed by military in 1922 and at the beginning were used as shooting targets for air defense units. The first fully operational device was constructed in 1955 and it was Northrop Radioplane SD-1 Falconer/Observer used for surveillance purposes [2].

UAVs are divided in two categories: fix wing-like Short Take-Off and Landing (STOL) and helicopter-like with hover abilities Vertical Take-Off and Landing (VTOL) vehicles. In addition there is another division of UAVs into two types bound up with a type of control system: Remotely piloted vehicles (RPVs) are managed and controlled by an operator from a remote special center. The last solutions are newer autonomous UAVs, which flight is fully programmed and Global Positioning System (GPS) is used for flight control. Some of them, more sophisticated designs, can operate in both modes.

The UAVs designed for logistic purposes can be equipped with all types of devices and sensors available on the free market. These can be special surveillance cameras, both infrared or digital, night vision equipment, all kinds of indicators and sensors. The UAVs deliver imagery of monitored area to operators in real time, day and night.

In logistic applications UAVs can be very functional for monitoring of land transportation of hazardous or very valuable cargos (transports of nuclear waste, explosives, expensive loads etc.). For example the flying devices can track routes of truck convoys or monitor valuable freight trains and are able to send information about road conditions, situation on road crossings, traffic jams etc. Furthermore they can improve security of transported loads and protect them against robbery, hijacking or terrorist attacks. What's more, if an accident happens the public security services can get the information from UAVs quicker and react faster according to the situation development. In the case of a fire or collision, drones can send pictures from the scene of mishap in order to identify results of the disaster. Furthermore drones can e.g. identify sources of fire or help to estimate zones of contamination and assess a scale of calamity without putting human resources in danger.

Another possibility of UAVs' implementation is the protection of storage facilities such as large storehouses, un- and uploading areas or transportation systems. Additionally drones will be used for small-scale logistic supply tasks. VTOL UAVs do not need much place for take-off and landing than the rotor size. The military industry works very intensively on developing such planes and moreover they can find commercial applications. An Israeli VTOL called AirMule, which is a development concept of Urban Aeronautics Company [3], being tested now could be an example. The aircraft can carry up to 226 kg of payload, move at a cruise speed of 185 km/h with standard duration of 2-4 hours (depending on the fuel tank type). The design was originally intended to support Israeli troops on battlefields in various ways, from supplying with combat and logistic materials up to reconnaissance tasks. In the future the AirMule is predicted to be utilized for commercial use as a smart courier for delivering small cargos at short distances.

Another intelligent drone concept of Israeli military industry consortium Elbit is the “Flying Elephant”. It is planned that the UAV will have a double transport capacity of the AirMule [4]. Admittedly the flying robot was developed for military supply purposes, but probably it will find its “civilian use” in logistic matters very quickly. A “civilian” example of a UAV design developed typically for commercial use is a small drone called the DragonFly DF2 [5]. Transport companies can use it for fast delivery of lighter cargo. The device can operate at a cruise speed of 56 km/h and carry payload of 136 kg with standard duration of 45 minutes. It means that it can deliver a cargo for dozens of kilometers. A further version with an extra fuel tank can deliver only 36 kg of load, but is capable to operate in the air for 90 minutes. An alternative kind of UAVs – the STOL type presents bigger transportation capacities but they need some small landing area. An example of this kind of equipment could be the “Predator” drone, well known from Afghanistan military operations, which version MQ 9 can transport payload of approx. 400 kg, at the operational speed of around 300 km/h. The UAV can operate about 30 hours, can be refueled in the air and represents an effective alternative for fast transportation of heavier cargo at longer distances [6]. As mentioned above, the "Predator" type devices need more place for take-off and landing (approx. 470 m) than VTOL designs, but their speed and range make those drones a perfect alternative for courier companies such as DHL, FedEx, UPS and others.

Summarizing one can say that UAVs are a new kind of robotic machines, which can find very quickly a broad spectrum of applications in the logistics. The devices are especially suitable for monitoring, guarding or transporting loads. At first they were designed for military purposes but after some adjustments they have been adapted to commercial use to support the traditional way of solving logistic problems. Both types of UAVs, VTOLs and STOLs, have their pros and cons. STOLs have larger payload, longer duration, range and greater velocity than VTOLs, but they need specially prepared runways for take-off and landing, which restricts their use and flexibility. In fact smaller drones can be launched from special self-propelled launchers and "catch" with help of special devices (lines and nets), but this solution is not applicable to larger vehicles. On the other hand VTOLs can operate for a shorter time and can carry less payload, are slower and can fly shorter distances but in particular applications, such as surveillance, monitoring, security and protection, the vertical flying machines offer much greater capacities and possibilities than the airplane type drones. Especially VTOLs are very useful for surveillance purposes because of their hovering abilities, they can approach an object very close, can follow a suspected person or vehicle. In transportation applications they can operate inside urban areas to deliver precisely ordered cargos. Every type of UAVs is specific and in the future can find their "niche" for logistic use.

3 Unremitting Guardians and Workers – UGVs

An abbreviation UGV stands for "Unmanned Ground Vehicles", which are autonomous or remotely operated mobile ground robot systems.

UGVs can find a broad spectrum of application in many logistic areas. In security issues the robots can be an ideal solution as sentries in harbors, trans-shipment areas, airports, cargo deposit points etc. to guard and protect the logistic infrastructure. Smaller size designs can be used inside depot buildings to maintain and outgoing goods. In protection matters the machines can be equipped with a wide range of sensors, cameras, indicators etc. like the above mentioned AUVs, but they can operate directly on the ground and with their cross-country abilities (UGVs can be wheeled or tracked) can have a direct access to an investigated place or a controlled person. Those abilities open new dimensions for utilization of the device. The intelligent machines equipped with special scanners can identify authorized personnel having a special kind of identifiers (ID badges, signal transmitters, etc.) and effectively watch over a facility and protect it from visits of unwanted guests. The security robots equipped with microphones and loudspeakers can be used by human operators to maintain a direct contact with intruders, give somebody instructions or orders. There are even technical possibilities to arm the machine with non-lethal weapons or deterrence systems in order to incapacitate interlopers, but it is a rather moral issue of a machine using force against a human being. An integrated concept of UGVs use as a part of a guarding system is called Mobile Detection Assessment and Response Systems (MDARS) for patrolling the storage areas.

MDRAS UGVs are used now by The National Nuclear Security Administration, which is a part of US Department of Energy, to supervise and guard the Nevada National Security Site being a former nuclear tests area and current Area 5 Radioactive Waste Management Complex [7]. Independently operated MDRAS vehicles are equipped with real-time video cameras, sensors and communication tools such as loudspeakers and microphones, which permit the human operator to notice trespassers or detect suspicious activities and clarify the situation by a direct verbal contact with the intruder. By the way, UGVs seem to suit the nuclear industry very well. They can not only guard the nuclear power plants or disposal areas but as shown by the case of Fukushima nuclear power plant disaster these intelligent devices can be sent to the damaged reactors to measure the radiation level, temperature, to estimate the inside conditions, to send real pictures from the catastrophe site [8]. Furthermore the robots will be used not only for estimation of the situation but equipped with special manipulators they will handle the radioactive debris, conduct maintenance and repair operations in radioactive contaminated zones.

Generally, in the case of environments hazardous to human beings, which occur always after disasters such as a fire in a road tunnel or a warehouse, a petrol depot or heavy contamination after some accidents, robots equipped with a fire extinguisher, manipulators, cameras can replace people and fulfill “manual” tasks previously done by a man.

Nonetheless UGVs can find more opportunities for use in logistic tasks. The transportation of cargos and the delivery of goods is another area of the ground operated robots application in the near future. A practical example could be the use of intelligent machines in trans-shipment zones. The Hamburg harbor uses now unmanned so-called Automated Guided Vehicles (AGV) for those purposes. AGVs are mobile platforms equipped with a GPS system receiver, sensors and are used for transportation 20, 40 or even 45 feet containers. They are fully computer controlled, use special electronic route markers for transportation of containers from the quay to the storage area. In combination with a special sophisticated Automated Stacking Cranes the harbors such as Hamburg or Antwerp are manned only with the minimum number of supervision staff.

On a smaller scale intelligent mobile platforms are used for transportation of goods. The most advanced research programs are conducted by military for logistic purposes, that’s why the findings and results of these researches will be adopted very quickly for “civilian” use.

One of promising solutions is a Multifunction Utility/Logistics and Equipment vehicle (MULE) developed by the Lockheed Martin. By the way, a mule is an offspring of a horse and a donkey, which is considered as a strong, persistent and quite smart animal used for transportation means. The same characteristics have been planned for this intelligent ground robot with substantial cross-country abilities.

The task of the fully autonomous UGV is to follow and support soldiers in combat to carry approx. 900 kg of their military equipment and logistic supply. The MULE is not only a transportation vehicle but an intelligent robot, which will follow orders received from soldiers and perform given tasks. The machine will be equipped with optical, infrared thermal cameras for observation, sensors for identifying chemical or biological threats and will be a real support for small fighting units. From a “civilian” perspective one can imagine using MULE-like UGVs in depots or storehouses and in the near future even in cities for delivering small size orders from warehouses to shops or other end users or in airports for transportation pieces of luggage or small cargo. Smaller MULEs can be applied as smart couriers in factories, offices etc., in short, everywhere where there are needs for transport of something.

The same technology as mentioned above can be applied for ground robots used for managing storage areas, warehouses etc. Intelligent, automated forklifts supported by laser range finders and signal receivers from transponders installed in a depot can accomplish tasks issued by special management software. The machines equipped with bar-code scanners can use automated identification systems for recognizing, precise location and putting on a proper place the stored items in order to find them later and to give to recipients. An intelligent storehouse managed by UGVs will be the future direction of development in this sphere of logistic solutions.

The UGVs possibilities of independent movement can be exploited as autonomous movable supply stations. For example a UGV specially designed for the role of a tank truck can extend an operation timeframe of other unmanned vehicles used even in very secluded areas or places dangerous for people such as nuclear waste depots. This option of machines operation as movable refueling stations could significantly reduce the need for employment of a man for this kind of activities. In the future an autonomous refueling station could be a solution for transportation of cargo through distant, uninhabited areas such as deserts, tundra or polar region. Operated from special bases the UGVs can build a “chain” of supply where autonomous truck convoys will be refueled at rendezvous points or specialized tank UGVs will follow such formations and refill automated cargo machines (wheeled, track, or hovercraft type) on demand. Furthermore the UGVs can supply even human crews in remote operation centers with food, water or other goods. Furthermore the refueling capacities of the ground machines can support another kind of robots: namely UAVs, especially VTOL type. As it has been shown above, VTOL – type machines have a limited operation time, which is strictly connected with the amount of fuel they can take. On the other hand the more gasoline tanks will be mounted at the drone, the less payload could be carried by the machine. The combination of vertical landing and take-off abilities of VTOL systems with the transportation capabilities of UGVs in the form of movable refueling stations provide a unique role in extending the operation time and range of VTOLs. In the near future integrated ground/aerial robot systems will be developed and could be sent to fulfill various joined missions. The first quite obvious application of this new kind of robots would be monitoring and surveillance missions for protection purposes, e.g. the above mentioned autonomous convoys as well as in coping with effects of disasters and catastrophes both natural or man-made.

4 Underwater Control and Transport - Autonomous Underwater Vehicles (AUVs)

Autonomous Underwater Vehicles (AUVs) are another type of unmanned vehicles. In comparison with both other types this technology is relatively new for civilian purposes, because for quite a long time the military restricted the access to this type of technology. Remotely operated vehicles (ROVs) were forerunners of AUVs, used by the offshore industry for repairs of undersea installations or drilling platforms. ROVs are still in use and they are operated by an operator located on a vessel. ROV robots caught worlds' publicity attention in 1966 after revealing the fact that they had been used in operation of retrieving a thermonuclear bomb from the sea bottom by a CURV type submersible. The bomb was lost during a crash of an American B-52 bomber nearby Palomares (Spain) [9].

Arming the underwater vehicles with high-tech equipment evolves to designing a new kind of intelligent underwater robots, which nowadays are widely used by the maritime industry. Recently the main task of unmanned vehicles is the underwater protection of logistic sea infrastructure and transport. Current research programs in the field of security are focused on two areas: guarding of harbors against underwater intrusion and inspection of ships and boats under the waterline.

The systems have been developed and are used in practice. US Coast Guard have been using such constructions. The Underwater Inspection System manufactured by CodaOctopus utilizes special sonar used for searching, inspecting, detecting and tracking unexpected divers [10].

Another option for increasing the maritime security is the use of Autonomous Underwater Vehicles (AUVs) which can operate only with minimum human supervision. An example could be a sophisticated underwater robot of REMUS family manufactured by the company named Hydroid. AUVs can be equipped with optical or acoustic equipment and may be utilized for safeguarding of harbors entrances or inspection of ships, underwater pipelines systems or the port infrastructure. Real time pictures or sensor imaging can help to inspect conditions of harbors underwater facilities to identify and to localize damages, fix defects, support divers with delivering supplies during their underwater work.

This kind of maintenance tasks conducted currently on small scale will be probably one of the most important in the future. The underwater robots will be applied as a special type of "servicemen", which will inspect the transmission infrastructure (e.g. pipelines, pipe nodes, cables etc.) lying deep on the sea bottom, will provide maintenance and routine repairs autonomously or with human supervision or involvement. Recently AUVs are used for monitoring conditions of drilling platforms and equipped with manipulators allow an operator to conduct maintenance work. We have to keep in mind that the sea environment is very dangerous for the human beings and operating in the sea abyss even in specially equipped bathyscaphes is a risky business for a man. A further big challenge for scientists will be to develop and apply huge AUVs for underwater cargo transportation. Undersea transport could be effective means to carry goods. An unmanned automated submarine would be slower, but it could have immense GRT (Gross Register Tonnage), and would be safer than the surface one. Moreover this kind could be independent of weather conditions. Besides, computer controlled invisible freight between e.g. islands could not disrupt surface activates of ships and other vehicles. In the future large, unmanned, nuclear powered, submerged cargo vessels, using GPS and controlled via satellites, could transport a large amount of goods in a cost-effective way without risk and environmental pollution.

According to the current demographic research in further perspective the humankind has to find new dwellings areas and one of the solutions is to colonize the sea in order to establish new places for living. Artificial cities will be constructed not only on the sea surface but underwater, too. It will open new areas for AUVs as transportation means and of supplying mechanisms between the mainland and underwater human dwellings.

5 Conclusion

Logistic safety is a concern of all companies. The modern technology enables to increase the level of security by applying new know-how, which can replace human beings in the most arduous or hazardous activities. Scientists and constructors try to design machines which have a broad spectrum of employment in many fields. Very often the designs prepared for one branch can serve in other businesses. One example of such kind of technology transfer between branches is the transfer of military designs into the area of logistics interest. The use of previous military development as unmanned robots “armed” with artificial intelligence can effectively support logistic processes. The presented areas of employment of smart machines are quite new and one can say it is the beginning of the process of development of unmanned vehicles, which are growing up from small “toys” to a serious logistic means which would dominate future landscape of the earth. The progress in development and application of telematic solutions is unavoidable and the robots will be systematically employed in many fields of logistics. The process will continue in the upcoming decades. After all fully automated trains, which in fact are huge UGVs on the rails, are a reality at the present time. Unmanned, intelligent “hawk eyes” will monitor, coordinate and react to the traffic on the roads. Those aerial observation points will send data about road circumstances to automated cars and trucks and will adjust their speed or routes according to the received data. Fully autonomous harbors will receive goods delivered by large underwater vessels without crews in order to dispatch them to autonomous depots and warehouses for further shipment via UAV or UGV carriers of various sizes. An intelligent army of robots will supervise all processes and guard the facilities against unwanted intrusion. Telematic solutions are the future of logistics and the trend of replacing people with intelligent machines will be continued in the forthcoming years.

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Experiences with Video-Based Incident Detection and Parking Space Surveillance Systems on Motorways in the Free State of Saxony

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Abstract. Today, video cameras are widely used to monitor the state and level of traffic. However, while planning a system for the motorways in the Free State of Saxony (Germany), three major problems became obvious. Most commercial image processing software depends on a particular camera model, and it must be calibrated by a professional. In addition, the diverse and sometimes severe environmental conditions are still a challenge for most algorithms. The research goal of the presented work was to resolve these problems with a novel in-house development. The methods developed for incident detection and parking space surveillance do not disclose vehicle-specific characteristics. Only stochastic and non-specific characteristics are used for image processing. Significant results are a remarkable robustness against weather and lighting conditions as well as minimal requirements regarding camera height and direction. The latter leads to low procurement costs as existing infrastructure can be used for the camera installation.

Keywords: video-detection, incident detection, parking space surveillance, stochastic image properties, traffic management.

1 Introduction

Video detection has been an established part of modern traffic management systems for several years. Nevertheless, while planning such a system for the motorways in the Free State of Saxony (Germany), three major problems became obvious. Most commercial image-processing software is restricted to a particular camera model; secondly, this software must be calibrated by a professional. Finally, diverse and sometimes severe environmental conditions are still a challenge for most algorithms. Most known methods are based on either the tripwire principle [1], [2] or the tracking principle [3], [4], and [5]. Known drawbacks of the tripwire methods include sensitivity in reflectance, shadows and headlights as well as occlusion of non-occupied areas by large vehicles. Known drawbacks of the tracking methods include high computing power, a lot of parameters for distinguishing between different types of vehicles, and sensitivity in camera vibration and shadows. Because the advantages of one principle are the disadvantages of the other – e.g. tripwire methods are almost insensitive to camera vibration and require less computing power then tracking

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algorithms – we opted for a novel development that combines the advantages of both methods and minimises most of the disadvantages.

We encountered a similar situation in tackling the problem of the video-based analysis of parking space. The solutions provided by the literature are not suitable for our requirements. Video surveillance utilising image sequences is described in [6]. An approach using geometric features from aerial images can be found in [7]. Tracking and recording of the movement of vehicles to find an empty parking space is described in [8]. In [9] the calculation of the width and length of vehicles based on shapes and trigonometric relations is proposed. The methods [6], [7], [8], and [9] have high computation and storage requirements.

A method based on trajectories of vehicle movement is described in [10]. Our camera installation covers little environment information, so we were not able to trace trajectories after all. The popular stereo camera methods, as mentioned e.g. in [11], required still too expensive hardware components for a project of this size. Many applications based on licence plate recognition had been developed, e.g. [12]. There were some problems in the realisation of such a system: occlusion of licence plates, deep mounted cameras and data protection – with the latter being the most significant problem. For all these reasons, we developed a new algorithm.

This paper is organised as follows: In order to compare the two systems, the appropriate chapters have the same structure. First, the specific properties of the application deduced by our research will be discussed. These properties motivate the development of the novel methods. While this paper is focused on the experiences with the realised systems, only the basic ideas are presented here. The results highlight the proposed system's real-time ability, accuracy, and robustness.

A Conclusion will summarise the results and main ideas of the presented work.

2 Incident Detection

2.1 Deduced Properties of Video-Based Incident Detection

In our system, we are using existing infrastructure with a camera height of about 7.5 m – which is rather low when compared to a common truck at 4 m. This causes a rapid change of the vehicle shape, size and details in an image sequence (Fig. 1). We solved this problem by using non-specific stochastic features of the traffic stream as a whole; this idea will be explained in section 2.2. A well-known effect in image processing is the so-called corresponding problem. For traffic applications, this is part of the central problem of movement analysis, which is the basis of our incident detection. Using operations that only analyse a limited area of the image – the so-called local operators – the tracking of vehicles is only possible when the colour or brightness of their pixels is correlated. If not, the corresponding problem occurs.

As an example, because of the limited dynamic range of the camera, the top of the truck's tarpaulin appears as homogeneous white in the image (Fig. 1). The impossibility to detect the movement inside the area of the tarpaulin illustrates the corresponding problem: There is no relation between the inner tarpaulin's pixels from one image to the next.

Fig. 1. Example of the rapid change of vehicle size in an image sequence with a camera high of 7.5 m. As a consequence, the tracking of the object across the whole image is difficult to accomplish.

A special case of the explained problem is that the tracking of a moving edge is only possible when a corner is included. Otherwise, the movement vector is ambiguous, except for its component perpendicular to the edge. This is called the aperture problem. This name derives from the limited field of view of local operators.

2.2 System Description

Fig. 2 shows a typical camera installation from our project. The camera is mounted at a height of about 7.5 m and analyses as many lanes simultaneously as it can see.

Fig. 2. A typical camera installation with example images for day and night. The lights on the vehicles in the right image are sufficient for our image processing algorithm. The camera uses the power supply of a meteorological station.

To consider the deduced properties from section 2.1 with a robust and simple-to-handle system we neglect single-vehicle data and focus on the distinction of three Levels of Service: fluid traffic, semi-fluid traffic and traffic congestion. The principle for determining the Levels of Service from an image sequence is explained in Fig. 3. The method is based on grey values; colour information is not measured or taken into account, particularly at night. Since this paper will discuss the experiences with stochastic-based approaches, it is not focused on image processing. The corresponding algorithms are described completely in [13] and [14].

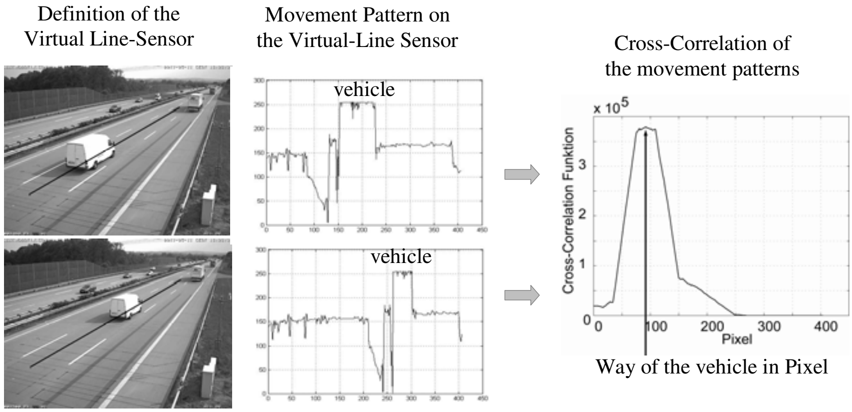

Fig. 3. The Cross-Correlation of the movement patterns of two consecutive images leads to an estimation of the distance covered by the traffic stream. Dividing by the time difference of the images allows one to obtain the traffic stream velocity. With the help of thresholds, this velocity will be translated into Level of Service information.

2.3 Results

The image processing algorithms for incident detection today are implemented for 16 cameras on the motorways of the Free State of Saxony (Germany). Since the system has been proven (see Fig. 4), it will be further expanded.

Fig. 4. Examples of the display of automatic switched alarm images for the Level of Service "traffic congestion" under different conditions. Left image: occlusion in driving direction, middle image: occlusion sideways, right image: fog and snow.

Because it requires low computing power, the system has real-time ability and can be run with all 16 cameras on a standard PC. For the complete system, however, a server computer may be necessary. The total accuracy of the velocity estimation is in worst cases about 80 %. This is always sufficient for the distinction of the three Levels of Service. For one measurement, two images with an interval of about 0.25 seconds are needed. The required value depends on the length of the virtual sensor. It is worth mentioning that we do not need four images every second; there can be a gap of up to 60 seconds between individual measurements.

A comparison of the vehicle lights in the left and right lanes in the right image of Fig. 2 shows that because of the low camera height it is advantageous to look with the camera in the direction of travel. This reduces glare at night.

3 Parking Space Surveillance

3.1 Deduced Properties of Video-Based Parking Space Surveillance

As in the case of incident detection, it might also be possible to consider the vehicles as a whole for parking space surveillance. The disadvantage of this is that only the total number of free parking spaces – but not their location – is ascertainable.

Therefore we decided to focus on individual (single) parking space detection and had to take into account the large variety of vehicle types as shown in Fig. 5. To solve this problem, the identification and analysis of non-specific stochastic features of the single vehicle is necessary. This idea will be explained in section 3.2.

Fig. 5. The use of non-specific vehicle features is necessary to consider different types and sizes of vehicles. Small vehicles can be anywhere on the parking space, so an analysis of the whole area is necessary.

From the viewpoint of image processing, stationary and moving traffic differ significantly, so the methods are not transferable. We found two main differences between moving and stationary traffic:

1. The lack of motion information.
2. The lack of vehicle light.

Due to the lack of motion information, difference-image methods had to be neglected, while the vehicles will have disappeared after a while in the difference-image. Because of the lack of a vehicle light, additional illumination is required. Entering or leaving the parking space at night can cause short-time disturbances (right image in Fig. 6) in sensitive, night-optimised algorithms. Other deviations from the standard parking situation include crossing the parking space, passing in front of or behind the parking space, as well as persons on the parking space. Additionally, in winter, road markings were covered with snow, meaning that vehicles cannot be placed correctly and could occupy two parking spaces.

3.2 System Description

A typical camera installation for parking space surveillance from our project is shown in Fig. 6. At night, we use an 80-Watt infrared light. Because of the occlusion of the middle parking space by the adjacent vehicles we need two cameras for five parking spaces.

Fig. 6. Typical view of a camera installation with infrared light on a 10 m pylon. The right image shows a typical situation at the exit of the parking area at night.

In the scope of parking space surveillance we had to solve two main tasks: the counting of free parking spaces and the triggering of alarm pictures in the case of illegal parking in the entrance or exit of the parking area. Because of the difficulties explained in section 3.1, we needed a vehicle-independent measure for the all types of vehicles under all viewing conditions. As an appropriate signal model for that, we have identified the vertical edges on the masked parking space (Fig. 7).

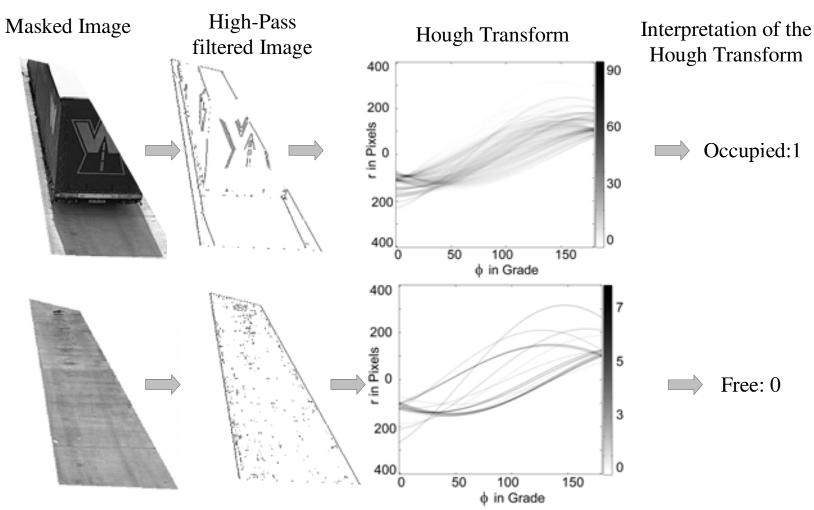

Fig. 7. In order to obtain a vehicle-independent representation, the masked parking space will be High-Pass filtered. The result differs significantly between the free and occupied parking spaces. Afterwards the calculation and interpretation of the Hough Transform leads to a binary information, 1 for “occupied parking space” and 0 for “free parking space”.

To consider different lighting conditions, including above all day-night differences, we have developed an adaptive threshold for edge detection. Furthermore an algorithm for the automated interpretation of the Hough Transform was necessary, since this transform yields only a measure of the intensity of the edges. These details are described completely in [15], since we focused on the system as a whole in this paper.

3.3 Results

Our system for parking space surveillance is prototype installed on the PWC-Nöthnitzgrund, driving direction Prague, on the A 17 motorway in Germany. In the future, this prototype will be enlarged as a part of a parking management system.

Figure 8 shows a programmed information board with the amount of free parking spaces. It will be provided to the user together with an overview image to evaluate the results. In the absence of strong shadows, we have identified with the help of the images an accuracy of 98 %. But since shadows cause edges similar to the vehicles, it is not easy to account for them. A simple shadow handler, based on the variances of dark and light areas, has already been implemented, but it is not yet sufficient, so some additional research and literature review must be done in the future. The system works thanks to the infrared lighting at night as well as during the day. This ability had been externally evaluated [16].

Every viewing direction yields significant features for vehicle recognition, but it is important to preserve the privacy of the driver. Therefore, the camera should look at the vehicles from behind. This allows the system to be acceptable.

As a timeframe for image analysis and transmission, one minute is sufficient. Significant changes in the situation normally do not occur within this time period, so it is sufficient to register it after one minute. The indication of a change in the number of free parking spaces by the system should be preceded by a user-programmable time delay. This prevents the display of short-term changes in occupancy, caused for example by persons and the passing of vehicles.

Fig. 8. Programmed information board with the amount of free parking spaces. The result can be verified by the image in real-time. The right image shows an example for triggering an alarm image while someone was parking in the exit of the parking area.

4 Conclusion

In this paper we have presented novel systems for video-based incident detection and parking surveillance which are in operation on a 24-hour basis.

The image processing is based on non-specific and stochastic features of the vehicles. That leads to a high robustness in different and severe viewing conditions at a camera height of only 7.5 m.

An image resolution of 640x480 pixels is sufficient for image processing and the display of alarm-triggered images. While an alarm means “traffic congestion” or “invalid parking”, the latter has proved in practice to be important. A large number of cameras required the automatic selection of images. The incident detection is technically mature, but the shadow model in the parking-space surveillance system has to be improved.

Both systems will be important components of the future traffic management system on the motorways of the Free State of Saxony (Germany).

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Intelligent Transportation Systems in Transportation Policy of the Cities

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Abstract. A transportation policy of a city defines the directions and means of functioning of a specific urban transportation system within a given timeframe. The notion of functioning includes both the operation of the system as well as the implementation of the relevant plans. The shape of the policy depends on a number of interrelated factors, the set of which defines the options of the policy. The multi aspect nature of an urban transportation policy reveals itself in the way it is approached as required from a number of angle points: social, political, environmental, economic, spatial and time related. This multi aspect nature of the transportation policy of a city causes a number of objectives and tasks to be defined which concern a number of operating areas of the urban transportation system. A consequence of this multi aspect character of the policy is the use of a range of methods and means in the implementation process. Therefore, the relevant toolset becomes extensive. The present paper undertakes the discussion aimed at defining the place of an ITS in the transportation policy of the city within the context as outlined above. Starting with the opportunities created by the ITS for the development of modern urban transportation systems, the constraints created by the city transportation policy are pointed out. Those two groups of factors determine the current position of the ITS.

Keywords: urban transportation, transportation policy, ITS applications.

1 Introduction

A transportation policy of a city defines the directions and the modes of operation of the relevant urban transportation system within a specific timeframe. The basis for its development is the strategy of development of the transportation system. Such an approach ensures the coherence of both programme documents, critical for the city.

The complexity of the problems of functioning and development of the transportation system makes it necessary for the transportation policy to take into account also a number of aspects related to the dynamic environment of the transportation system. The multi-aspect character of the policy creates a need for formulating diversified goals and tasks with a wide-range toolset necessary for their implementation.

Both theory and practice prove that more and more often in the process of creating and implementing the transportation policy of a city advanced ITS technologies are

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being applied. Thus, issues of the mutual relations between the transportation policy of the city and the ITS applications arise. At present, the applications are most often the tools of the policy; however, due to the tendencies of ITS implementation, in the future they will become one of the objectives of the policy. The dependencies of the problem formulated in such a way are the topic of the discussion in the present paper.

2 The Goals of the Transportation Policy of a City

There are a number of causes for the need to formulate the transportation policy of a city. The most important ones form a logical chain and are related to:

- the management of the city as a component of its attractiveness,
- the city development strategy which is a necessary instrument of effective management,
- the need to develop and make more detailed the city development strategies, to a degree allowing the accomplishment of the accepted detailed and strategic objectives.

In the process of city development which is a continuous one, the attractiveness of the city area plays a key role. There are four components of the feature of attractiveness, as presented in Fig. 1.

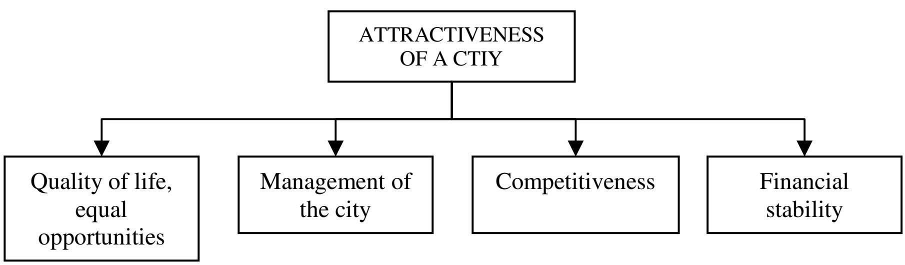

Fig. 1. The components of the attractiveness of a city according to the World Bank [29]

One of the elements of the attractiveness of a city is its management mode, being [13]:

- the definition of the strategic objectives and tasks (as described in the city development strategy),
- the definition of the holistic policy of the city and the public policies, among which the transportation policy of the city plays an important role,
- the implementation of the city policy and the public policies by its organisation structures,
- the coordination, control and evaluation of the performance of the bodies executing the relevant tasks (according to the predefined criteria).

Effective management of a city requires that the governing body has assumed a development strategy. The latter is a tool of a long term planning for the city. The necessary decision making process and parameters defining a specific direction and methods for the development (i.e. the transformation of the existing transportation system) is defined in the transportation policy of the city. For the planned activities to be coherent with the objectives of its development strategy, the strategy needs to be assumed as a foundation for building the programme of the policy.

Mutual relationships of the city development strategy and the transportation policy are very close; they have been illustrated in Fig. 2. As seen from the diagram, the strategic decisions are carried over from the strategy platform to both strategic and short term dimensions of the transportation policy.

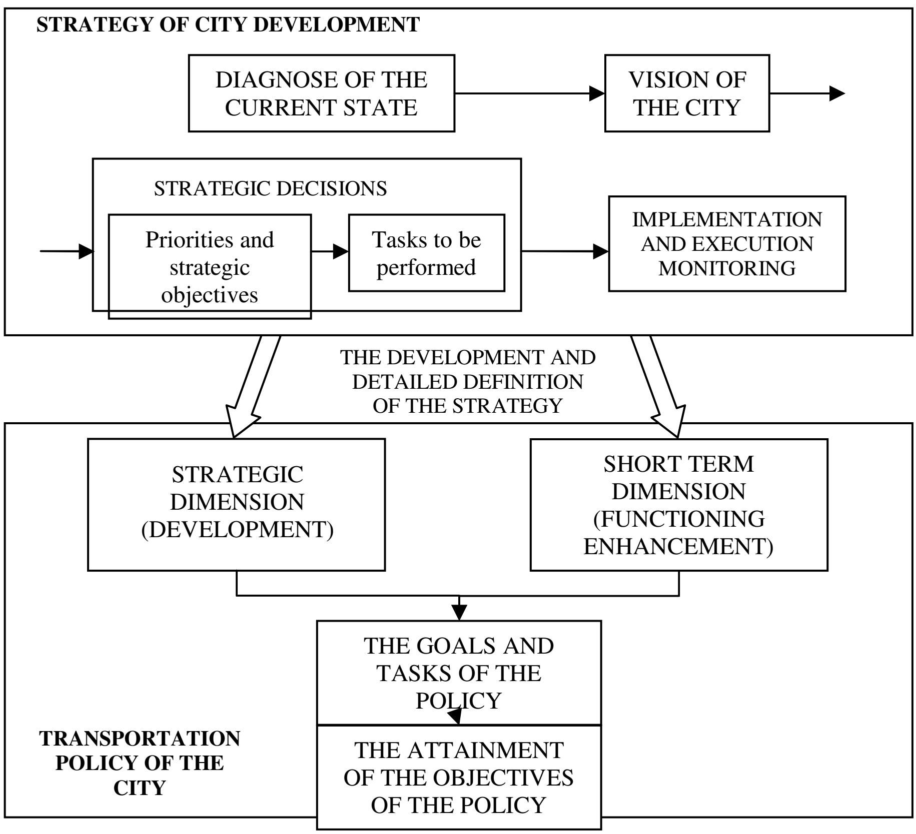

Fig. 2. City development strategy as a basis for the formulation of a transportation policy

The transportation policy needs to take into account a number of aspects related to the dynamic environment of the urban transportation for the needs of which it has been developed. These aspects influence its substantive content and thus also the proposed activities. Fig. 3 illustrates the components of both of these elements of the process of constructing the programme for the transportation policy of a city.

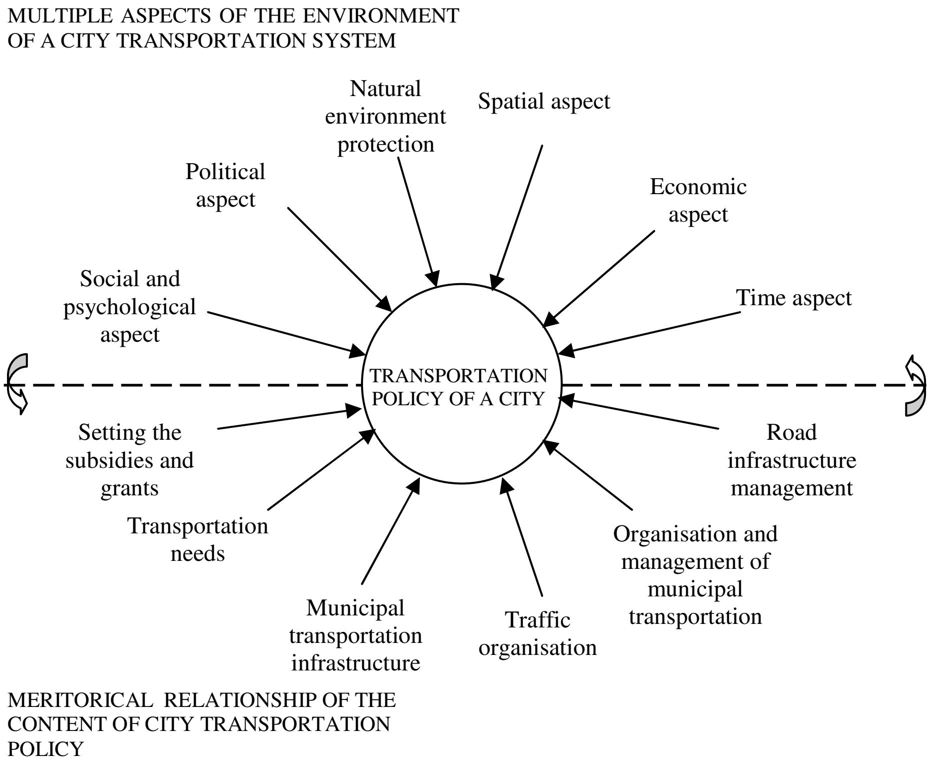

Fig. 3. The aspects of the environment of a transportation policy of a city influencing its substantive content [2]

To take into consideration multiple aspects of the influence of the environment of the transportation system of the city it becomes necessary to formulate a range of objectives and tasks. Also these tasks and objectives concern a large number of areas of functioning of the city and its transportation system. Therefore, in the transportation policy of a city the objectives may be approached from the point of view of their different characteristic features which with such an approach become the selection criteria. Thus the objectives of the transportation policy of the city become differentiated by, among others [9] the capacity, the degree of generality, the assignment range, its subject, its timing, spatial characteristics, types of activities, way of measuring, area of relevance and the degree of complication.

By combining the goals of the transportation policy of a city, one may reach a practical way of their categorisation as shown in Fig. 4. With such an approach, the goals may be classified as general, primary and specific. The activities planned within the transportation policy of a city should make possible the attainment of the following general objectives [3]:

- in a long term perspective – the limitation of the transportation needs within the city,

- in a short term – the rationalisation of the modal split of the transportation tasks, directed towards the principles of sustainable mobility and towards stimulating the expected transportation-related behaviour of the city inhabitants.

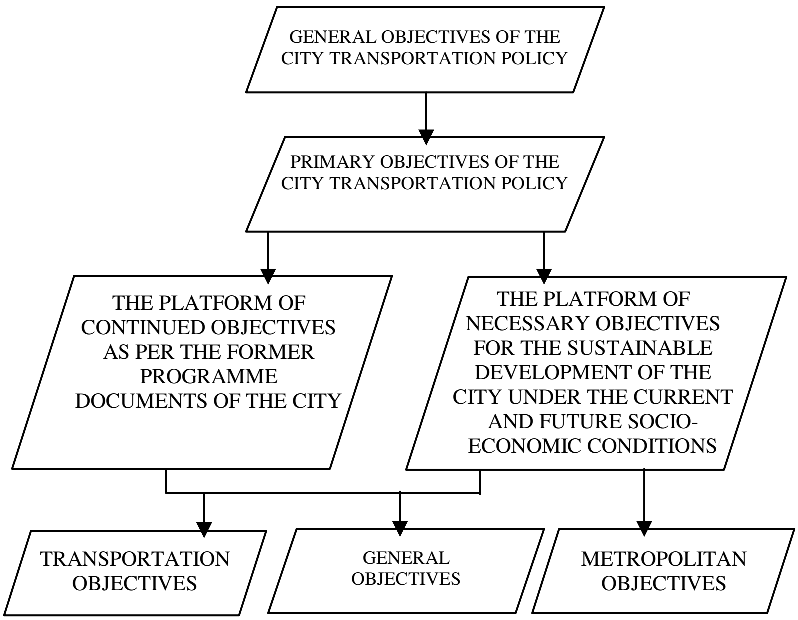

Fig. 4. The per type structure of the objectives of a transportation policy of a city – practical approach [24], [25]

The primary objectives of the transportation policy of a city include, among others [4]:

- the improvement in accessibility of various different areas in the city, specific from the point of view of the activity of the population and the spatial organisation,
- transportation creating the conditions for the social and economic development of the city,
- reduction of the travel costs borne by the users of municipal transportation,
- the improvement in safety in transportation,
- the limitation of the negative impact of the transportation on the environment [6], [20].

To answer the question on the position of the advanced ITS applications in the transportation policy of a city one needs to find out the degree to which the ITS technologies may support the activities forming the transportation system. This specific topic is the subject of discussion in the following part of the present paper.

3 ITS Applications in the Transportation Systems of Cities

The contemporary inadequate degree to which the ITS applications are utilised to solve the problems of city transportation may be considered a development barrier for the urban transportation and in particular for the public transportation in the urbanised areas. Such a perception of the intelligent transportation systems takes place when the observations of two effects typical for large cities and agglomerations are compared. One is the focus of a number of specialists dealing with transportation on expensive infrastructural investment projects, the completion of which may solve the problems of urban transportation only partially. Another one is still a low level of utilisation of advanced ITS technologies [21].

The applications of telematics in urban transportation may be considered at different aspects. The most important approaches take into consideration:

- the economic problems of functioning of the urban transportation systems,
- running transportation business and managing the transportation under the conditions when the transportation processes are integrated into one entity,
- the degree of complexity of the possible solutions from the ITS domain.

The economic aspect of functioning of the urban transportation systems means the introduction of ITS applications in a sequence of effects and practices positively affecting the cost of transportation. Stimulation of the desired transportation related behaviour, meaning the increased demand for public transportation, leads to lowering the transportation fares. The reduction of these fares may be a result of the reduction of the operating costs of transportation in the given city. This positive effect may be accomplished by utilising the advanced ITS applications [23].

Integration of inter- and intra-branch transportation processes is possible if their respective stages or the whole of the processes may be linked, using the ITS technologies. The applications integrate the branches and types of transportation, the means of transportation, the transportation infrastructure as well as the subjects of the supply side of the transportation services market. This makes possible the collaboration and cooperation with the entities on the demand side of the market [5], [10], [22], and [30].

The areas of application of basic systems of IT support for management in urban public transportation are primarily [7]:

- vehicle localisation, necessary for the service coordination, used in passenger information systems, in the management of public transportation routing and in the organisation of passenger interchanges,
- fare collection achieved using a variety of technical means allowing ticket integration, clearing operations between the operators, price structure management etc.,
- the identification of passenger flow magnitudes on specific routes, used for the service offer planning and settling the cross charges in public urban transportation,
- management of transportation production means and optimisation of the tasks such as the assignment of the vehicle base, staff scheduling, identification and regulation of cost of providing the transportation services.

In the proposed concept of the intelligent public transportation management system for the Upper Silesian agglomeration [18] with a practical application of the approach presented above it has been assumed that the efficiency, the effectiveness and safety of the existing transportation infrastructure will be achieved. These benefits will be achieved by means of implementing the organisation solutions employing advanced IT technologies while the investment in the infrastructure is limited to a minimum. Seven modules of the agglomeration-wide ITS system are to be implemented, as illustrated in Fig. 5. The traffic management module, public transportation vehicle base management module and the fare collection module are of critical importance as they affect the traffic smoothness within the territory of the whole agglomeration.

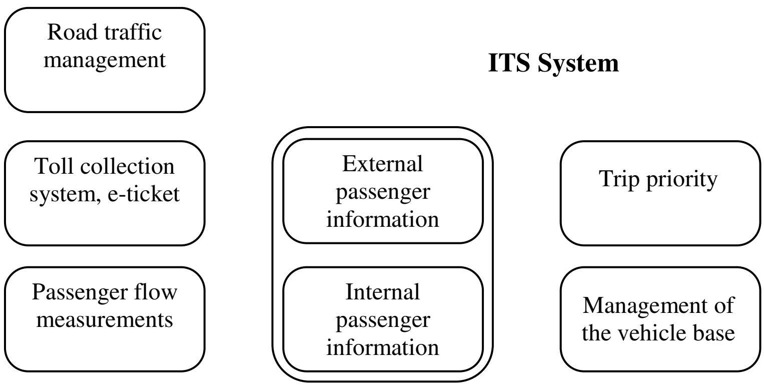

Fig. 5. The modules of the intelligent system of public transportation management in the Upper Silesian agglomeration [19]

The degree of complexity of the ITS applications which may be used in solving the urban transportation problems may be described as follows [11]:

- the modules of the advanced ITS technologies, to be used as separate individual solutions,
- the modules of the advanced ITS technologies which, interworking with other ones, form the intelligent quasi-systems of transportation; such systems are capable of addressing wider problems and become one of the elements of the urban transportation system,
- complete ITS systems composed of a number of modules.

The example of a model of an intelligent public transportation management system for the Upper Silesian agglomeration mentioned earlier may, due to its design, offer also the solutions in the form of individual modules (such as external passenger information module) and in the form of quasi-systems (addressing for example the issue of traffic smoothness and requiring the collaborating modules of public transportation vehicle base management and fare collection module). Table 1 presents the overview of the selected ITS application in the domain of public collective transportation, at the assumed complexity level.

Table 1. Selected ITS applications for public transportation systems [12]

ITS Module Name	Degree of complexity of the solution
1	2
1. IT tools related to large data volume handling supporting the public transportation management process and their exploratory analysis	Individual solution
2. Location services for public transportation	
3. Fare collection	
4. Passenger stream identification	
5. Cross-charging system	
6. Driver and vehicle schedule planning	
7. Traffic controller support	
8. Transportation services cost calculation	
9. Passenger information systems	
10. Urban public transportation supervision including monitoring systems in vehicles	
11. System for automatic passenger stream measurement	Sub-complex solution
12. Electronic charging system	
13. Public transportation management system	
14. CCTV monitoring system	
15. Passenger information system (external and internal)	
16. Holistic ITS module implementations (pos. 11-15)	Systemic solution
17. Holistic application of extended ITS modules: Systems listed herein (pos. 11-15) Weather system Passenger car user support system Emergency centre system and 112 Emergency Code handling system Motorway management system Emergency incident notification system	

In the discussion so far we have stressed the diversification of the goals of the transportation policy of the cities and have pointed out the possibilities of using the ITS application in the tasks and activities undertaken in the area of public urban transportation. The influence of both those factors on the role and position of the ITS in the city transportation policy will be discussed further on.

4 The Position of ITS Applications in the Transportation Policy of Contemporary Cities

The diversification of the transportation policy of the cities and the broad range of ITS technology applications which may be used in urban transportation domain make the role of ITS applications in the city transportation technology crucial. Both of the listed factors have dual connections to the discussed problem of the relationship of the city transportation policy and of the ITS application use. The first case concerns the answer to the question of whether the development of ITS applications in a specific area of operation of the municipal transportation may be a direct objective of the related transportation policy. The source of the second case in turn is the consequence of the diversification of the objectives of the city transportation policy leading to the use in the process of these objectives implementation of an extensive toolset. With the high capabilities of the ITS systems suitable for the development of modern urban transportation systems it is a right thing to ask a question if ITS applications may be one of the tools to accomplish the goals of the city transportation policy. It is also possible to link the ITS being a tool for the implementation of certain goals of the city transportation policy with them being an objective of the policy in case of a different range of topics undertaken therein.

In theory, all options of the mutual relationship of the city transportation policy and the ITS technologies discussed earlier ale allowed and acceptable. The proposed solutions implementing the ITS applications are of a critical importance to the degree of complexity. A case of a systemic solution – encompassing at least a whole transportation subsystem if not a whole of the transportation system of a city – a solution of a concrete problem (such as urban traffic management utilising an intelligent, ITS based management system) may be considered one of the goals of the transportation policy of the city. In all other cases the advanced technologies will only be a tool of accomplishment of specific goals, such as for example the improvement in the availability of the public transportation services by means of the implementation of a dynamic passenger information system. The relationship between the degree of complexity of ITS solutions and the transportation policy of a city is shown in Fig. 6.

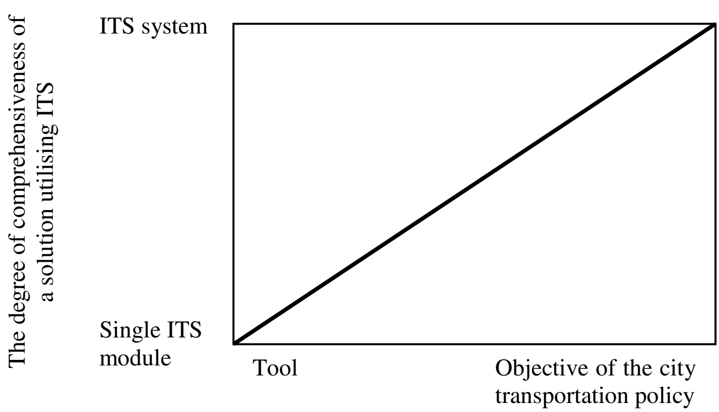

Fig. 6. The comprehensiveness of the ITS solutions as a determinant of the role of ITS in the transportation policy of a city

In conditions typical for the Polish cities, where the available financial means are very limited, the advanced ITS technologies have to be treated primarily as one of the effective tools for the accomplishment of specific objectives of the transportation policy. The review of the transportation policy documents of the cities of Kraków, [14], Warszawa [15], Łódź [16], Poznań [17], Katowice [26] and Dąbrowa Górnicza [27] confirms the instrumental approach to the ITS applications.

More sophisticated approach to the relationship of the city transportation policies and the advanced ITS application has been presented in the strategic documents of the EU dedicated to the transportation sector in recent years. The Green Paper: "Towards a New Culture for Urban Mobility" [8] mentions the development of the applications of the intelligent transportation systems as one of the main directions to be pursued in the pursuit of the new mobility culture. These applications should support the basic operating areas of urban transportation (such as fare collection, collective transportation, etc.) as well as the information system allowing balancing of the mobility (passenger information, interoperability, delivery of loads). At the same time the ITS applications are the tools allowing resolving the problems of sustainable mobility such as the quality of traffic in the cities, safety and reliability of the urban transportation and the limitation of the negative effects of the functioning and the development of transportation.

In the "Action Plan on Urban Mobility" [1] in turn, in the subject groups concerning the quality of life of the population and the continuous care about the level of the quality of life as well as the optimisation of the mobility in the cities, it has been stressed that ITS applications are necessary in order to achieve the programmed objectives. It is therefore assumed that the advanced ITS technologies are tools allowing solving the problems emerging in the above mentioned areas.

The White Paper: "Roadmap to a Single European Transport Area – Towards a Competitive and Resource Efficient Transport System" [28] published this year approaches the topics related to advanced ITS technologies as key elements of the process of formation of the transportation system of the future (until 2050). ITS applications find their important place in the vision of competitive and sustainable transportation and at the stage of projection of the activity directions of implementation of the vision. The primary role in the construction of the future European transportation will certainly be with the new technologies of traffic management in land, air and maritime transportation and with the effective and available information on the whole of the transportation system and the subjects involved. The relevant applications:

- prepare the transportation systems for the future tasks,
- enhance the utilisation of the transportation,
- improve the degree of integration of the network,
- are a necessary factor for the formation of environmentally friendly urban transportation as well as the sustainable mobility,
- improve the degree of safety in transportation.

In the future transportation policy of the EU the advanced ITS technologies will be both the goal of the policy as well as an effective toolset of the accomplishment of its goals. Similarly, on cities and agglomerations scale, where the increase in the number of comprehensive solution may be expected, a shift of the role of the ITS from the instruments towards the objectives of the future transportation policies of the cities will be observed.

5 Conclusions

Already now there is a need for approaching the relationship between the transportation policy of a city and the advanced ITS application from a right perspective. The White Paper: 'Roadmap to a Single European Transport Area – Towards a Competitive and Resource Efficient Transport System' indicates in the perspective until 2050 that the implementation of the vision of the transportation of the future requires using innovative technologies as well as creating by means of these technologies the behaviour of the transportation users being consistent with the sustainable development principles. Without ITS applications the achieving of the territorial cohesion of the EU will not be possible similarly as its economic growth.

These are affected by the modern transportation infrastructure and the related advanced ITS technologies. Sustainable mobility in the cities plays also a key role in the strategy of the sector. On the road to sustainable mobility the number of high complexity advanced ITS technologies used must grow. The activities supporting these directions will be more and more frequently included in the transportation policy documents of the cities and because of its spatial and technological dimension, will become the goals and not only the instruments.

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Transportation Systems Modelling as Planning, Organisation and Management for Solutions Created with ITS

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Abstract. The principal models used in traffic analyses and forecasting in transportation system are reviewed in the paper. Further on, with the perspective of continuing growth of motoring and of the mobility of citizens, a necessity of using ITS solutions as well as of traffic modelling is pointed out to be a consistent approach to the problem of congestion in the cities and agglomerations. An example is given of traffic disturbance leading to obstructions and dangerous incidents at a local site with capacity limitation located within in an intra-node weaving section in Katowice (Upper-Silesian Agglomeration in Poland).

Keywords: transportation modelling, level of service LOS, intelligent transportation systems ITS, Upper-Silesian Agglomeration in Poland.

1 Introduction

Modelling of transportation systems provides practical solutions for traffic management and control within the structures known as *ITS - Intelligent Transportation Systems*. Transportation models are practically used to [1], [3], and [20]:

- evaluate, simulate or optimise the operation of transportation facilities and systems;
- model the existing operations and predict likely outcomes of proposed design options;
- evaluate various analytical contexts, including planning, design, and operational/ construction projects.

In addition, ITS offer the potential to improve traffic safety, to reduce traffic congestion, and to increase economic productivity, by means of the following user services (on the National ITS Architecture example – [4], [9], [19], [23], and [26]):

- *Travel And Traffic Management* with: Pre-trip Travel Information, En-route Driver Information, Route Guidance, Ride Matching And Reservation, Traveller Services Information, Traffic Control, Incident Management, Travel Demand Management, Emissions Testing And Mitigation, Highway-Rail Intersection,
- *Public Transportation Management* with: Public Transportation Management, En-route Transit Information, Personalised Public Transit, Public Travel Security,

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– *Electronic Payment*,
– *Commercial Vehicle Operations* with: Commercial Vehicle Electronic Clearance, Automated Roadside Safety Inspection, On-board Safety And Security Monitoring, Commercial Vehicle Administrative Processes, Hazardous Materials Security And Incident Response, Freight Mobility,
– *Emergency Management* with: Emergency Notification And Personal Security, Emergency Vehicle Management, Disaster Response And Evacuation,
– *Advanced Vehicle Safety Systems* with: Longitudinal Collision Avoidance, Lateral Collision Avoidance, Intersection Collision Avoidance, Vision Enhancement For Crash Avoidance, Safety Readiness, Pre-crash Restraint Deployment, Automated Vehicle Operation,
– *Information Management* with Archived Data,
– *Maintenance and Construction Management.*

2 Classification of Transportation Models and Traffic Analysis Tools

Basic types of the models can be grouped into the following categories [27]:

a) sketch-planning models [3], [20]:
  – provide estimation of *travel demand* and traffic in response to transportation improvements,
  – allow evaluation of projects without conducting an in-depth analysis,
  – use simplified analytical techniques and aggregated data to prepare preliminary budgets and proposals,
  – are usually limited in scope, analytical robustness, and presentation capabilities,
  – they are not a substitute for the detailed analysis needed later in the implementation,
  – generally are the simplest and least costly of the traffic analysis techniques,

b) travel demand models (see example on Fig. 1 and Fig.2) [3], [20], and [12]:
  – allow *forecasting future travel demand* based on current conditions and future projections of household and employment characteristics [10],
  – take into consideration [16] the destination choice, mode choice, time-of-day travel choice, and route choice, and the representation of traffic flow in the transportation network [11], [14],
  – they are not used to evaluate travel management and operational strategies, such as intelligent transportation systems (ITS), because of limited capabilities to accurately estimate changes in operational characteristics (such as flow, speed, density, delay, and queuing) and poor representation of the dynamic nature of traffic [15],

c) analytical deterministic models [2], [17], and [29]:
  – in principle implement the procedures of the Highway Capacity Manual (HCM),
  – provide estimates of *capacity, density, speed, delay,* and *queuing* on a variety of transportation facilities and performance measures in order to determine the *level of service (LOS)*,

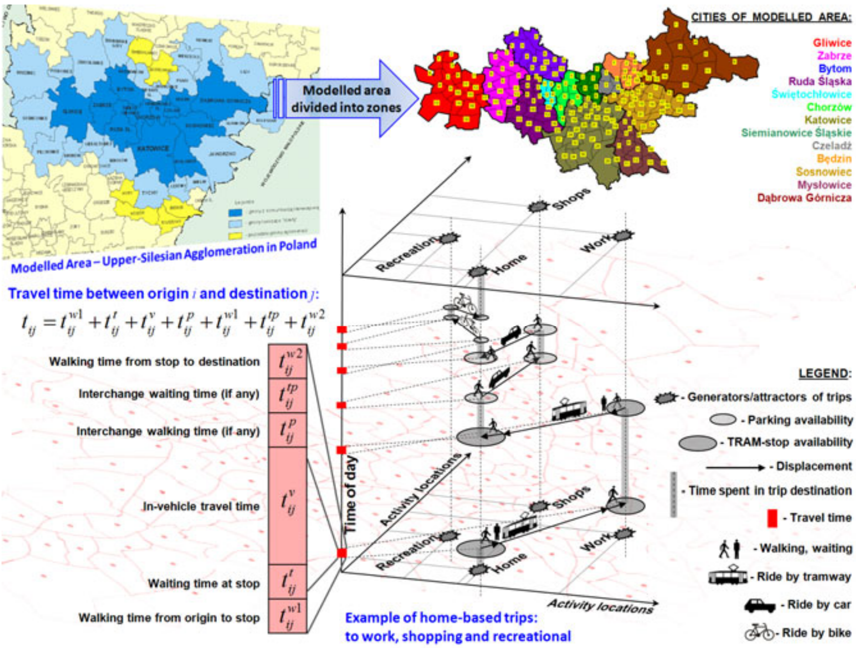

Fig. 1. Travel time between activities (generators/attractors) – example of Upper-Silesian Agglomeration in Poland

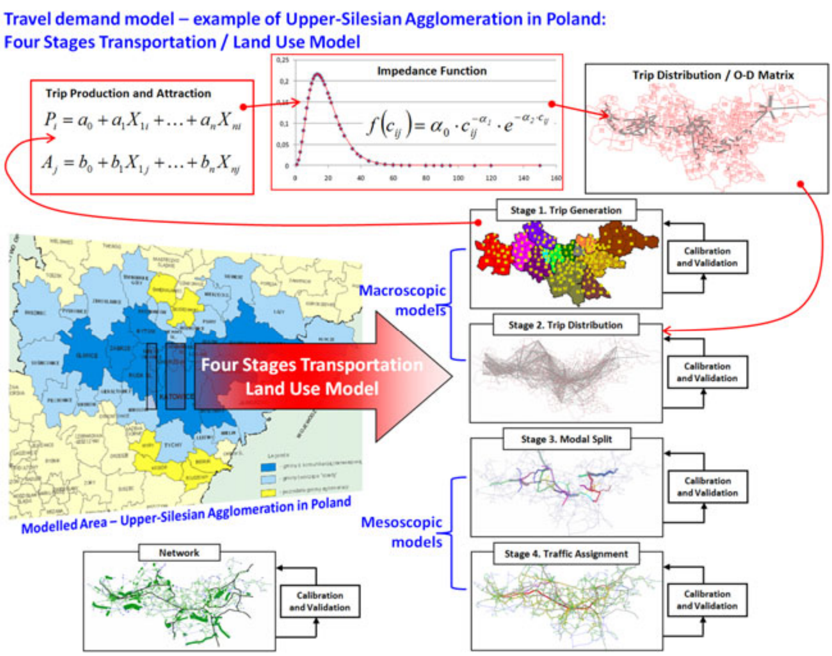

Fig. 2. Travel demand model – example of Upper-Silesian Agglomeration in Poland

- they are macroscopic, deterministic, and static models; input and output data are average during a 15-minute or a 1-hour analytical period,
- utilised to analyse the performance of isolated or small-scale transportation facilities; limited in their ability to analyse network or system effects,

d) traffic signal optimisation models [3], [20]:

- are mostly based on the HCM procedures,
- allow capacity calculations, cycle length and splits optimisation; make possible the coordination of offset plans to develop optimal signal phasing and timing plans for isolated signal intersections, for arterial streets or signal networks,
- they are used for *ramp metering systems* and merging traffic control for work zones [5], [8], and [21],

e) macroscopic simulation models (Fig. 3 shows an example) [3], [20], and [24]:

- based on fundamental diagram with deterministic relationships of the flow $q(t)$, mean speed $v(t)$, and density $k(t)$ of the traffic stream at a certain time t,
- simulation takes place on a section-by-section basis and takes into account clusters of vehicles in traffic flow over short time increments rather than tracks individual vehicles,
- they do not provide ability to analyse transportation improvements in as much detail as the microscopic models, and do not consider trip generation, trip distribution, and mode choice in the evaluation of changes in transportation systems as the travel demand models do,

f) mesoscopic simulation models [3], [20], and [24]*:*

- combine the properties of both microscopic and macroscopic simulation models,
- the unit of traffic flow is individual vehicle type and driver behaviour as in the microscopic models, ,
- movement of the unit follows the approach of macroscopic models and is governed by the average speed on the travel link,
- travel prediction takes place on an aggregate level and does not consider dynamic of flow-density-speed relationships,

g) microscopic simulation models (Fig. 4 shows an example) [6], [18], [22], [28], and [30]:

- movement of individual vehicle types and driver behaviours is based on car-following and lane-changing models,
- in stochastic process vehicles are entered into the simulation using statistical distribution of arrivals and are tracked through the network over brief time intervals (such as 1 second),
- traffic operational characteristics of each vehicle can be influenced by vertical grade, horizontal curvature, and super elevation.

3 Traffic Conditions and Level of Service

The basic description of the traffic conditions is provided by specifying the *capacity* and by defining the *level of service (LOS)* (cf. Fig. 3). The *LOS* is dependent on the geometry of roads and streets, including the super elevation and vertical cross-section geometry. These parameters practically do not change in time (with the exception of the surface deterioration due to premature wear and tear). *Traffic conditions* mean a

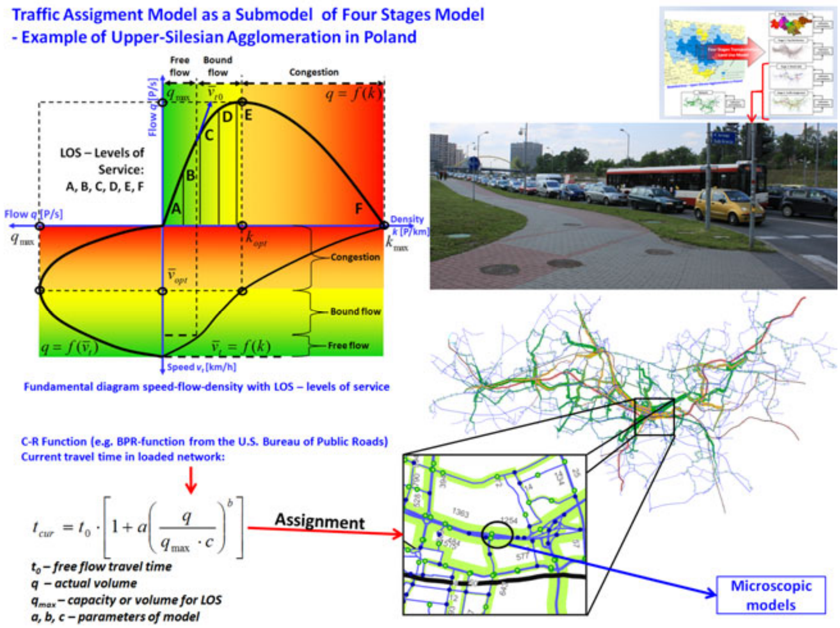

Fig. 3. Fundamental diagram with Level of Service (LOS) and traffic assignment model

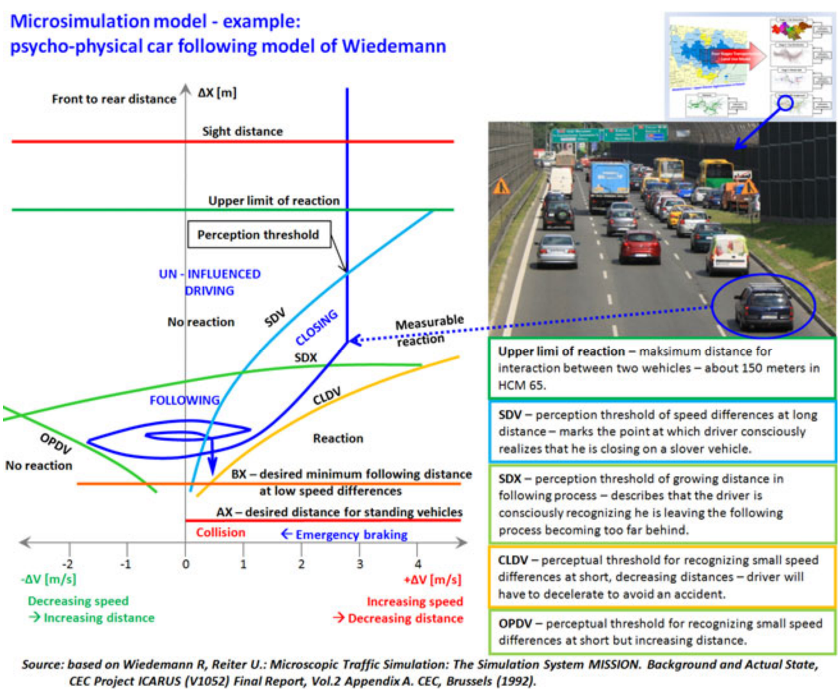

Fig. 4. Micro-simulation model: psycho-physical car following model of Wiedemann

set of factors influencing *drivers' behaviour* and *traffic smoothness*. These include, among others, the vehicle types in the stream, weather conditions, lighting conditions, drivers' knowledge of the way as well as (for the *weaving sections*) – the directional structure of the *weaving streams* and the *volume* and *density* of the streams. The influence of the traffic conditions on the capacity and in particular the *random character of the drivers' behaviours* means that the capacity needs to be considered a *random variable* with *different distributions* and parameters.

When frequent occurrences of detrimental traffic factors are likely to occur frequently and this is not accounted for in the calculations, the effect may be very high traffic disturbances causing large reductions of speed and limited ability of manoeuvring leading to dangerous incidents. In addition, driving in a traffic flow *at high density or at saturation* means detrimental conditions for the drivers as the travel speed is low and the ease of manoeuvring (change of speed, change of lane, overtaking etc.) is highly limited. Therefore, apart from the capacity, the traffic conditions are also determined by the LOS. The principal measure of traffic conditions in HCM-2000 method in case of multi lane freeways is the *traffic density* (expressed by veh/km/lane) at specific LOS levels: LOS A (free flow) – 7, LOS B (reasonably free flow) – 11, LOS C (stable flow) – 16, LOS D (approaching unstable flow) – 22, LOS E (unstable flow) – 25÷28, LOS F (forced or breakdown flow). Under ideal conditions the capacity of one lane is 2200 veh/h/lane (2400 veh/h/lane for a highway).

Similarly as for the *multi lane roads*, LOS is used to evaluate the traffic conditions also at *weaving sections*, as well as at *entrance* and *exit ramps* of the *interchanges*, Weaving sections are usually the elements of interchanges and may have different configurations [7], [31]. Three of them are distinguished here: *type A* – where each of the interweaving vehicles changes one lane; *type B* – where one traffic stream does not change lane and the other vehicles change lane at least once; *type C* – is an extension of *type B* by taking into account the fact that the vehicles changing lane change it at least twice. The traffic conditions on the above mentioned sections are substantially dependent on the following parameters:

- the *length of the weaving section* which is appropriate for the section configuration and the stream volume;
- *number of lanes*, divided into those where *weaving* may take place (including those effectively used) and those running undisturbed traffic;
- *flow volume* subdivided into lanes and weaving streams.

The LOS evaluation of the weaving sections requires determining the *mean speed of streams*, the *occupancy* of the lanes and *mean traffic density* in the weaving section. The limiting values of the traffic density for the individual LOS are assumed as follows (expressed by veh/km/lane): LOS A – 8; LOS B – 15; LOS C – 20; LOS D – 23; LOS E – 25.

The evaluation of the LOS for a specific road section is performed using the HCM method at the planning, design and modernisation stages as well as during the detailed analyses of the traffic efficiency (operational analyses). It needs to be stressed that the HCM methods in case of multi lane roads and weaving sections have been developed and used for the cases of sections without junctions controlled by traffic signals as well as of sections with traffic light controlled junctions located sporadically at distances bigger than 3 km (entrances and exits may appear at these sections). The LOS evaluation is performed separately for the sections with uniform characteristics and the separation lines correspond to the areas where the number of lanes change, at ramps (with inclination over 2% at sections longer than 1200 m), the areas of changed speed limit, changed number of entrances and with junctions with traffic signalling. At the same time, the analysed sections should not be shorter than 760 m.

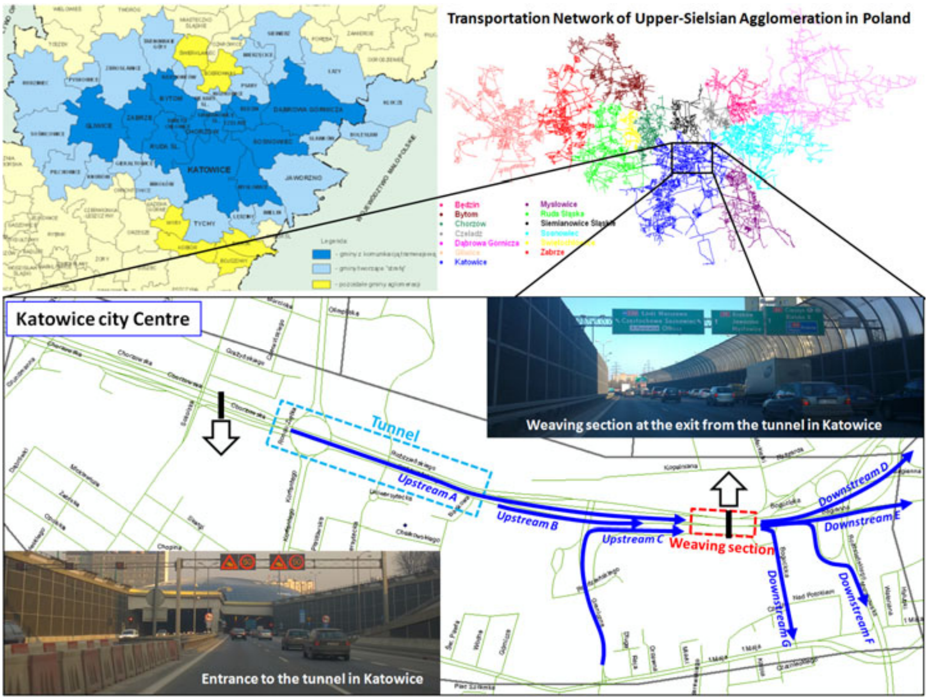

Fig. 5. The location of the analysed local bottleneck in the Upper-Silesian Agglomeration

4 An Example of Traffic Disturbance at Local Bottleneck

One of examples of *area of limitations of capacity* and *traffic disturbance* within the dense transportation network of the Upper Silesian agglomeration in Poland is a *short weaving section* between the two interchanges (cf. Fig. 5).

This example is related to an entry on a S86 express way passing through a built up area and to a *short weaving section* located immediately further on where *traffic smoothness* is disturbed. It should be noted that in General Traffic Measurement (GPR 2010)[1] on this section of S86 express way (between cities Sosnowiec and Katowice) was observed traffic flow ***104 339 veh/24h – the most traffic volume in Poland in 2010 year*.**

[1] GDDKiA - General Directorate for National Roads and Motorways (in Poland) `http://www.gddkia.gov.pl/987/gpr-2010`

Fig. 6. Weaving section at the exit from the tunnel with flows in four directions – see road sign

The weaving section is located at the eastern exit of the tunnel running under the Gen. Ziętek Roundabout in Katowice (cf. Fig. 5).

The flows have three main sources:

A. Upstream A (3 lanes) coming from the tunnel serving regional transit relations and internal urban traffic (cf. Fig. 6).
B. Upstream B (2 lanes) from the city centre with internal urban traffic. The entry lane includes also a bus stop for 26 bus lines (with agglomeration coverage).
C. Upstream C (1 lane) from the city centre with internal urban traffic.

The flows interweave in four main directions (cf. Fig. 6):

D. Downstream D (Express Way S86), direction: Łódź, Warszawa (Warsaw), Częstochowa, Sosnowiec, Pyrzowice (Katowice Airport), Olkusz.
E. Downstream E (National Road No 79), direction: Kraków, Jaworzno, Mysłowice, Sosnowiec.
F. Downstream F (National Road No 86), direction: Cieszyn, Bielsko Biała, Kraków (via A4 motorway).
G. Downstream G (Bogucicka street), direction: Katowice city centre.

While outside peak hours the traffic at the discussed section stays at the free and partially forced states (LOS B and C), in peak hours and (because of the increased traffic outgoing from Katowice) in particular during the afternoon peak the state of the flows reaches or even exceeds the capacity of the section (calculated deterministically using the HCM-based methods). For extended periods of time LOS is E and F (cf. Fig. 7 and Fig. 8) and traffic density at that section and at subsequent sections (in the direction opposite to traffic direction, i.e. towards the tunnel) grows rapidly as the vehicles catching up reduce their speed rapidly and hence the traffic intensity falls rapidly as well resulting in a jam.

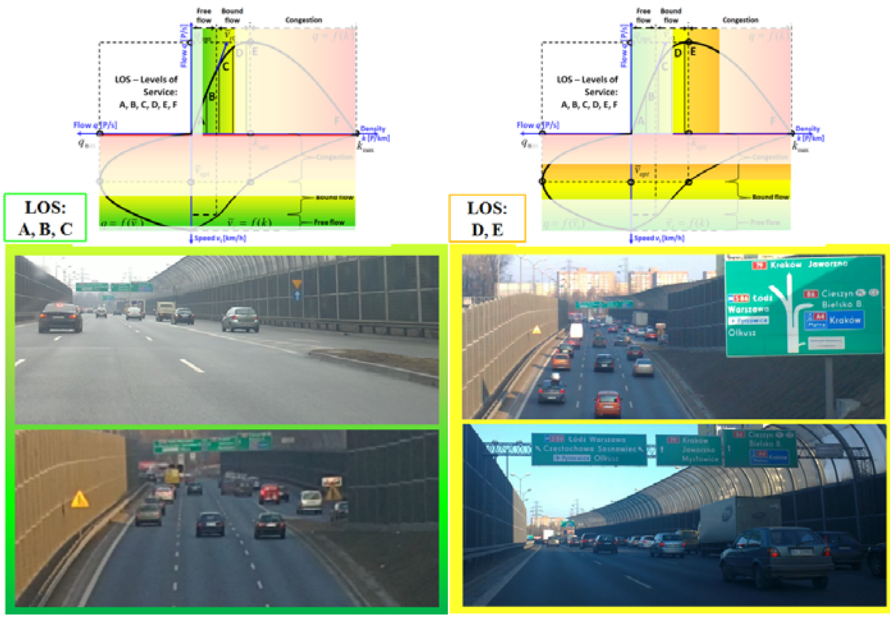

Fig. 7. Traffic conditions and level of service (LOS) on weaving section at the exit from the tunnel – flows in LOS A, B, C and D, E

The main reasons for jams at the discussed section is the interweave of upstreams A, B and C in four main directions – downstreams D, E, F and G with a high number of vehicles changing lane across five lanes over a section of length about 400 m. The lane changes are performed by vehicles moving at a range of speeds: some drivers stop on the lane with the intention to change while the other try to change the lane in a 'smooth' way, bypassing the stopped vehicles (cf. Fig. 8) while yet other drives (those unfamiliar with the traffic and road situation) upset with the chaos at this road section, try to force the right of priority on other drivers [25]. Abrupt lane changes create a number of dangerous situations, resulting sometimes in accidents or collisions [32] and hence extended blocking of the section, extension of the jam area and obstruction for the rescue services trying to reach the accident spot (cf. Fig. 8). Moreover the streams are non uniform as some of the vehicles move in columns in which the minimum headway (or gap) may be constant or may change according to a specific distribution (cf. Fig. 6).

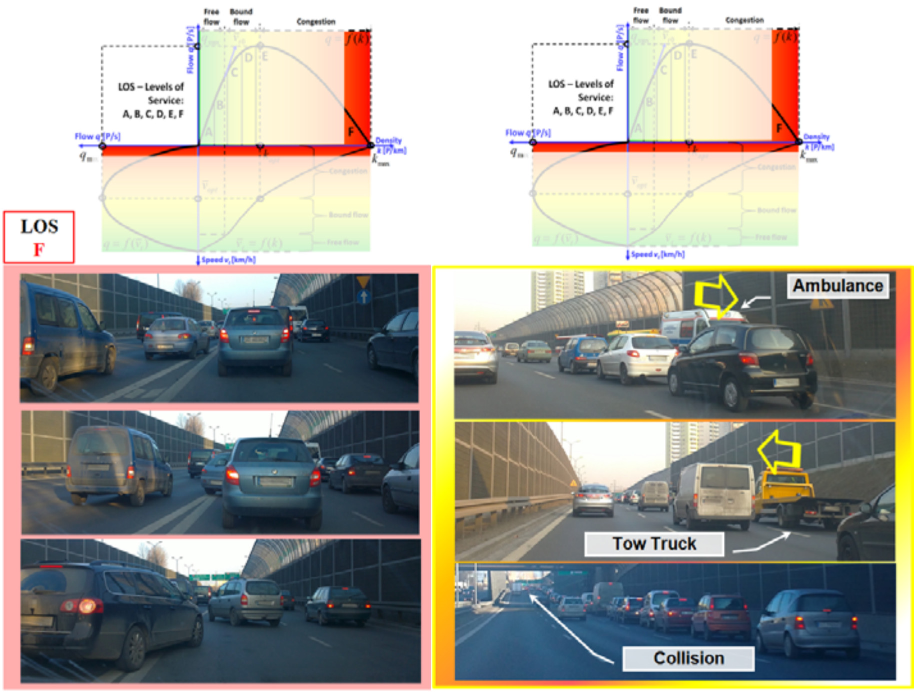

Fig. 8. LOS F and collision: ambulance moving against the traffic to a collision site, just before the weaving section at the tunnel exit and tow truck moving within a stream immediately before a collision spot hidden behind the white van

Such a non-uniform structure of the interweaving streams is in this case caused by the operation of traffic signalling located at different distances from the weaving section. Upstream A is regulated by the traffic signals located at the tunnel entrance, at a considerable distance (over 700 m) from the beginning of the weaving section. In such a case, it is possible that the columns of vehicles formed while waiting for the green light are partially dispersed while passing the tunnel with the speed limited to 70 km/h and in crisis situations even lower – 50 km/h (*VMS – Variable Message Signs* located before tunnel entrance – cf. Fig. 5). Upstream B and upstream C are controlled by the signalling located in the direct vicinity of the weaving section, at the beginning of ramp entrance. This streams cannot disperse (in peak hours) before they reach ramp entrance, especially that they merge at the entry and stay in queue. The range of influence of the disturbances at the weaving section on the traffic in the surrounding area is significant. Forming queues affect the traffic conditions at preceding crossings and streets. Apart from the disturbances caused by the local surpassing of the weaving section capacity, also the interferences to the traffic smoothness appearing at the end of weaving section affect the traffic conditions and cause disturbances. The disturbances have a form of traffic jams at next interchange carrying downstream D and next sections of S86 express way. Systematic analysis of the factors that potentially impact the capacity of freeway three weaving sections along the Queen Elizabeth Expressway (QEW) in Toronto, Canada, which includes the length of the weaving section, the weaving ratio, the percentage of heavy vehicles, and the speed differential between freeway and ramp traffic have been presented in [31].

The solution applied in similar cases abroad are *RMS – Ramp Metering Systems* and *lane manager systems*, both falling into the ITS category. *RMS* utilise the algorithms controlling the signalling at the ramp entrance [5], [21]. The control is dependent on the measurements of upstream and downstream at the weaving section [7], [8]. In the discussed case application of such a system would require taking into account the fact that the weaving section is located directly between two road junctions and that it carries very large interweaving flows. These facts require careful setup of the control algorithms and proper lane control. In addition, ramp metering is not always effective, in particular in the cases when the entry lane section is too short so the incoming vehicles cannot reach the speed of the vehicles on the main road as well as in the cases of high traffic rate in the subordinated flow [21]. Both of these cases take place in the discussed area, therefore other, more comprehensive solutions need to be found. Additionally, due to the density of the agglomeration network, the traffic rates and density as well as due to the bottlenecks resulting from the lack of alternative routes for agglomeration flows, it becomes necessary to introduce solutions from the area traffic management category.

5 Conclusion

The presented and initially diagnosed problem of traffic smoothness breakdown and of jam creation which become permanent in peak hours, from the point of view of probabilistic micro-simulation models is a case of changes of the probabilistic characteristics describing the probability distributions of the vehicle count, headways (or gaps), speed and travel time. The probabilistic description of the traffic phenomena variable in time must therefore include the non-stationary character of the traffic processes. These states are obviously not desirable and hence they should be forecasted and eliminated in advance, initially at the trip plan stage (macro scale) and next during the detailed analyses using the meso- and microscopic scale models.

Unfortunately, despite the correctness of the traffic analyses and forecasts (at the investment project design stage) the causes of the described disturbances and the ones similar to them may be:

- the changes of the spatial distribution (the changes in the traffic distribution in the trip model – cf. Fig. 1) due to the travel and traffic forecasts being too general or too incomplete;
- the changes of the distribution of the flows in the network causes by other changes in the infrastructure and in the transportation network (other investment projects which could have been taken into account not adequately enough in the traffic forecasts) [12], [13],
- changes in the composition of the flows (e.g. increased share of goods vehicles in transit or internal traffic),
- current and temporary changes to the distribution of the flows in the network due to refurbishment and construction works (closed lanes, streets, temporary bypasses and changes to traffic organisation).

Therefore, in cases of highly urbanised and industrialised areas with high density transportation network with congestion (all of these conditions are present not only in Katowice but in the whole of Upper Silesian Agglomeration) it is recommended to perform the analyses of traffic conditions utilising the micro-simulation models, which would cover the whole of the artery and not only the artificially isolated models of the junctions. The flows should be controlled in real time by ITS-type systems (cf. Fig. 9) [15].

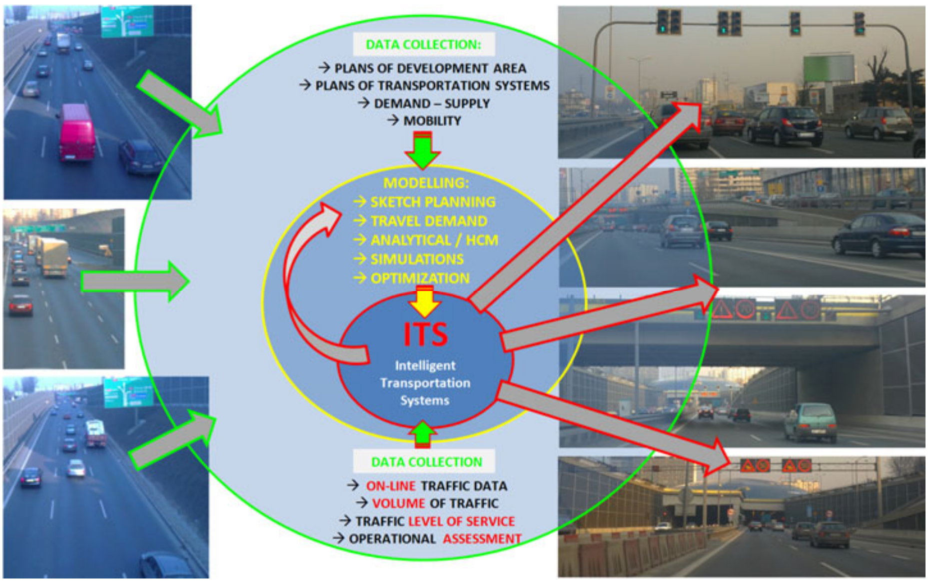

Fig. 9. Transportation Systems Modelling and ITS

These solutions, being the systems from the domains of automatic control, telematics, computer science and data transmission, should take a comprehensive view at the traffic processes in the transportation network and over the adjacent urbanised area. ITS systems should be able to resolve problems both in micro and macro scale (the latter meaning the control and traffic management taking into account the factors generated by the whole agglomeration and its surroundings).

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The Influence of Motorcycling and Cycling on Small One-Lane Roundabouts Capacity

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Abstract. The number of travels by a bicycle as a means of transportation in Poland in recent years, in spite of lack of a complex network of the bicycle tracks, has been systematically increasing. The growth of the number of people using a bicycle as a means of transportation is not accompanied by the growth of a proper infrastructure for cyclists or by any promotion campaigns. There is a lack of appropriate number of separate bicycle paths, bicycle lanes, so bicyclists, motorcyclists and vehicles form mixed traffic flows. The problem of the influence of motorcyclists and cyclists in mixed traffic flows on small one-lane roundabouts capacity has been presented in this article. The results of analysis have shown that motorcyclists and cyclists trajectories on small one-lane roundabouts have strongly influenced other traffic participants' behaviour.

Keywords: roundabouts, mixed traffic flows, cyclists, motorcyclists.

1 Introduction

The number of roundabouts in Poland is on the increase today. One example is the city of Rybnik, where 26 roundabouts were built in 1996-2011, with 5 other being under construction in the area of the city [4], [15]. Building of such a high number of roundabouts in one city was supported by European Union funds. Rybnik is not the only city in the south of Poland which managed to use these opportunities. At the same time in Tychy, 12 roundabouts and four intersections located at the main thoroughfares running through the city were also built. Owning to a plethora of advantages, these objects are successful not only in the cities but also in undeveloped areas.

The roundabout entry capacity is affected by a number of factors which are deterministic and variable in time and space. They mainly include the roundabout geometry, the structure of directions and the type of traffic and the intensity of non-motorised road users who are involved in the traffic in the area of the roundabout. The structure of type is connected with participation of different categories of vehicles in the traffic stream. In order to determine their effect on conditions in the traffic stream, the vehicles were divided into four type groups in consideration of the weights characteristic of each group (calculation coefficients).

According to [19], an equivalent coefficient for a particular type of vehicles expresses the number of passenger cars (termed car equivalent) which affect the conditions of traffic stream similarly to the analysed vehicle.

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There are some studies in the world literature in this domain of science which present the values of equivalent coefficient for individual type groups of vehicles moving on different components of road infrastructure e.g. inter-junction sections [7], [13], crossroads without traffic lights [5], [6], crossroads controlled with traffic light [2], [12] and roundabouts [5], [6], [9], [10], [11], and [14]. Because of the policies of sustainable development in transport, the number of travels by bicycles has significantly risen in recent years. A number of studies focused on the problem of urgent need for building facilities for cyclists, such as separated lanes or paths [16], [17]. However, few studies in Poland have focused on the determination of the values of calculation coefficients for single-track vehicles, e.g. [8], [20].

The paper attempts to determine the effect of single-track vehicles on conditions of traffic in crossroads such as small single-lane roundabouts. The empirical investigations covered only those research plots where no components of road infrastructure were found to facilitate traffic and enhance safety of single-track vehicles, such as bicycle paths or separated bicycle lanes.

2 Methods Used for Assessment of the Value of Equivalent Coefficients for Individual Type Groups of Vehicles

The term 'equivalent coefficient' was first used formally in 1965 in Highway Capacity Manual (HCM 65), when L. Werner took into consideration the effect of trucks and buses on the conditions of traffic on two-way roads and road intersections. Introduction of calculation coefficients allowed for identification of detailed traffic conditions in individual components of road networks. Traffic freedom levels are their interpretation which allow for conventional determination of traffic conditions between free traffic and the traffic at the verge of saturation. Furthermore, conditions of road traffic are typically affected by the following parameters: capacity, speed, traffic density and intensity.

There are several methods of evaluation of the value of equivalent coefficients for individual type groups of vehicle. These methods were discussed in e.g. [1], [3], and [18], [19]. The determination of calculation coefficients is based on statistical methods [1], [19] and on computer simulations [3], [18].

In order to determine the effect of single-track vehicles on conditions of traffic at the intersections such as small single-lane roundabouts the values of equivalent coefficients for two groups of single-track vehicles (bicycles and motorcycles) were assessed. With this aim in view, the following mathematical model was employed [7], [13]:

$$E = \frac{V_c / V_i}{A_c / A_i} \quad [-] \ . \tag{1}$$

Where:

E - value of equivalent coefficient [-],
V_c - mean speed for cars in the traffic stream [m/s],
V_i - mean speed for motorcyclist/bicyclist in the traffic stream [m/s],
A_c - projected rectangular area on the road for cars [m^2],
A_i - projected rectangular area on the road for motorcyclist/bicyclist [m^2].

In order to use the above model for individual types of vehicles (bicycle, motorcycle and different types of passenger cars) mean values of surface area taken by these vehicles were evaluated. A detailed description of methodology of measurements and analyses necessary for the evaluation of calculation coefficients for single-track vehicles were discussed in the study [8].

3 Results of Research

It was found during the first stage of the analysis that the traffic trajectory for single-track vehicles in the area of a roundabout significantly impacts on the way the other road users move. If motorcyclists or bicyclists move at the outside edge of a roundabout lane (in the entry, circular roadway and exit), their presence does not considerably affect the traffic of other types of vehicles. If a single-track vehicle takes the middle part of the lane, it considerably prevents other drivers following this vehicle from performing the manoeuvres of overtaking. During empirical studies carried out in roundabouts situated in Poland, the former case was predominantly observed (i.e. single-track vehicles moved at the outside edge of the lane). This fact caused that the calculation coefficient evaluated based on the author's own study showed relatively insignificant values and that mean speed in a roundabout traffic stream does not significantly fluctuate with changes in participation of single-track vehicles in the traffic. Fig. 1, 2 and 3 present mean values of speed within the traffic stream at a roundabout depending on the proportion of single-track vehicles in the traffic (motorcycles, bicycles and both type groups in total). Participation of single-track vehicles ranging from 0.3 % to 32.0 % was observed in the traffic streams examined in the study.

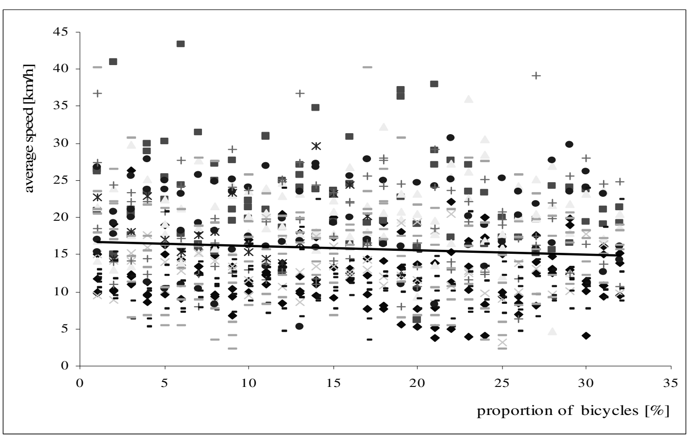

Fig. 1. Average value of speed within the traffic stream in a small one-lane roundabout depending on the proportion of bicycles. Source: own work.

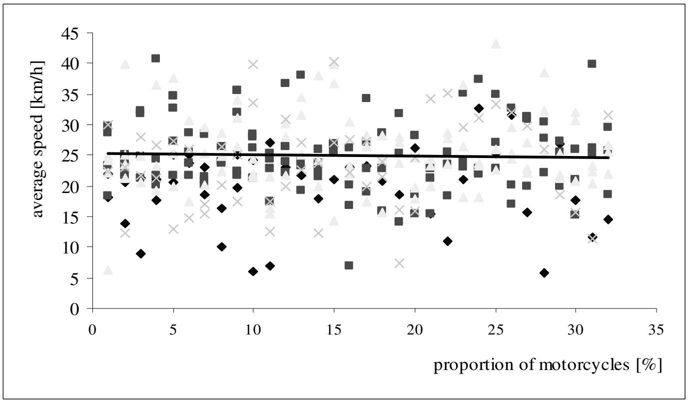

Fig. 2. Average value of speed within the traffic stream in a small one-lane roundabout depending on the proportion of motorcycles. Source: own work.

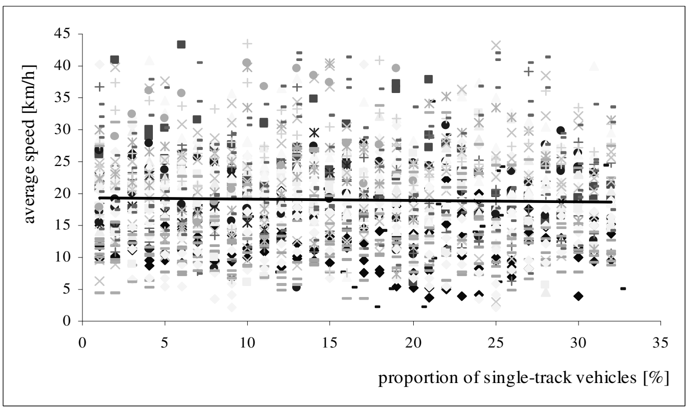

Fig. 3. Average value of speed within the traffic stream in a small one-lane roundabout depending on the proportion of single-track vehicles. Source: own work.

A further stage of the analyses concerned the determination of the value of possible entry capacity at a small single-lane roundabout, evaluated using the value of coefficient obtained from the author's own study (E_{MR} = 0.225 [-]) and used in the current recommendations of Polish Method of Calculation of Roundabout Capacity (Polish: Metoda Obliczania Przepustowości Rond) (E_{MR} = 0.500 [-], [20]). The comparison of the value of possible entry capacity at small single-lane roundabouts reveals that the capacities evaluated by means of the calculation coefficient proposed in the present paper have the values by 2% higher than the values determined by means of the coefficient according to the Method of Calculation of Roundabout Capacity (Fig. 4). An insignificant difference is caused by a lower value of equivalent coefficient presented in this paper compared to the value proposed in the Method of Calculation of Roundabout Capacity.

The lower value of equivalent coefficient obtained as a result of the author's study is closely related with traffic conditions which were observed during the measurements. When single-track vehicle traffic occurred at the right edge of the lane, all other vehicles could move freely on this lane.

It should be noted that the traffic trajectory for single-track vehicles determines the way other road users move on the roundabout and the capacity of individual roundabout components (entry, circular roadway and exit). If the vehicles move at the right edge of the lane, the effect of trajectory of single-track vehicles on possible roundabout entry capacity is insignificant. A strong effect of trajectory of single-track vehicles on the capacity value of individual roundabout components can be expected when the single-track vehicles move in the middle of the lane. However, this situation would not be analysed due to insufficient number of samples collected on each research plot.

Additionally, when single-track vehicles go in the middle of the lane, the risk of collision for single-track vehicles is increased. The awareness of this risk causes that both bicyclists and motorcyclists prefer moving at the right edge of the lane at roundabouts.

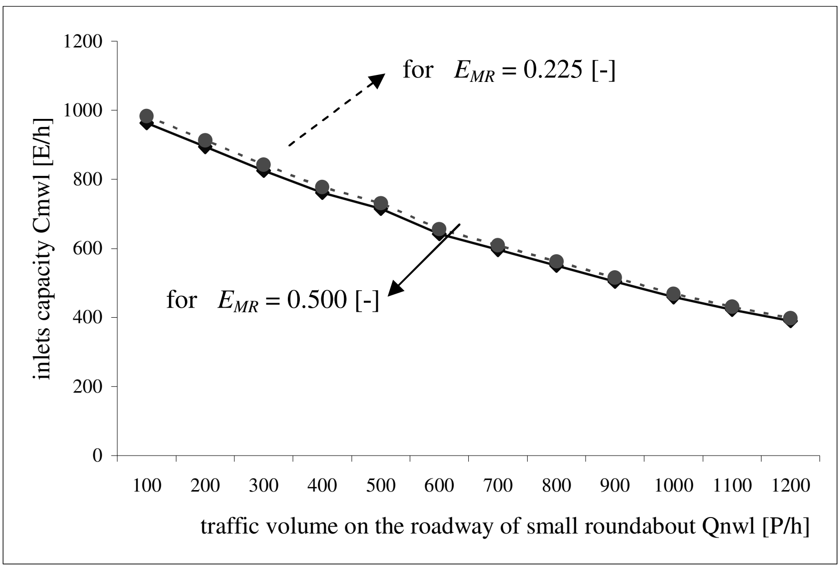

Fig. 4. Small one-lane roundabout entries capacity for passenger car equivalent E_{MR} = 0.225 [-] and for passenger car equivalent E_{MR} = 0.500 [-]. Source: own work.

The final stage of the analysis involved comparison of the value of possible roundabout entry capacity (C_{mwl}) evaluated by means of calculation coefficient presented in this paper and recommended by the current Polish Method of Calculation of Roundabout Capacity [20], with different participation of single-track vehicles in the traffic stream (u_{MR}) (Fig. 5). The comparison of these values reveals that higher participation of single-track vehicles in mixed traffic stream corresponds to higher value of possible roundabout entry capacity. For example, after increasing the percentage share of single-track vehicles in the mixed traffic stream from 8 % to 16 %, a possible roundabout capacity will increase by approx. 5 %. If the percentage share of single-track vehicles is reduced from 8 % to 4 %, the value of possible roundabout entry capacity will be reduced by approx. 3 %.

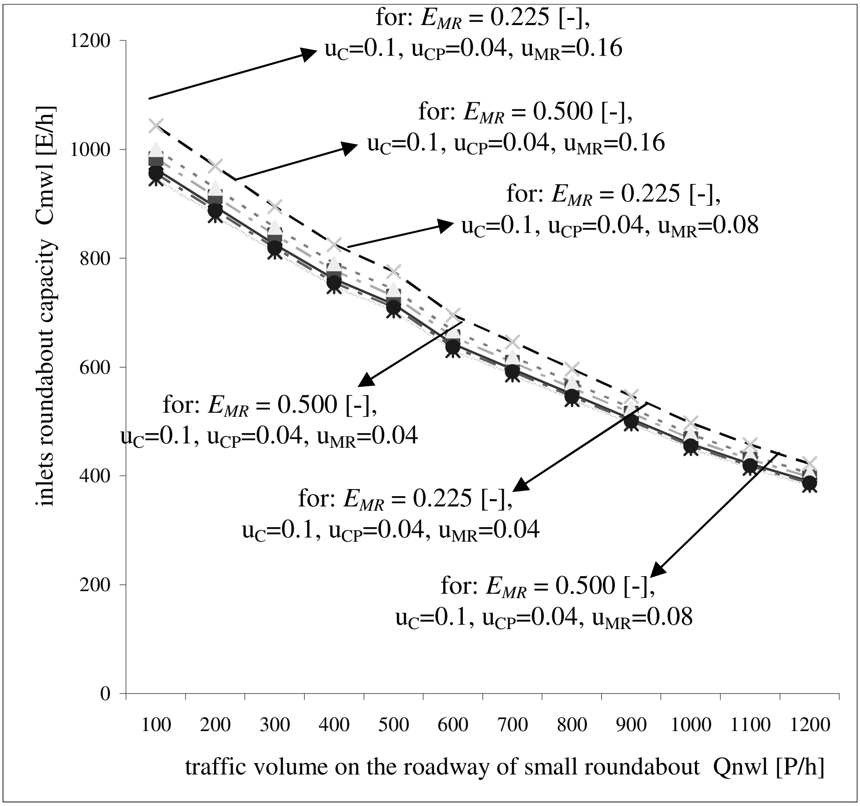

Fig. 5. Small one-lane roundabout entries capacity for passenger car equivalent E_{MR} = 0.225 [-] and for passenger car equivalent E_{MR} = 0.500 [-] with different proportions of single-track vehicles in the traffic stream. Source: own.

4 Conclusions

Cyclists and motorcyclists as well as drivers are the equal users of any transportation system. Because of much smaller number of the cycle travels in Poland than in the countries of Western Europe, one does not find a large variety of solutions relating to the cycle traffic on roundabouts. This situation causes that bicycles, motorbikes and vehicles create mixed traffic flows. From the analysis presented in this article the most important conclusions are drawn:

- the trajectory of single-track vehicles in the area of a small single-lane roundabout considerably affects the behaviour of other road users. This effect is noticeable in the case of speed of other road users, values of calculation coefficient for single-track vehicles and also in the case of possible capacity of a small single-lane roundabout.
- when single-track vehicles move on the outside edge of the traffic lane at the roundabout and do not limit the freedom of manoeuvre for other types of vehicles, the calculation coefficient for single-track vehicles has relatively insignificant values,
- if single-track vehicles move in the middle of the lane, it would be right to expect a considerable increase in the value of calculation coefficient for single-track vehicles. However, this situation would not be analysed due to the insufficient number of samples collected on individual research plots,
- when single-track vehicles move on the outside edge of the lane, the mean speed in the traffic stream at the roundabout does not essentially fluctuate with changes in participation of single-track vehicles (at the participation of single-track vehicles in the traffic stream ranging from 0.3 % to 32.0 %),
- when the proportion of vulnerable road users in the traffic stream increases, possible capacities of roundabouts will also increase.

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Responsibilities of Airport Management in a Crisis Situation - Information Flow

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Abstract. This article focuses on the regulations pertaining to communication between airport services in situations which are regarded as being critical, in Poland. The risk of threat faced by airport staff and passengers using an airport result in the necessity of regulatory tools including laws regarding all aspects of aviation activities and operations, including (and perhaps first and foremost) safety. The present article aims to provide an outline of the problems and issues regarding ensuring safety eg. for passengers as well as allowing readers, who are also passengers, to understand controls put in place at an airport and enforced by airport services, which ostensibly 'impede' travel, are based on existing and binding laws, ensuring passengers safe carriage.

Keywords: Airport, management, crisis, security, information, civil aviation office, anti-crisis center, act of unlawful interference, terrorism, baggage communication, passenger, awareness.

1 Introduction

As an "area on land, water or other surface, in whole or in part designated to perform take offs, landings and surface movement of aircraft, including all buildings within its borders, and equipment and is entered into the register of aerodromes", an airport is particularly susceptible to the threat of extraordinary or critical situations. Large numbers of people of many different nationalities and cultures travelling, one may say, simultaneously, to different parts of the world, generate the need for areas such as airports, to be treated with particular care. It is not without reason therefore, that air travel has been hedged with a plethora of laws and regulations, with aviation laws binding, first and foremost, airport managements to uphold. These regulations may not be immediately obvious to passengers. In order to understand the role of airport management in terms of the functioning of an airport, it is necessary to understand national and international legal acts, from local regulations such as the National Aviation Law through to specific executive provisions such as one of the most fundamental documents in terms of aviation safety – the National Civil Aviation Security Programme (NCASP).

J. Mikulski (Ed.): TST 2011, CCIS 239, pp. 299–305, 2011.

2 Crisis Situation at an Airport

In terms of the subject being addressed, the focus will rest on the role of the airport management or executive in the event of what can be broadly referred to as a crisis situation or incident at an airport.

First and foremost, what exactly is a crisis situation? Legislation has attempted to define the concept. The National Civil Aviation Security Programme in Poland states that a crisis is a security risk or the possibility for the occurrence an act of unlawful interference in civil aviation.

This definition begs the question: What is an act of unlawful interference? The National Civil Aviation Security Programme document states:

An act of unlawful interference in civil aviation is an unlawful and deliberate act involving:

a) The use of violence against a person on board an aircraft during a flight, should this act threaten the safety of this airship,
b) the damage or destruction of an aircraft causing damage preventing a flight to take place or one that may endanger the safety of the airship,
c) the placing an object, device or substance on board an aircraft thus endangering the health or life of passengers or crew, or the destruction of the aircraft or cause damage that could prevent the flight taking place or endanger the safety of the aircraft during flight,
d) the hijacking of an aircraft with or without crew and passengers on board, or the utilisation of the aircraft as a tool for a terrorist attack from the air,
e) the destruction or damage of ground equipment or aircraft, disruption of their activities, where this may cause significant disruption of air traffic or pose a threat to aviation security,
f) the transfer of false information causing danger to people and property in air transportation,
g) the destruction or serious damage to equipment at an airport, causing significant disruption to air traffic or the operation of the airport or a threat to civil aviation safety.

During normal everyday airport activities, we are met with situations which according to existing laws and regulations could qualify as critical situations or incidents on an almost daily basis.

Unfortunately, information that passengers possess, regarding safety and security in civil aviation, or rather a lack of information, is significant in generating these types of crisis situations. Apart from deliberately committed acts of unlawful interference, which unfortunately also take place relatively often, these types of cases are generally caused by the ignorance of the perpetrators.

Returning to the main topic of communication in a crisis situation at an airport, the issue of circumstances in which these crises occur needs to be raised.

Even for ‘experienced’ passengers who frequently travel by air, the process of air travel may create emotional experiences which, as is often observed, adversely affect the process of rational perception and as well as the process of associating facts. Generally, passengers only learn of certain limitations of a given carrier (eg, the maximum luggage weight) or limitations resulting from implemented security controls, upon arrival at the airport. This, in turn, may cause additional stress.

These factors result in passengers focusing on only one aim: “to get on board the aircraft as quickly as possible”.

All too often there is a need to evacuate passenger terminals owing to suitcases, bags or even plastic bags being left unattended. For security staff working at an airport, unattended luggage is synonymous with only one thing: the threat of bombing, resulting in the need to implement special procedures –and therefore, an impeding crisis situation.

It must be emphasised that as with other situations of this type, the safety training of all airport employees does not allow for the presumption that unattended luggage or other objects may be a false alarm. There is always a presumption of real danger.

How is a threat identified and who notifies airport services? Any person employed at the airport must pass security awareness training prior to being granted permission to move around a given airport. This training includes raising an awareness that it is the duty of every single airport employee to play an active role in the often repetitive, but necessary, work related to their own safety, as well as that of eg, passengers.

Therefore, airport security services are not the only ones who are constantly on the look out for security threats but every airport employee is required to immediately notify security personnel in cases of any suspected irregularities.

Depending on the type of hazard, after informing security services is where the role of airport staff-members regarding ‘outside’ persons ends, leaving further action to uniformed services.

In discussing crisis situations, it should be noted that in each case, there is a ‘crisis team’ called. This crisis team operates in accordance with paragraph 105 item 2 of the NCASP and includes:

1) Airport management or a person appointed by the airport executive who is responsible for airport security.
2) Representatives of:
   a) security services,
   b) Customs Service,
   c) Airport air traffic control services,
   d) Fire brigade units as defined by the airport security programme,
   e) Medical and ambulance services as defined by the airport security programme,
   f) The air operator or other entity providing aviation services, as appropriate,
   g) Army units co-using the airport.

A crisis situation is often sudden in nature, so managers convene staff using telephone and radio connections.

Taking into consideration the number of entities participating in the Crisis Team, it is necessary to maintain a disciplined line of communication regarding decisions reached by the team quickly and effectively through to the operational services managing a given crisis situation, particularly since the staff also work with government institutions and air traffic management authorities, thus contributing to the prevention of unlawful acts and their consequences. For this purpose, airport management should develop a plan to combat the crisis situations in civil aviation, in consultation with the Police and Border Guards as well as co-users of the airport. This plan should take into account the conditions and procedures for cooperation and coordination between the various entities in the system of airport security, the manner in which to respond to threats, how to deal with emergencies and to inform about the threat of those responsible for airport security systems.

During a crisis situation, reliable and accurate communication between all levels of crisis management is a very important issue. It should be noted that although here, a crisis situation at an airport is being considered, yet the consequences of such an act of unlawful interference reach to the very top of government bodies.

After receiving information about an act of unlawful interference at an airport or onboard an aircraft, a series of activities is set into action almost automatically; activities which are interrelated and affect each other:

1) The management team immediately notifies the President of the Civil Aviation Office;
2) Airport Management immediately notifies the President of the Civil Aviation Office and the appropriate regional crisis management centre, and calls its crisis team;
3) The President of the Civil Aviation Office notifies the appropriate minister for transport;
4) Security services undertake actions and activities as set out in the airport security programme.

For each of the above authorities, the information provided initiates necessary procedures for a given situation. So, the Regional Crisis Management Centre sends to, what's referred to as a 'concentrated area', medical services in the form of ambulances, the fire brigade and rescue and fire-fighting services. Police and Border Guards call for additional back-up to cope with additional security.

The obligation of immediate notification also applies to the air carrier, where the commander of the aircraft in case of an emergency or act of unlawful interference is obligated to provide all available means of communication regarding the threat or crisis situation to the air traffic management authority, with which it is in contact at a given point in time.

This in turn causes further action to be undertaken by the management body, which includes:

1) having informed the President of the Civil Aviation Office, communicating information to the airport executive to which the aircraft is making its way;
2) communicating information to the appropriate government offices and national administrations of the airspace through which the flight is or will be passing through;
3) communicating information to air-defense services;
4) undertaking actions aiming to ensure the secure and safe conclusion of the flight.

If, however, that management authority has received information about an act of unlawful interference, also manages the airport to which the threatened aircraft is being guided, this information shall pass directly to airport management and executive.

In turn, in the case of a crisis situation, the Civil Aviation Office immediately informs the following institutions:

1) the appropriate government institution where the aircraft is registered;
2) the appropriate government institution of the air carrier;
3) the appropriate government institution of the countries whose citizens were harmed or injured or detained as a result of the event;
4) the appropriate government institution whose citizens are on-board the aircraft;
5) the International Civil Aviation Organization (ICAO).

And finally, after the crisis incident is over, the airline and airport management provide information about the crisis to the President of the Civil Aviation Office, including a full description of events and actions undertaken and complete all the necessary paperwork, within 15 days of the incident's occurrence. The President of the Civil Aviation Office, in turn, communicates the following by mail to ICAO in one of the official languages of the organisation:

1) Introductory report - no later than 30 days from the date of the act of unlawful interference;
2) Final report – no later than 60 days from the date of the act of unlawful interference.

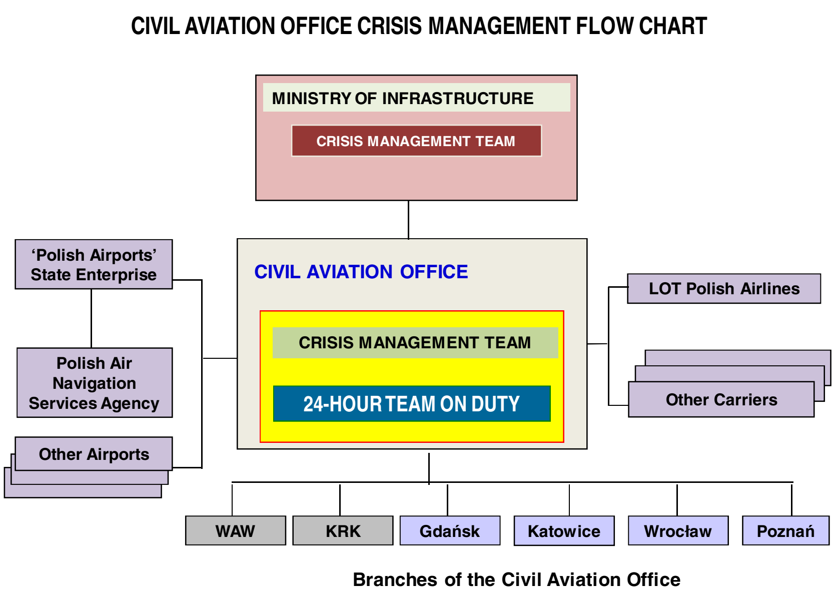

Fig. 1. Civil Aviation Office crisis management flow chart [1]

It is impossible to describe the principles of information flow between departments during an emergency or crisis situation without including one more extremely important aspect of communication – between the airport executive and the media.

Paragraph 117 of the NCASP states that airport management or authorised staff-members shall provide information about the act of unlawful interference to the media.

Owing to the delicate circumstances of an ongoing act of unlawful interference, and the actions implemented at the time, it is very important that the information is conveyed by a competent individual.

Experience has shown that a crisis involves not only the passengers and staff at an airport, but also the victims' families interested in the fate of their loved ones and expecting information about their relatives and in the media (TV, radio, press). The media, in turn, struggles to compete with each other in providing the latest news from the crisis event to its audiences.

Information provided by the person heading the crisis team must be carefully prepared, accurate and reliable in order to satisfy people's curiosity and interest, while at the same time avoiding the introduction of additional confusion through unauthorised information or disclosing information that is reserved for government services until circumstances regarding the incident are clarified.

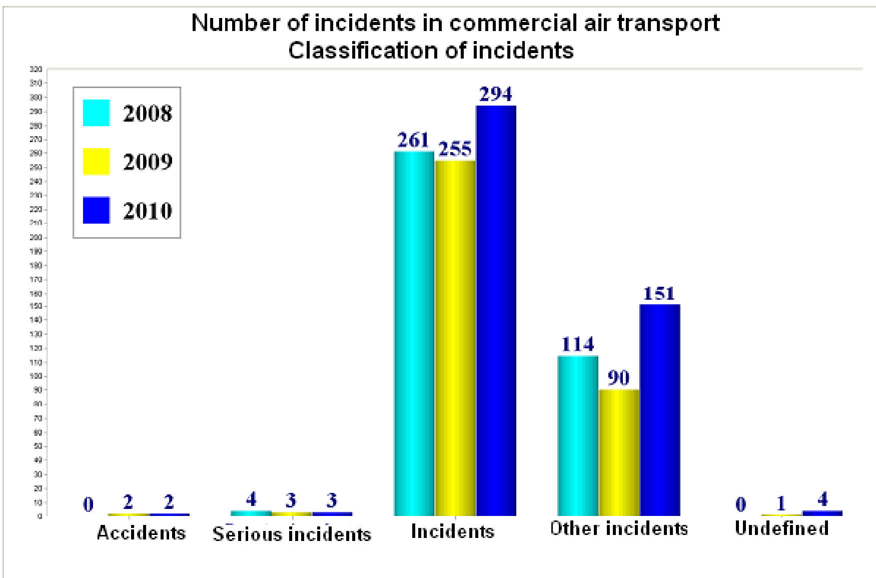

Fig. 2. Number of registered aviation incidents in Poland 2008-2010

To conclude, it should be emphasised that crisis events, affecting the safety of people at either the airport or on board an aircraft, can be generate not only by people through their intentional or unintentional actions, but also forces of nature, which as a result of atmospheric conditions (eg rain, hail or blizzards), wildlife (eg. birds) may result in tragic consequences. Overall, the frequency of events such as these, as shown by statistics in Fig. 2 and Fig. 3, continues to rise from year to year.

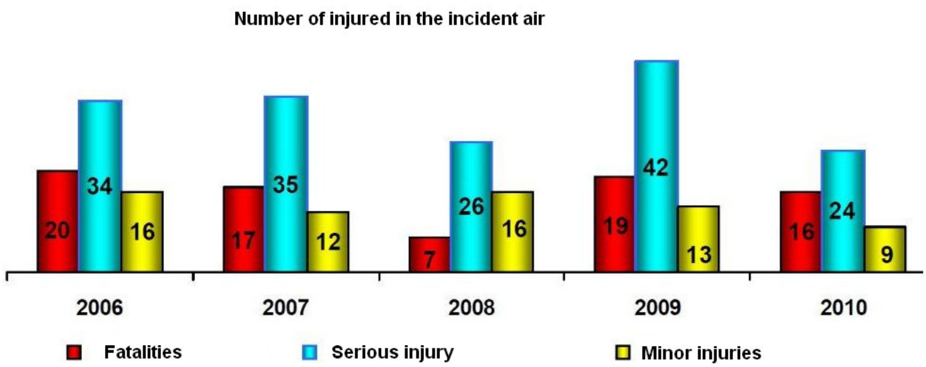

Fig. 3. Number of people injured in aviation incidents in Poland (2006-2010) [3]

3 Conclusion

It is clear that the main objective of a properly organized system of communication is to prepare all necessary departments to act in a crisis situation in order to efficiently and effectively limit the scope and impact of a crisis by isolating its location.

A properly and correctly devised crisis action plan allows to avoid the frequent panic that accompanies such incidents, both in the operations of services and from outsiders involved in the crisis situation.

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Personalised Passenger Notification in the Case of Incidents

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Abstract. Due to incidents or delays in public transportation, passengers are usually prevented to reach the destination of their planned journeys on time. In particular, unplanned incidents with a major extent, e.g. accidents and breakdowns, can lead to major delays. Although such events rarely occur, the implications for the passengers may be serious. The paper presents an information service that individually informs the passengers if they will not timely reach the destinations of their planned journeys due to an incident or delay. In addition, the service tries to individually re-plan the journey of each affected passenger, so that he reaches his destination on time.

Keywords: public transport, personalised, passenger information service, journey re-planning.

1 Introduction

To inform passengers about the offered runs has always been a part of public transportation. Timetable notices, timetable books and information provided by the staff has been main information sources for passengers for a long time. The advances in information and communication technologies and their wide use in the population have now opened new possibilities for passenger information. According to [1], the journey planning over the Internet is currently the most common source of information with 56.1% followed by the classic timetable notice with 51.8%.

Incidents and cancellation of runs repeatedly occur in public transportation. The problems at the Deutsche Bahn AG over the Christmas holidays in Germany in 2010 with numerous cancellations and huge delays due to the continuous snowfall [2] are a prominent example. The passengers would have a more sympathetic response to the problems at least if the information about the extent of an incident and in particular on alternative travel options would have been sufficient.

1.1 Existing Forms of Passenger Information

Notices, displays and announcements are classic forms of passenger information at stations and in vehicles. Very popular is the journey planning via the Internet. Together with auxiliary systems like the HAFAS Information Manager (HIM) [3]

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existing incident information is additionally displayed to a found journey. So-called "departure monitors" display the next actual departure times of runs at stations and on the Internet. With cell phones, passengers can get journey planning information and departure monitor information by SMS. The same features provide applications for Internet-enabled mobile phones with much more comfort.

Subscription services (or push services), which monitor the planned journeys and notify passengers automatically and individually in the case of a problem, are not yet often used. However, the currently existing services often have deficits. The subscription service SMS Alert of the Swiss Federal Railways [4] regards only delays and track changes. Alternative travel options are not provided. The service pVID [5] helps in the case of delays. The service PIEPSER [6] takes into account spatial incidents and cancellations. Both services pVID and PIEPSER individually provides alternative travel options. However, they must previously be specified by the passenger himself. During the research project "BAIM plus", a subscription service has been developed which includes delays and elevator malfunctions [7]. SMS Alert is the only service of its kind in practice within German-speaking countries.

1.2 Desired Improvement and Approach

This paper would like to eliminate the above-described shortcomings in existing subscription services. A subscription service will be designed which includes delays, spatial incidents and cancellations. An automatic journey re-planning should be carried out so that a passenger reaches its destination on time. The input values are the timetable, the incidents and the planned journeys of the passengers. The output values are the messages to the passengers with the re-planned journeys. The approach is firstly to model these parameters and their relationships to each other. The starting point here is a method of journey planning. On that basis, the recognition of a disrupted journey and its recalculation will be build up.

2 Fundamentals of Journey Planning

The principle of journey planning is to model the timetable data as a graph in order to apply a slightly modified shortest path algorithm. Details can be found in [8]. In this section only the relevant contents are briefly described. A system that is based on is, for example, HAFAS [9].

2.1 Time Dependent Model

The data of a timetable comprises stations, runs with departure and arrival times at the stations and operation dates of the runs. Formally, it is given a set of runs R, a set of stations S, and a set of elementary connections C. The elements c of set C are 5-tuples of the form $c = (r, s_1, s_2, t_d, t_a)$. Such a tuple means, that run r leaves station s_1 at time

t_d and arrives without stopover at station s_2 at time t_a. The departure and arrival times are integers in the interval [0, 1439] representing the time of the day in minutes.

Two models for representing the timetable data in a graph are presented there: the time expanded model and the time dependent model. Here we are working only with the time dependent model. Therefore, the time expanded model is not elaborated. In the time dependent model all stations are modelled as nodes. If there is at least one elementary connection between two stations, a directed edge will be created between the corresponding nodes. An edge has a field of all elementary connections with the same departure and arrival station.

2.2 Modification of Dijkstra's Shortest Path Algorithm

A well known shortest path algorithm is from Dijkstra [10]. In order to apply this algorithm to the graph of the time dependent model, the time has to be considered instead of the distance. When considering a station at a certain time, all elementary connections of the connecting edges have to be sorted regarding this time. The elementary connection at the first position after sorting is chosen to get to the next station. Two problems are solved this way:

- *Problem 1:* Find the shortest time journey from a station s_1 to a station s_2 with the earliest departure from s_1 after a certain time t.
- *Problem 2:* Find the shortest time journey from a station s_1 to a station s_2 with the latest arrival at s_2 before a certain time t.

When solving problem 1 the search starts at s_1. When solving problem 2 the search starts at s_2.

3 Recognition of a Disrupted Journey

Journeys and incidents inevitable have a close relation to the timetable. In order to make this relationship clearer, the graph is transformed to an object-oriented model. Then the models of journeys and incidents will be added to this model.

3.1 Object-Oriented Timetable Model

According to the time dependent model from section 2.1, the classes `Timetable`, `Station`, `Edge`, `Elementary Connection` and `Run` has been created (see Fig. 1). The relations between the classes also correspond to the explanations of section 2.1. The class `Edge` contains an attribute `walking time`. If this attribute is set, the edge represents a planned footpath transition between the two referencing stations. Such `Edge` objects usually have no elementary connections. An according elementary connection has to be created dynamically while calculating the journey.

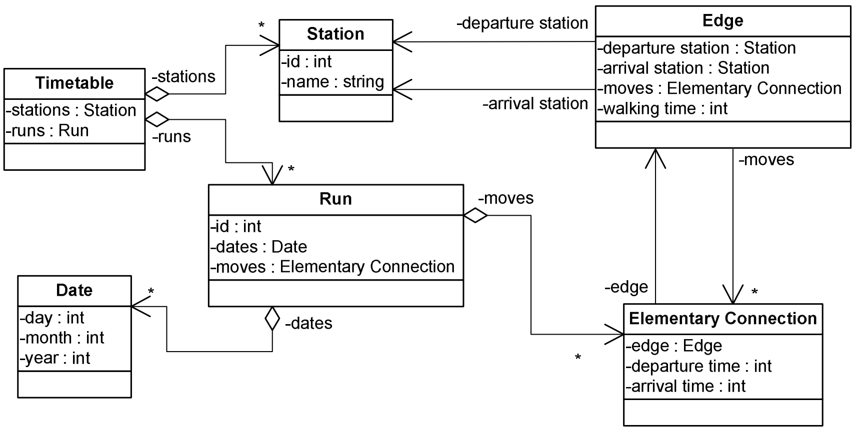

Fig. 1. Time dependent model transformed to an object-oriented model

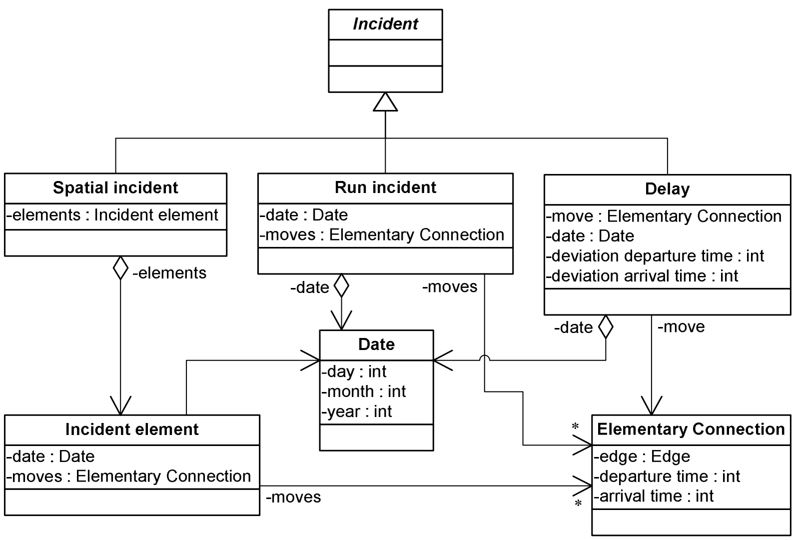

Fig. 2. Types of incidents

3.2 Incidents

By analysing historical incidents three types of incidents have been identified, which are depicted in Fig. 2:

- *Spatial incidents* are related to a section of the public transportation network for a certain period while no vehicle can pass. Construction works and accidents are mostly seen for instance. In principle, the corresponding elementary connections cannot take place. The set of affected elementary connections may vary between different dates within the period of the spatial incident.

- *Run incidents* may occur due to a breakdown of a public transport vehicle. So, a certain run and its corresponding elementary connections are unavailable.
- *Delays* are deviations from the timetable with respect to the departure and arrival times of elementary connections.

3.3 Journey

A journey of a passenger is considered as a chain of stages firstly with the way from a start location to the start station, then with the public transport to the destination station and finally to the destination location.

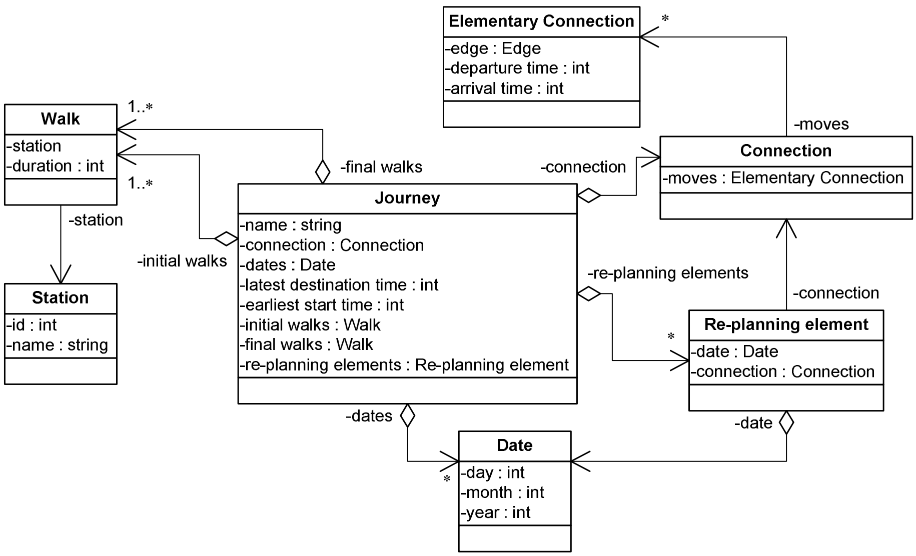

Fig. 3. Model of a journey

A journey is represented by the homonymous class (see Fig. 3). Due to the fact that a journey includes more than the list of elementary connection, the term 'journey' has to be clarified. Hence, the term (and class) 'connection' should be additionally introduced. A connection represents the list of elementary connections and so describes the route from the start station to the destination station within the public transport. The connection itself and all other belonging aspects are subsumed under the class `Journey`. In any case, a journey maintains a list of the travel dates. (Please note that the other classes and attributes in Fig. 3 will be explained later.).

A passenger's journey may be really disrupted or delayed only. We define a journey as disrupted if the passenger is not able to reach the destination location before a desired time. So, if the journey is affected by a spatial incident or a run incident, the journey is disrupted in any case. In contrast, a delay may lead to a disrupted journey but it does not necessarily. A delay causes a disrupted journey when any change of the journey will be missed or when the arrival time at the destination location is later than the desired arrival time there. The desired time is represented by the attribute `latest destination time` of the class `Journey`.

4 Journey Re-planning

Journey re-planning not only means to perform the recalculation of the connection when an incident occurs which affects a passenger's journey. In particular the state transitions of an incident and the simultaneously occurrence of several incidents have to be regarded.

4.1 Required Passenger Data

Besides the travel dates and the latest arrival time at the destination location, there are further passenger data needed in order to perform the recalculation of the connection:

- *Earliest start time from the start location.* When a passenger is constrained not to leave the start location before a certain time (e. g. end of shift), he may define this time which is a stronger criteria than the arrival time at the destination location.
- *Stations to embark and to disembark the public transport.* There are more possibilities for an alternative connection if several stations are suitable for a passenger to get on and off the public transport. Unfortunately, door-to-door journey planning currently is only partly suitable for pedestrians due to the fact that common used maps are mostly limited to streets usable by motorised vehicles. Therefore, we propose to let the passenger specify the further suitable stations as well as the particular walking times (see class `Walk` and attributes `initial walks` and `final walks` of class `Journey` in Fig. 3).

4.2 Performing Connection Recalculation

When recalculating the connection of a journey, all elementary connections that are unavailable due to incidents must not be considered. Time deviations caused by delays have to be taken into account instead of the planned departure and arrival times of elementary connections. For each combination of a station to embark the public transport to a station to disembark the public transport a connection will be calculated. The best of them will be sent to the passenger.

4.3 Real-Time Conditions

Suppose the occurrence of an incident at a certain time t_1 and an existing replacement connection which requires the start time t_2. The replacement connection has to be calculated and sent to the corresponding passenger until t_2. How to guarantee meeting the deadline we have not yet investigated. At least as a first thought, it seems to make sense to keep the time for journey re-planning as short as possible. A simple method which re-plans the journey every time an incident occurs and simply sends the current best connection to the passenger, for example, may take too much time. Considering the complexities of the tasks for recognising an disrupted journey with *O(1)* and for recalculating a connection with *O(n log n)* with *n* as the number of stations [11] it is clear that the number of performing connection recalculation must be minimised.

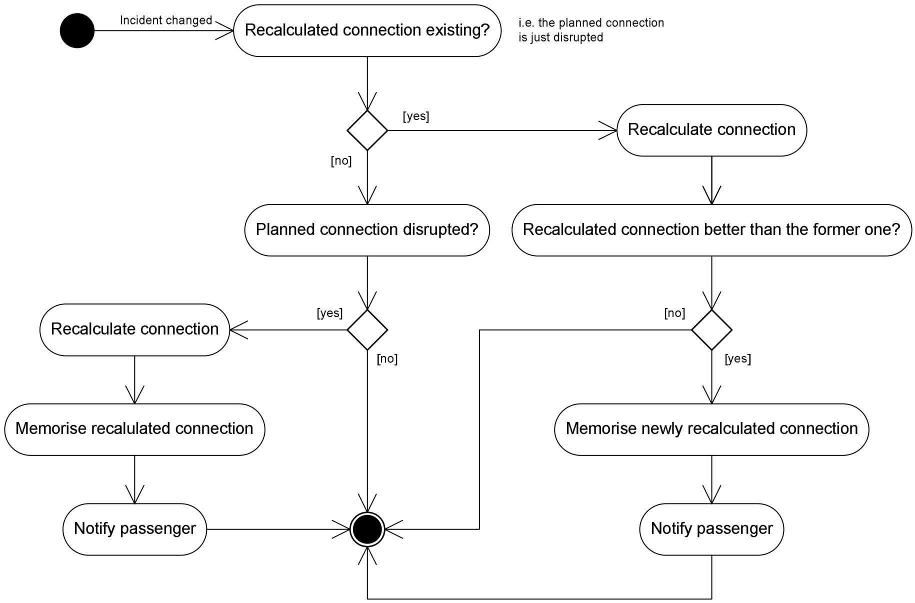

Fig. 4. Activities when an incident changes

4.4 The Occurrence of an Incident

If a journey is affected by an incident, the connection has to be recalculated. It may happen that a further incident occurs which now affects the recalculated connection. In this case, the connection has to be recalculated again. In order to recognise a disrupted recalculated journey, it has to be memorised. It is sufficient to memorise only the last recalculated connection, because former recalculated connections become obsolete with newer recalculations. The model has been accordingly extended by the class `Re-planning element` (see Fig. 3).

4.5 The Changing of an Incident

The extent of a spatial incident in particular may vary over the time. This is because the extent of an incident can not always be accurately estimated by the staff from the outset. When an incident is changed, the set of unavailable elementary connections can changes too with the effect that connections of passengers are now disrupted or better connections than the current one are available. To solve this problem recalculating the connection and comparing it with the perhaps former recalculated connection is needed. Fig. 4 shows the necessary activities.

5 Conclusion

The described information service for automatic journey re-planning and passenger notification in the case of incidents has been implemented for the public transport company of Magdeburg, Germany, which has a population of about 230.000 people. If there is no connection available which enables the timely arrival of the destination location, at least the next possible connection is calculated and submitted to the passenger. For acquiring delays, the Intermodal Transport Control System (ITCS) of the public transport company is used on the one hand. On the other hand spatial incidents and run incidents are entered by the staff through a graphical user interface.

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Reliability Analysis of Power Supply Systems for Devices Used in Transport Telematic Systems

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Abstract. The paper presents questions connected with the transport telematic systems. One of the most important attributes of telematic systems is the data transfer and transmission. The transmitters and receivers applied require reliable power feeding sources. Therefore, buffer power supply units are used that cooperate with backup power sources, such as rechargeable electrical power sources (batteries).

Keywords: reliability, power supply, process of exploitation.

1 Introduction

One of the most important attributes of telematic systems is the data transfer and transmission, namely its flow. The telematic data flow is related directly to telecommunications, or a remote transmission of messages via various types of signals – nowadays mostly electrical or optical signals. Both wired and wireless media (e.g. GSM, radio lines) are used for transmission. The transmitters and receivers applied require reliable power feeding sources. Therefore, buffer power supply units are used that cooperate with backup power sources, such as rechargeable electrical power sources (batteries). The paper presents a reliability analysis of such type of devices.

2 Power Supply Systems for Devices Used in Transport Telematic Systems

Buffer power supply units are the power supply systems that are commonly used in transport telematic systems. They are supplied with a primary voltage (~ 230V AC) and co-operate with lead-acid, dry battery. It provides a backup power supply (-12 V DC). Then, the power supply unit controls the process of battery charging and maintenance automatically. It should also automatically perform a dynamic test of the battery and provide protection against excessive discharge. This has been illustrated on the diagram in Fig. 1. In addition, they are very often equipped with optical and (or) acoustic signalling that informs about its operating status. It may also be provided to technical outputs to remotely control the operation of a power supply system.

J. Mikulski (Ed.): TST 2011, CCIS 239, pp. 314–319, 2011.

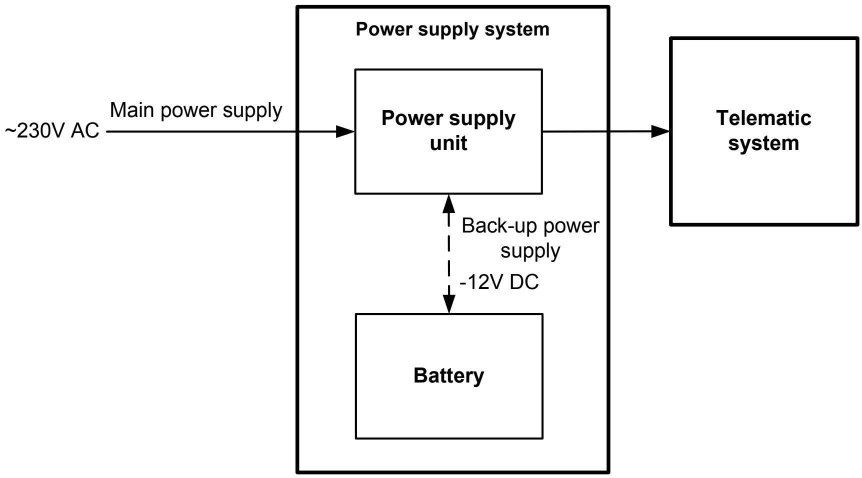

Fig. 1. Power feeding diagram using a buffer power supply unit

The power supply units hereto presented interact with many other systems and external environment, and they may contain a lot of component subsystems [5], [6]. The information about their technical condition is very often transferred to the transportation management centre. For this reason, a significant role in those systems is played by power supply systems. Fig. 2 illustrates an example of a telematic system. Regardless of whether this is the transportation management centre or a supervised by it local telematic system, they have the main power supply of 230 [V] AC and the backup power supply, namely: a rechargeable source of energy in the form of battery (usually 12 [V] DC). The values that characterize the reliability-operational indices should be appropriate [3,4]. Therefore, the issue of reliability analysis of power supply systems for devices that are used in transport telematic systems as well as the determination of selected reliability-operational indices grows so much in its importance [1] ,[2], and [7].

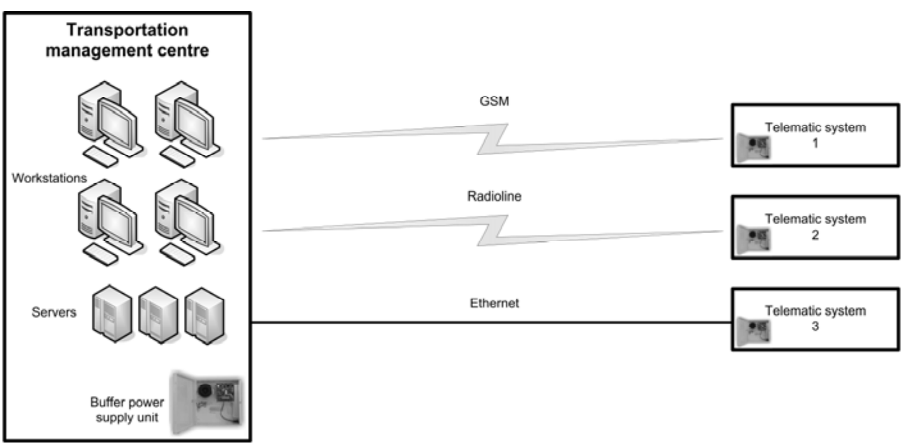

Fig. 2. Example of telematic system diagram

3 Reliability Analysis of Power Supply Systems for Devices Applied in Transport Telematic Systems

By analysing the power supply systems for devices used in transport telematic systems, the relationships that occur in a given system in terms of its safety can be illustrated (Fig. 3).

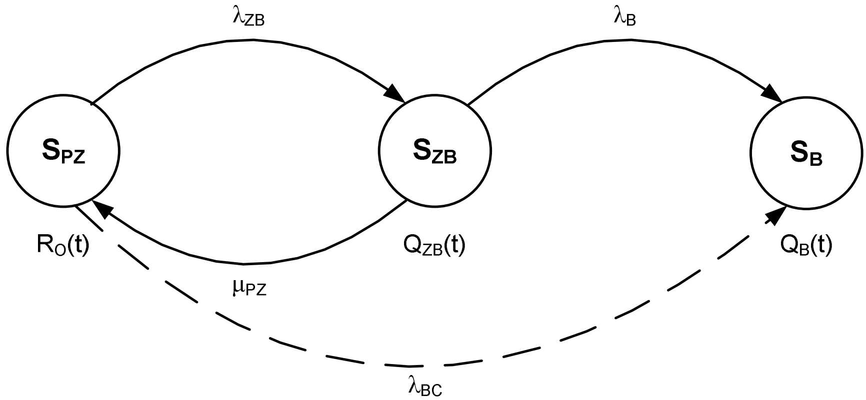

Fig. 3. Relationships in the system

Denotations in the figure:

$R_O(t)$ – the probability function for a device to stay in the state of full fitness,

$Q_{ZB}(t)$ – the probability function for a device to stay in the state of endangered safety,

$Q_B(t)$ – the probability function for a device to stay in the state of safety failure,

λ_{ZB} – the intensity of transitions from the state of full fitness to the state of endangered safety,

μ_{PZ} – the intensity of transitions from the state of endangered safety to the state of full fitness,

λ_B – the intensity of transitions from the state of endangered safety to the state of safety failure,

λ_{BC} – the intensity of transitions from the state of full fitness to the state of safety failure.

The system presented in Fig. 3 can be described by the following Kolmogorov-Chapman's equations (in further considerations, it has been assumed that the intensity of transitions from the state of the full fitness to the state of security failures $\lambda_{BC} = 0$. It is dictated by the fact that during the normal process of those devices operation such transition does not occur. Such situation is currently being only considered and theoretically analysed by the authors of this paper):

$$\begin{aligned} R_0'(t) &= -\lambda_{ZB} \cdot R_0(t) + \mu_{PZ} \cdot Q_{ZB}(t) \\ Q_{ZB}'(t) &= \lambda_{ZB} \cdot R_0(t) - \mu_{PZ} \cdot Q_{ZB}(t) - \lambda_B \cdot Q_{ZB}(t) \\ Q_B'(t) &= \lambda_B \cdot Q_{ZB}(t) \end{aligned} \tag{1}$$

Assuming the initial conditions:

$$\begin{aligned} R_0(0) &= 1 \\ Q_{ZB}(0) &= Q_B(0) = 0 \end{aligned} \tag{2}$$

The following linear set of equations is received using the Laplace Transform:

$$\begin{aligned} s \cdot R_0^*(s) - 1 &= -\lambda_{ZB} \cdot R_0^*(s) + \mu_{PZ} \cdot Q_{ZB}^*(s) \\ s \cdot Q_{ZB}^*(s) &= \lambda_{ZB} \cdot R_0^*(s) - \mu_{PZ} \cdot Q_{ZB}^*(s) - \lambda_B \cdot Q_{ZB}^*(s) \\ s \cdot Q_B^*(s) &= \lambda_B \cdot Q_{ZB}^*(s) \end{aligned} \tag{3}$$

Using the inverse transforms, we obtain:

$$R_0(t) = \begin{bmatrix} \cos\left(\sqrt{2 \cdot \lambda_{ZB} \cdot (\mu_{PZ} + \lambda_B) - 4 \cdot \mu_{PZ} \cdot \lambda_{ZB} - \lambda_{ZB}^2 - (\mu_{PZ} + \lambda_B)^2} \cdot \frac{t}{2}\right) + \\ + \frac{\mu_{PZ} + \lambda_B - \lambda_{ZB}}{\sqrt{2 \cdot \lambda_{ZB} \cdot (\mu_{PZ} + \lambda_B) - 4 \cdot \mu_{PZ} \cdot \lambda_{ZB} - \lambda_{ZB}^2 - (\mu_{PZ} + \lambda_B)^2}} \cdot \\ \cdot \sin\left(\sqrt{2 \cdot \lambda_{ZB} \cdot (\mu_{PZ} + \lambda_B) - 4 \cdot \mu_{PZ} \cdot \lambda_{ZB} - \lambda_{ZB}^2 - (\mu_{PZ} + \lambda_B)^2} \cdot \frac{t}{2}\right) \end{bmatrix} \cdot \\ \cdot \exp\left[-\left(\frac{\lambda_{ZB} + \mu_{PZ} + \lambda_B}{2}\right) \cdot t\right] \tag{4}$$

$$\begin{aligned} Q_{ZB}(t) = {} & \frac{2 \cdot \lambda_{ZB}}{\sqrt{2 \cdot \lambda_{ZB} \cdot \lambda_B - 2 \cdot \mu_{PZ} \cdot \lambda_{ZB} - \lambda_{ZB}^2 - (\mu_{PZ} + \lambda_B)^2}} \cdot \\ & \cdot \sin\left(\sqrt{2 \cdot \lambda_{ZB} \cdot \lambda_B - 2 \cdot \mu_{PZ} \cdot \lambda_{ZB} - \lambda_{ZB}^2 - (\mu_{PZ} + \lambda_B)^2} \cdot \frac{t}{2}\right) \cdot \\ & \cdot \exp\left[-\left(\frac{\lambda_{ZB} + \mu_{PZ} + \lambda_B}{2}\right) \cdot t\right] \end{aligned} \tag{5}$$

$$Q_B(t) = 1 - \left[\begin{array}{l} \cos\left(\sqrt{2 \cdot \lambda_{ZB} \cdot (\mu_{PZ} + \lambda_B) - 4 \cdot \mu_{PZ} \cdot \lambda_{ZB} - \lambda_{ZB}^2 - (\mu_{PZ} + \lambda_B)^2} \cdot \frac{t}{2} \right) + \\ + \frac{\mu_{PZ} + \lambda_B + \lambda_{ZB}}{\sqrt{2 \cdot \lambda_{ZB} \cdot (\mu_{PZ} + \lambda_B) - 4 \cdot \mu_{PZ} \cdot \lambda_{ZB} - \lambda_{ZB}^2 - (\mu_{PZ} + \lambda_B)^2}} \cdot \\ \cdot \sin\left(\sqrt{2 \cdot \lambda_{ZB} \cdot (\mu_{PZ} + \lambda_B) - 4 \cdot \mu_{PZ} \cdot \lambda_{ZB} - \lambda_{ZB}^2 - (\mu_{PZ} + \lambda_B)^2} \cdot \frac{t}{2} \right) \end{array} \right] \cdot \cdot \exp\left[-\left(\frac{\lambda_{ZB} + \mu_{PZ} + \lambda_B}{2} \right) \cdot t \right] \quad (6)$$

The relations obtained allow determining the probabilities for a buffer power supply unit to stay in the states of full fitness R_O, endangered safety Q_{ZB}, and safety failure Q_B.

The relations presented allow developing the reliability of power supply systems for devices already at their designing stage. This is possible inter alia by matching elements with suitable values of their reliability indices. At the same time, they allow to optimise the performance process of those devices through maximising the probability values of staying in the state of full fitness.

4 Conclusion

Telematic systems are nowadays a very large group that affects the safety of travelling. They include the management center that cooperates with local telematic systems. In order to ensure the data flow, it is essential to use different types of transmission media without which the data transmission would be impossible. The transmission media are used both to ensure fast and reliable communication with wide area systems, which require massive amounts of data transmission over long distances, and to transmit simple control messages or a simple measurement data from sensors over short distances. However, it is necessary for all of them to apply power supply systems with respective values of reliability indices. This can be ensured by using power supply systems with rechargeable sources of energy in the form of a battery.

The reliability and operational analysis of buffer power supply units, presented in this paper, has enabled to determine the relations allowing calculating the values of probabilities for the hereto discussed devices to stay in the states of: full fitness, endangered safety and safety failure.

The application of the hereto presented methodology of the reliability and operational analysis allows for increasing the values of reliability indices of the telematic systems being designed. This is possible through analyses and simulations, allowing matching power supply systems, having specific reliability and operational indicators, with the design requirements.

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LPV Flight Trials in Poland

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Abstract. The general idea of this project is to popularize the usage of EGNOS (European Geostationary Navigation Overlay Scientific). Research centers should prepare technical solutions for system installations on airports and on boards of aircraft, in frames certificate of projects and procedures. Under this notion one should understand two types of the certification: technical and operation procedures in flight (procedures of tricking both landing for aircraft and airports). Peculiarly they are being taken into consideration: safety while carrying out flights and Safety Case (analyses of the safety). Appropriately the prepared specialist, based on the specially prepared technical documentation, is making the essential installation equipping the EGNOS system, both on the board of the aircraft and on the airport, and next performs certification flights. To underline he belongs, that this appropriately prepared specialist should also supervise and conduct the practical training for the aircraft crew and ground, of which acquainting with functioning the EGNOS system and his implementation are a purpose while making of flights both procedures of the approach and landing.

Keywords: NPA, GNSS, navigation, EGNOS.

1 Introduction

It appears from European standard documents that the EGNOS system will be universally used both for civil as well as military needs. To mark belongs, that with coordinator of projects associated with techniques and satellite technologies, on our continent, there is a European Agency of – ESA outer space (European Space Agency) which is counting 18 membership, working states together above cosmic issues. Together not possible projects are being taken up for the individual accomplishment by the state. These projects are generating the new scientific knowledge and new practical applications in the exploration cosmic and are contributing to the energetic development of the European aeronautical industry. ESA has it points in a few European states. However a European Centre of Space Examinations and the – ESTEC Technology is deserving the special attention (European Space Research and Technology Centre), being in Noordwijk. There are this most important place and a technical ESA centre, also determined as the incubator of space European effort. ESTEC is an organizer, being held every two years, of workshops, during which outcomes of action are being presented in GNSS (Fig. 1).

J. Mikulski (Ed.): TST 2011, CCIS 239, pp. 320–329, 2011.

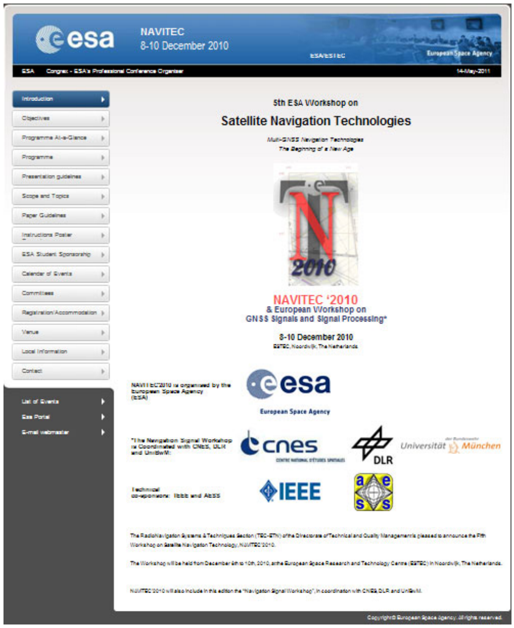

Fig. 1. ESA 2010 workshops

2 LPV Flight Trials in Poland

It is known, that supervision of the implementation of techniques and satellite technologies in aviation, are exercising in the EUROCONTROL EU and GSA. However an Office of the Civil Aviation but Poland are responsible for a certification the Polish Air Navigation Agency (PANSA) is supposed to provide with the operational work of systems and the navigational assistance.

The implementation and the certification of the EGNOS/GNSS system require significant powers and centers, so these issues are being taken in European Frame Programs, by international consortiums specially established at this target.

Realization of own plans, active participation on the international forum in teams task, dealing with the GNSS application for the purposes of aviation and the necessity of their implementation in Poland, they caused, that PANSA had been invited to the international consortium, carrying projects: “HEDGE” and “EGNOS Introduction it the European Eastern Region Mielec”. As part of these projects, was realized subject “General Aviation EGNOS APV Development and Demonstration in Poland”. Air tests concerning the final approach were the most important element according to EGNOS/GNSS system.

The process of the certification of the new system in aviation is long-drawn-out. Therefore, in order to shorten the time of the GNSS implementation, at keeping the appropriate level of the safety, the following assumptions were adopted and action was taken:

- executing procedures of the GNSS final approach with "overlines" method;
- approach procedures RNAV/GNSS of a few airports;
- applying on board, certificate of GNSS receivers;
- performing flights of solutions technical, in order to check established;
- operational of the EGNOS;
- experiment flights in frames of programs;
- collecting essential materials and study documents, necessary for the certification.

Drawn up stayed for communications airports: Gdańsk, Krakow, Katowice and Mielec (of the General Aviation representative) new RNAV/GNSS procedures. Another airports, particularly smaller, can see the chance of their development in final approaches, based for GNSS. However the applied "overlines" method is meeting requirements of the safety, because the GNSS procedure is becoming covered with standard procedure of the navigational system. In case of the breakdown one system of navigational aid, flight will be continued of flight based on other.

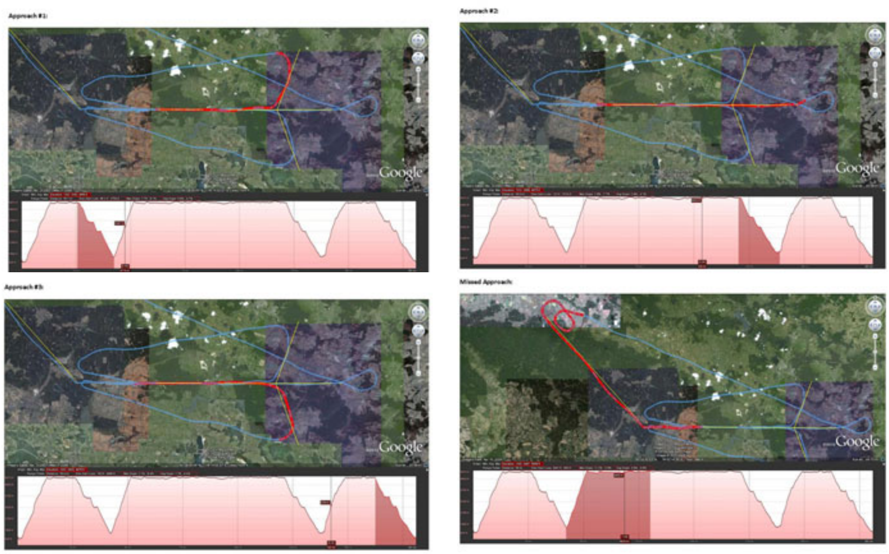

Fig. 2. Experimental LPV EGNOS/GNSS final approaches in Katowice – EPKT

In the framework of "HEDGE" and "EGNOS Introduction it the European Eastern Region Mielec" projects, after executing new procedures of the final approach RNAV GNSS and enter them into the Jeppensen's database, certificate on board receiver through EASA, obtain operational for EGNOS system, legitimate and necessary be based execute air experiments. Therefore 14 March 2011r. were made first in Poland, four experimental EGNOS/GNSS final approaches (fig. 2) with the vertical running (LPV) in MPL Katowice (EPKT). Emphasizing that representatives watched this experiment is legitimate: Ministries of the Infrastructure, the Office of the Civil Aviation and European Satellite Service Provider – ESSP and other.

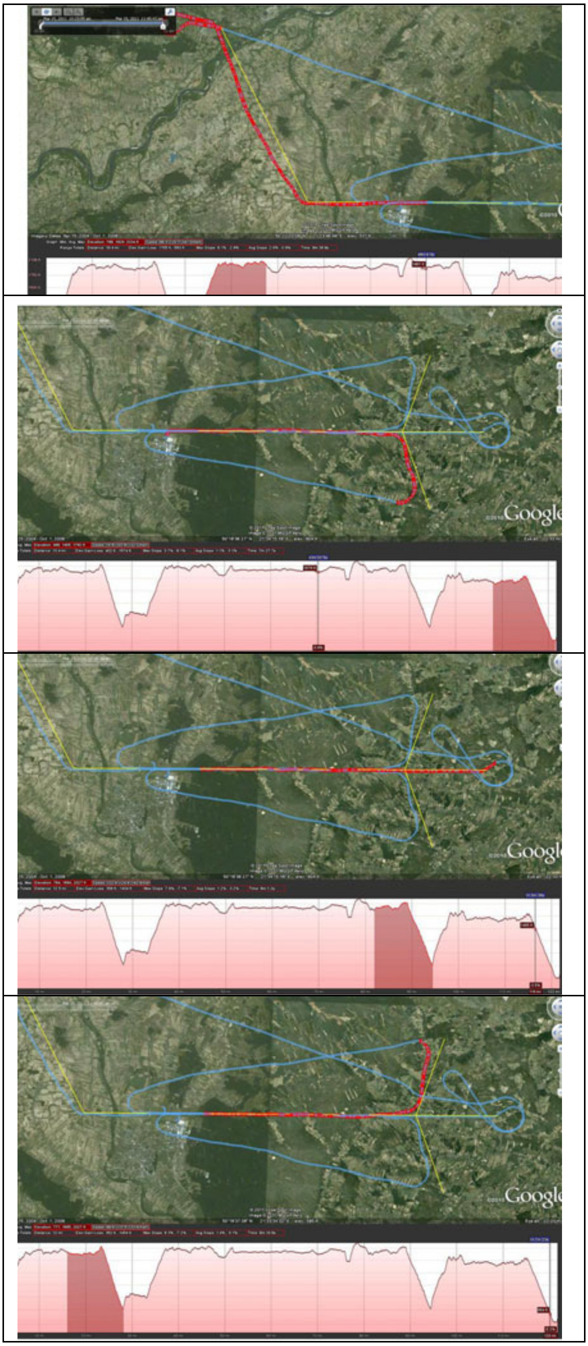

Fig. 3. Experimental LPV EGNOS/GNSS final approaches in Mielec - EPML

However March 15, 2011 experimental LPV EGNOS/GNSS final approaches (Fig. 3), were made on the airport Mielec (EPML). In this case imprecise attempts were performed, because on this airport no radio navigation systems are functioning.

First in Poland experimental, flights and LPV EGNOS/GNSS final approaches, in frames of “HEDGE” and “EGNOS Introduction it the European Eastern Region Mielec” programs, were made on Piper PA-34 Seneca plane II of the “Royal Star Aero” (Fig. 4), equipped in certificate Garmin GNS430W receiver and holding in Jeppensen's database procedures of the GNSS approach (Fig. 5).

Fig. 4. Piper PA-34 Seneca plane II LPV GNSS carrying attempts out

Fig. 5. The certificate and the Garmin GNS 430 receiver in

3 Chosen Elements of the Air Validation in EPKT

Area Navigation (RNAV) can be defined as a method of navigation that permits aircraft operation on any desired course within the coverage of station-referenced navigation signals or within the limits of a self contained system capability, or a combination of these. RNAV was developed to provide more lateral freedom and thus more complete use of available airspace. This method of navigation does not require a track directly to or from any specific radio navigation aid, and has three principal applications:

- a route structure can be organized between any given departure and arrival point to reduce flight distance and traffic separation;
- aircraft can be flown into terminal areas on varied pre-programmed arrival and departure paths to expedite traffic flow;
- Instrument approaches can be developed and certified at certain airports, without local instrument landing aids at that airport

Focusing on the last point, RNAV approaches can have several descent minima depending on the kind of RNAV approach to be flown:

- **RNAV (GNSS) NPA**: an approach without vertical guidance flown to the LNAV MDA/H;
- **APV Baro**: an approach with barometric vertical guidance flown to the LNAV/VNAV DA/H;
- **APV SBAS**: An approach with geometric vertical and lateral guidance flown to the LPV DA/H.

The 36th ICAO Assembly in 2007 passed a resolution encouraging States to implement approach procedures with vertical guidance (Baro-VNAV and/or SBAS) for all instrument runway ends, either as the primary approach or as a back-up for precision approaches by 2016.

APV SBAS is supported by satellite based augmentation systems such as WAAS in the US and EGNOS in Europe to provide lateral and vertical guidance. The lateral guidance is equivalent to an ILS localizer and the vertical guidance is provided against a geometrical path in space rather than a barometric altitude. The use of the European SBAS system – EGNOS – presents a feasible solution to APV approaches:

- Navigation system specifically designed for approach operations
- Europe coverage
- High accuracy and integrity
- Requires no infrastructure on the aerodromes themselves
- Supports autopilot coupling
- Standalone avionics possible thereby minimising retrofit costs.

Experimental LPV EGNOS/GNSS final approaches for EPKT were made based on the procedure specially drawn up and entered into the database (Fig. 6). In the process appointed characteristic points stayed (Fig. 7).

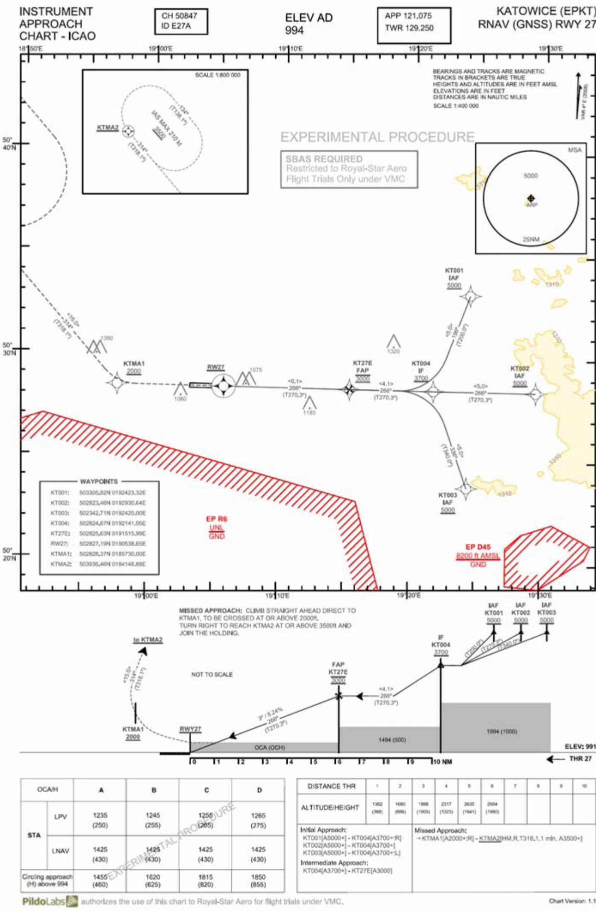

Fig. 6. Approach procedure EGNOS/GNSS for EPKT

WAYPOINTS LIST				
Fixes	**WP**	**Coordinates (WGS84)**		
IAF	KT001	503305.92N	0192423.32E	50.55164N,19.40648E
	KT002	502823.46N	0192930.64E	50.47318N,19.49184E
	KT003	502342.71N	0192420.00E	50.3952N,19.40556E
IF	KT004	502824.67N	0192141.05E	50.47352N,19.3614E
FAP	KT27E	502825.63N	0191515.99E	50.47379N,19.25444E
LTP	RW27	502827.19N	0190538.65E	50.47422N,19.09407E
	KTMA1	502828.37N	0185730.00E	50.47455N,18.95833E
	KTMA2	503936.46N	0184148.88E	50.66013N,18.69691E

Fig. 7. Characteristic waypoints

The following figures present the flight trajectories of the demonstrations together with the waypoints and runway threshold. It can be seen how the aircraft successfully accomplished the operations up to the OCA/H values, when either a missed approach or a landing was conducted. In the profile views, the next reference altitudes have been plotted:

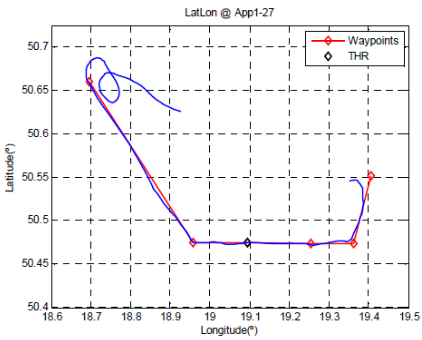

Figure 4-3: App1. Plan view of A/C flight path

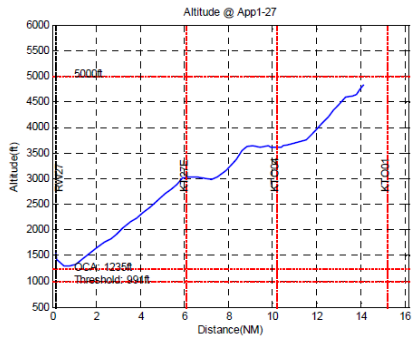

Figure 4-4: App1 A/C Altitude profile

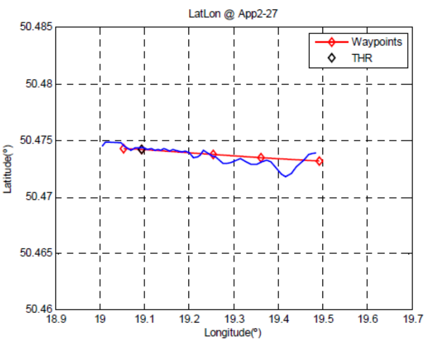

Figure 4-5: App2. Plan view of A/C flight path

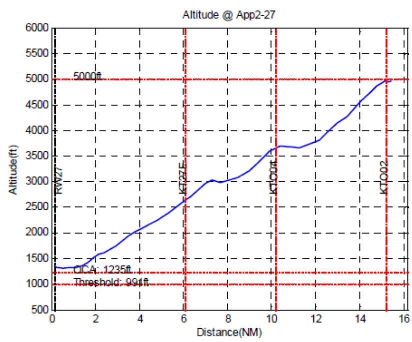

Figure 4-6: App2. A/C Altitude profile

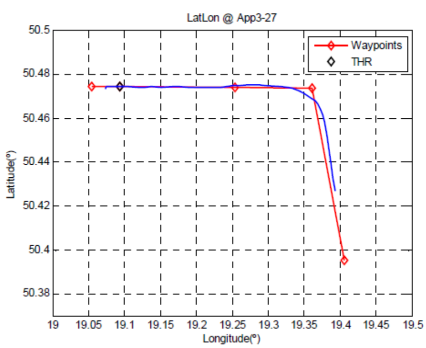

Figure 4-7: App3. Plan view of A/C flight path

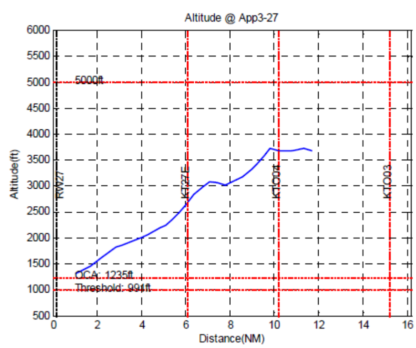

Figure 4-8: App3. A/C Altitude profile

Fig. 8. Flight trajectories of the demonstrations together with the waypoints and runway threshold

To have a clearer picture of the deviations presented to the pilot during the approaches, the horizontal and vertical deviations have been computed with respect to the desired flight path. The results are presented in the figures inside this section. The distances in the vertical axis represent the horizontal or vertical (FTE) in meters. The FTE is provided as guidance information to the pilot during the flight, while the NSE and TSE can only be determined using truth reference after post-processing the data. Figures located in the left show the deviations of the a/c during the intermediate and final approach segments, while the figures located in the right side offer a zoom of the deviations during the FAS.

The FSD (Full Scale Deflection) of the CDI/VDI is also plotted in the figures (light grey color) when contained in the figure limits, both in the horizontal and the vertical domain. These curves indicate the value of the deviations that the aircraft would have had with respect to the approach path if the CDI/VDI needles had been totally deflected. The curves have been calculated using in-house developed tools, in accordance to MOPS RTCA DO-229D. As can be seen, the FSDs are not constant, and they change between linear and angular along the approach, following the requirements laid down in the MOPS.

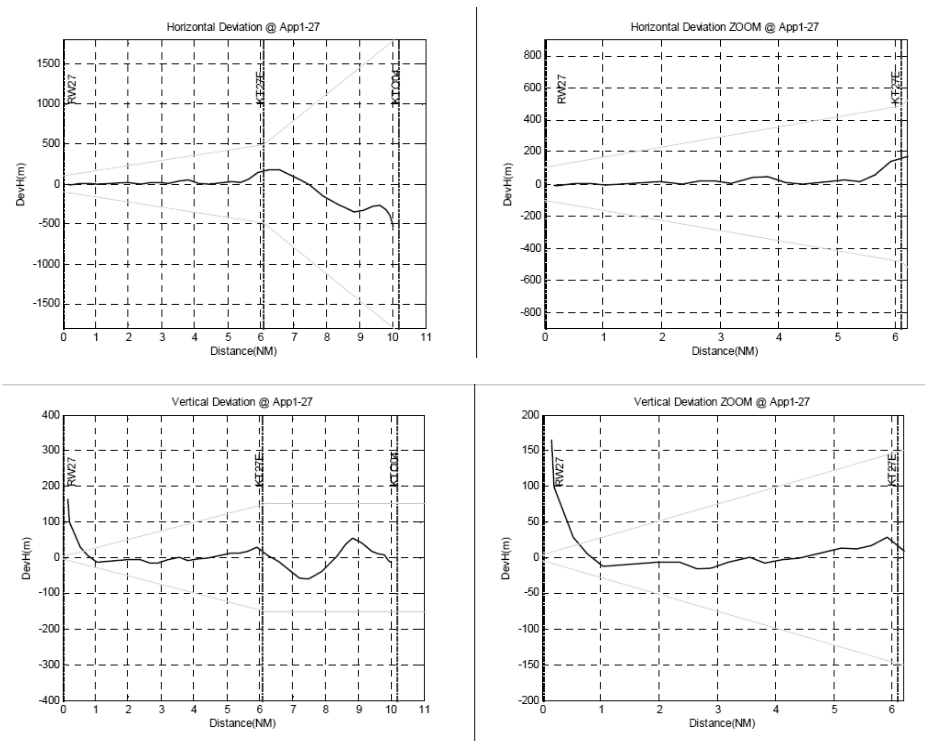

Fig. 9. The examples of horizontal and vertical deviations with respect to the desired flight path

On the base conducted tests, was drawn up for European Organization for the Safety of Air Navigation „Flight Validation report: RNAV GNSS approach procedure EPKT and EPML”. At the same time documentation which will serve for conducting the air certification of the system EGNOS/GNSS, while performing the RNAV operation.

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Technical Devices Cooperation to Obtain Data for 3D Environment Modelling

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Abstract. The paper describes an initial approach adopted by the authors to create a system used for modelling of 3D environment. Data for a model is obtained by a 2D laser scanner measuring a distance of the real environment points and by the SPAN device showing information about scanner movement. The communication between the devices (scanner, GPS, INS) is based on different protocols, so data must be extracted and synchronized. The procedure used to obtain and assign the values within the proper time is presented. Model creation succeeds to processing of obtained cloud of point data where each point carries basic information, i.e. three coordinates of the particular location in the space. Thanks to scanner movement the cloud of points has the shape of spiral. The paper also explains relation between the scanner head rotation frequency and its linear movement, necessary for obtaining the best reality scan.

Keywords: scanner, laser, modelling, 3D, protocol, GPS, INS.

1 Introduction

Creating 3D models seems to be an excellent method applied today to collect detailed data on various objects and environment. One of the application domains where 3D models can be especially useful is a road and its surrounding environment [3]. Different methods are used to get information, including CCD elements (cameras) and different kinds of scanners [1], [2]. The final 3D model representing the target of applied procedures described below should be created based on information collected from the roads and their environment. This vision predetermines considered equipment. System for collecting information as a whole consists of autonomous devices whose partial properties fits best for the given purpose despite their primary usage is a little bit different. In principle the 2D laser measurement system measures exact distance of scanned objects and creates their profiles using the specialized software.

To create 3D information about each point the scanner must move perpendicularly to the scanning plane and this movement must be monitored. Change of position may be recorded e.g. by sensing velocity of wheel rotation (provided that the scanner moves on wheels) or utilizing the GPS. However, the GPS itself without correction is not accurate enough. Therefore it is combined with other equipment [4]. The paper

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mainly concentrates on acquisition and processing of data further usable for creation of a graphic model. The graphic model itself is not discussed here.

2 Properties of Devices

2.1 Laser Scanner

The scanner operates with an infrared laser of the class 1. The laser beam cannot be seen by the human eye. The scanner interface outputs the contour data on the recorded surroundings in the form of constant raw data incorporating distance and angle values. The 2D profiles of the surrounding are scanned by the multiple pulsed IR laser beams transmitted via a rotating lens head. The sensor via these extremely short light pulses measures the determining the angle of the pulses sent back. Maximal pulse frequency of the laser diode is 14.4 kHz to produce a maximal head rate of 15 times per second. The scanning range of the scanner is dependent on the reflection of the objects to be detected. Scanning range may by up to 200m [6].

2.2 Synchronized Position Attitude Navigation (SPAN)

This equipment connects two different but complementary position and navigation systems – the Global Position System (GPS) and the Inertial Navigation System (INS). Combining them together we can determine position with higher accuracy and reliability than using both equipments separately.

The GPS receiver performs continuous calculations of position, velocity and time based on data received from orbital satellites. This position system has been introduced as a very accurate system with achievable accuracy of centimetres. Generally, a common user is subject to certain restrictions that limit accuracy to metres. To calculate coordinates one needs to receive signals from four satellites at least. If signal from some of them or from all satellites is unavailable, accuracy of position is immediately decreased or position cannot be determined at all.

The INS measures rotation and actuating forces via the Inertial Measurement Unit (IMU) to calculate position, velocity and attitude. Inside the IMU we can find accelerometers measuring changing forces in three perpendicular axes and gyroscopes measuring angular rotation around these axes. The output of the inertial navigation is in the form of very accurate information on acceleration; velocity and position, periodically provided in short time intervals. However, the INS must have information about initial position, initial velocity, rotation velocity of the Earth and gravitational field. Based on measured data (orientation and acceleration) the INS re-calculates a change compared to the previous position. Thus one can get information about the actual state. The initial parameters values must be obtained from an external source. Once given these values, the INS is able to provide autonomous solution without any other external inputs. Despite that IMU inaccuracies are minimal, with the growing number of measurements they become accumulated which degrades usage of the system itself without external information about position. Data processing is realized directly inside the GPS and INS. Thus from this point of view we work with a closed system.

The INS characteristic prioritizes it to applications in the mentioned environment (surrounding area of the road) where availability of the GPS signal is mostly stable. Adding information from the INS accuracy of measured position becomes higher and the system can also be used inside the tunnels where there is no GPS signal [5].

2.3 Data Processing Equipment

The Central Unit (CU) serves mainly the purpose of recording data from the scanner and SPAN obtained during measurements. All these devices create a mobile part of the system. Demands for computation power related to recording symbols to text files are not high. A notebook may be used as a CU provided it is equipped with necessary interface (serial port, Ethernet). On the contrary, the high computation power is required for off-line processing, therefore it realized by the high-duty PC. The block diagram of the whole system is indicated in Fig. 1.

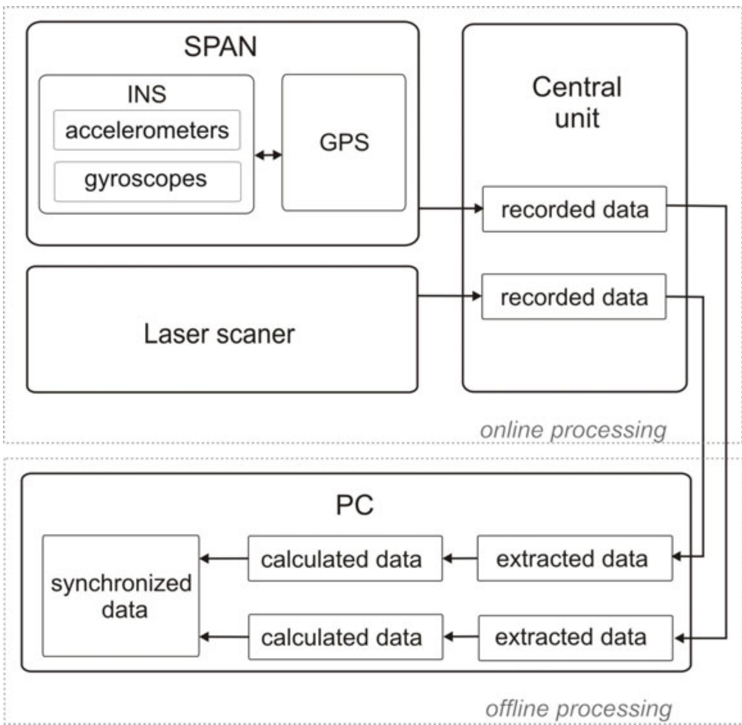

Fig. 1. Block diagram of data transmission and processing

3 Processing of Required Data

3.1 Extraction and Processing of Data from the Scanner

The scanner may send data through one of interfaces RS232, CAN, or Ethernet. For the research purpose the Ethernet has been used because of the highest data transmission rate among mentioned choices and the used TCP/IP protocol is suitable for packet capturing. Analysis of captured data makes the basis for determination of coordinates of the scanned point.

Data sent from the scanner has the fixed structure given by the producer and is inserted into the data part of the TCP/IP protocol. After determination of meaning of the individual words (2 Byte) in the packet the program has been created recalculating position of the point in the 2D coordinates system. Determination of the right algorithm is important (e.g. number of scanned points for the 270° scanned area, scanning frequency 10 Hz and angular resolution 0.25° is 10 800 per second). For a longer scanning period the scanner produces enormous cloud of points. Therefore it is necessary to make the algorithm for searching through the analyzed file as effective as possible. Since on-line data processing and synchronization would be problematic because of its enormous quantity we have decided to realize on-line only the primary record of data and perform its processing off-line. The recorded file contains a lot of information useless for calculation of point position in the coordinate system. It is necessary to extract the initial scanning angle, final scanning angle, angular resolution and distance of the point measured (calculated) by the laser scanner (Fig. 2). Individual packets are stored together with a time of their reception/sending. As a reference time the time value from the CU is used.

```
RECEIVE 2011-03-04 09:46:11.451 <02><02><02><02><00><00><00><27><73><52><41>
<00><62><00><10><81><ba><01><02><01><d8><00><00><00><04><00><00><00><14><00>
<01><00><04><00><05><10><e0><04><72><04><70><04><6d><04><6c><04><6c><88>
```

Fig. 2. Example of a packet received from the scanner. The highlighted data in the order: reception time, packet ID, initial scanning angle, angular resolution, final scanning angle, measured distances for 5 scanned points (underlined parts).

In the PC data from packets is being processed in the following way:

- Successive going through each line in the file; each line (space found between two demarcations "RECEIVE" and "SEND") beginning with the "RECEIVE" is tested for a number of symbols. After passing the size 18B (i.e. more than service data) we know that the packet also contains data about measurement and measured values in addition to service data.
- Within the given line the measurement identifier is found, containing packets with measured values only. This identifier grows continuously. Values located after the identifier carry information about the measurement. According to the order they are transferred to program values.
- Based on the rules specified in [6] data is transformed to meters (measured distance) and angles (angular resolution, initial/final value of the scanned sector).
- These four values are necessary for calculation of point position in 2D coordinate system of the scanner. Calculation follows simple algorithm using goniometric functions sinus and cosine. Result values are stored in the file in PC, together with time data relevant to scanning procedure.

3.2 Extraction and Processing of Data from the SPAN

The orientation of the SPAN in relation to the scanner movement is important. In this case default axes orientation has been respected, i.e. Z_N (up), Y_N (forward), X_N (left side in relation to Y_N). Correct functioning also depends on respecting the gravitation direction. Data form the SPAN is transmitted to the PC via serial ling RS232. Based on configuration different kinds of logs may be used, containing separate data from the GPS and INS as well as data obtained after synchronization of these devices. Output values are sent and with the help of terminal (a part of software packet delivered with hardware) recorded into the file. Recorded data corresponds to the NMEA format, using a sentence of the GGA type which makes extraction of data from the file easier thanks to known structure. Each sentence has an actual time of the CU assigned when being stored. Time value of the UTC in the sentence is irrelevant in this case since it need not be equivalent to the time value in the reference CU.

From each sentence a data about geographic position must be extracted. This is possible based on the known positions of these values in the used protocol. Position of the first scanning is made the initial value. Distance between the initial and any other recorded position is determined using the known algorithm. Calculated distance together with time data is saved to the file. Example of one sentence of the GAA type included in the file is as follows:

```
<14:58:32.907>$GPGGA,103520,4912.826,N,1845.236,E,1,07,0.
9,362.4,M,047,M,,*58
```

Values written in italics indicate geographic positions. All described operations are performed in the PC in the off-line mode.

3.3 Cooperation of Devices

Before processing of extracted data it is necessary to consider position of the reference point (intersection of axes X_N, Y_N, Z_N) of the navigation system in relation to the scanner head where a fictitious zero intersection of axes X_S, Y_S of the coordinate system of the scanner is defined. The output position Z determining change of the scanner position is calculated for the SPAN reference point. Devices are situated in such a way that intersection of scanner axes must lie at the axis Y_N (Fig. 3). Distance of the intersection of the scanner from the reference point of the SPAN is constant. Including this constant to the calculation the position calculated by the SPAN will exactly correspond to accurate position of the scanner head.

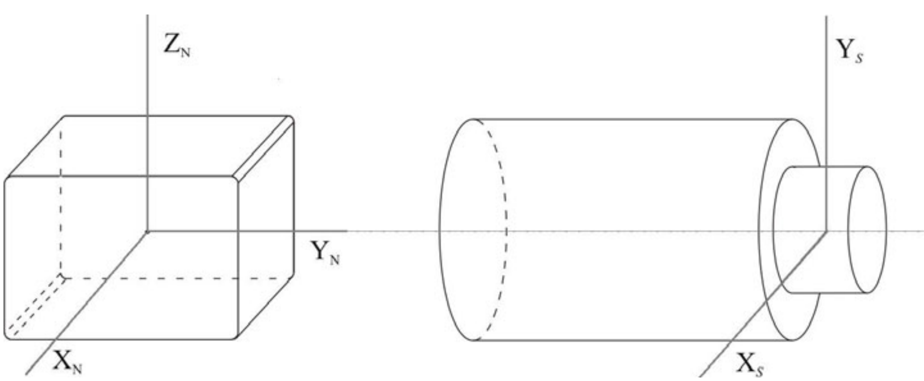

Fig. 3. Schematic position of device distribution and denoting axes for the SPAN (on the left side) and the laser scanner (on the right)

Then it is necessary to combine data, recorded from both devices and processed in a described way, to get final coordinates. For the purpose of synchronization there are used time data assigned to individual packets at the moment of communication and time data assigned to sentences sent from the SPAN. Time data expressed in ms seems to be sufficient. Scheme of time data assignment is shown below:

$$\begin{array}{lllll} t_{S1}\,[X_{S1}\;Y_{S1}] & t_{S2}\,[X_{S1}\;Z_{S1}] & \ldots\; t_{Sn}\,[X_{S1}\;Y_{S1}] & & t_{N1}\,[d_0] \\ t_{S1}\,[X_{S2}\;Y_{S2}] & t_{S2}\,[X_{S2}\;Z_{S2}] & \ldots\; t_{Sn}\,[X_{S2}\;Y_{S2}] & & t_{N2}\,[d_1] \\ \quad\ldots & \quad\ldots & \quad\ldots & & \quad\ldots \\ t_{S1}\,[X_{Sn}\;Y_{Sn}] & t_{S2}\,[X_{Sn}\;Z_{Sn}] & \ldots\; t_{Sn}\,[X_{Sn}\;Y_{Sn}] & & t_{Nn}\,[d_n] \end{array} \tag{1}$$

On the left side there is assignment of time to calculated coordinates of scanned points, on the right side there is assignment of time to calculated distances from the position of the first scanning. For each scanning (one rotation of the scanner head) there is assigned time of packet reception t_S, number of measured time values n is equivalent to number of scanner head revolutions. For the maximum frequency of rotation 15Hz, velocity of the system movement 5km.h^{-1} and the distance 100m it is 1 080 revolutions. The coordinates of the scanned points X_S, Y_S are assigned after re-calculation (figures in indices denote the sequence of the scanned point for the particular profile). Number of assigned points depends on initial setting of the scanning range and angular resolution (see 2.1) during one revolution of the scanner head. For the following scanning the number of scanned points is not always the same which may be caused by missing of reflected rays (or no reflection occurs) and distance of the given point has not been measured.

Each value of distance change calculated based on data from the SPAN has an assigned time t_N to CU. For each time value we have one distance value d representing distance of the system at the given moment from the coordinate system origin. The first position received from the SPAN whose time is closest to time of the first scanner head revolution has 0 value assigned. Recalculation of times follows the following rules: if $t_{Sn} \approx t_N$ then $[X_{Sn} \rightarrow X;\ Y_{Sn} \rightarrow Y;\ d_n \rightarrow Z]$, where $[X, Y, Z]$ are point coordinates in the modeled space in metres.

Based on this condition the file is being created containing 3D specification of all scanned points. Each packet containing cloud of points, corresponding to one scanner head revolution, is assigned a value of position, thus scanning results in creation of scanned profiles (see Fig. 4b). If each measured point has had assigned an instantaneous time values, distribution of scanned points in the space would create a spiral (Fig. 4a). Number of scanned points per second may exceed as many as 14 400 for the given type of scanner. Assignment of time value to each point would require CU with high computing performance. However, growing computing power also means growing energy consumption - one of problems being potentially urgent for a mobile installation.

Number of scanned points in both cases is approximately the same; it is not important what periodic formation will be created by coordinates. To get as detailed model as possible the minimum distance *d* between two periods is important (Fig. 4).

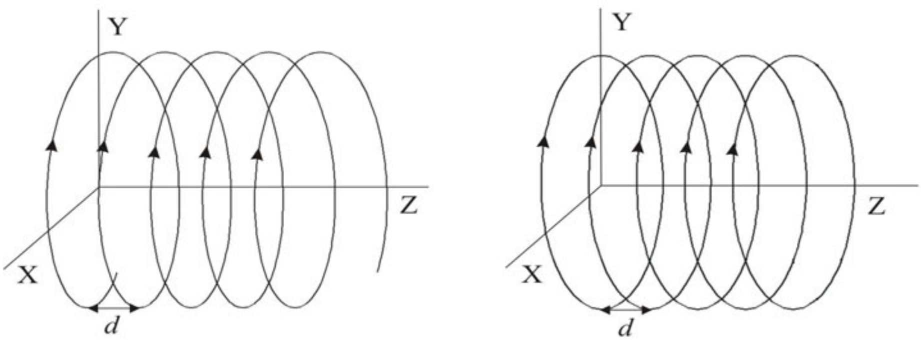

Fig. 4. Distribution of scanned points in the space: a) immediate assignment of time value to each point; b) assignment of one time value per one scanner head revolution

4 Conclusions and Future Studies

The used devices have been properly configured before measurements to utilize maximally their properties. In the case of laser scanner there was a limit of the maximum scanning frequency. It had to be adapted to frequency of sending data about the actual position. Therefore velocity of the whole system is limited. For the maximum velocity of scanner head rotation (15Hz) velocity of the system as a whole may not exceed 15 $km.h^{-1}$ to reach distance of profiles 10cm. This condition is a reasonably limiting factor for the application to be developed. Velocity could be doubled by usage of 2 scanners having the same parameters.

After configuration and initiation both devices send data autonomously, without possibility to change their properties. Mutual synchronization during running, without intervention to producer's service protocols, has been excluded. As an alternative solution synchronization was solved using the third component of the mobile part of the CU system which (in addition to initial configuration by delivered software) also served for data storing. Measured values obtained from devices together with reference time have been recorded to files at the CU. Each packet received from the scanner and frame from the SPAN has been assigned a momentary time of reception. Thus it is possible to reconstruct position of the scanner head for each of the received packets. For the need of creation of the 3D model of road communication we have not considered posting of the model into the real environment (place on the map) yet. However, the only thing to do is localize accurate position of the given point in the chosen 3D coordinate system. As the origin we can use the place where scanning was initiated. A graphical editor for drawing the cloud of points has not been completed yet.

Acknowledgments. This work has been supported by the European Regional Development Fund and the Ministry of Education of the Slovak Republic, ITMS 26220220089 "New methods of measurement of physical dynamic parameter and interactions of motor vehicles, traffic flow and road".

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Satellite Navigation Systems, Data Messages, Data Transfer and Formats

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Abstract. Each Satellite Navigation System (SNS) is comprised of three segments: satellite constellation, ground-control/monitoring network, and user receiving equipment. All satellites broadcast different navigation data messages at different rates. A detailed comparison of the messages of two SNS actually operational, GPS and GLONASS and one SNS under construction, Galileo, is presented in the paper. The transmission of data and differential corrections, raw measurements or position solutions from or to the user receiver can be based on various means of communication. Three formats, RTCM, RINEX and NMEA in different versions, internationally accepted and generally supported by all receiver manufacturers, have been specified for the exchange of satellite navigation data. The comparison of these formats is also presented.

Keywords: Satellite Navigation System, data messages, data transfer, data format, RTCM, NMEA, RINEX.

1 Introduction

In May 2011 a terrestrial position fix can be obtained with Satellite Navigation Systems (SNS) such as the GPS (the only fully operational) and GLONASS, in the future also with Galileo and Compass. All these systems and Satellite Based Augmentation Systems (SBAS) as EGNOS or WAAS are known as the Global Satellite Navigation System (GNSS). GNSS signal consists of three components – carrier, ranging code and binary-coded navigation message. In each GNSS at least one message consists of data on the satellite health status, ephemeris (satellite position and velocity), clock bias parameters, and an almanac giving reduced-precision ephemeris data on all satellites in the constellation [1], [2].

2 Navigation Messages

All code signals are modulated with data, which provides the user with the information necessary to compute the precise location of each visible satellite and time of transmission for each navigational signal. In each SNS the navigation message is generated by the ground segment and uploaded to own satellites in regular intervals. Initially, when GPS and GLONASS systems alike provided for civil users

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one service only, one data message was sufficient, actually new frequencies and new signals of these systems and knowledge of Galileo parameters caused that in each SNS different services use different data messages. It is common to all SNS that there is at least one service transmitting ephemerides data as well as time information. It is not advisable to mix the data from different navigation messages [1], [2], and [3].

The data rate of the navigation message is slow compared to the mapping codes or compared to typical communication channels.

2.1 GPS Navigation Data Message

All block IIR satellites and earlier broadcast one navigation message NAV only. Together with block IIR–M satellites and new L2C, L1M and L2M signals, new civil and military data messages were created, which are structured differently from the legacy navigation message. Their subframes, which are headed by a message type indicator, may be transmitted in any order. This provides greater flexibility to transmit different information at different rates. These new messages are designed to carry a new, modernized data format, which replaces the strategy of frame and subframes by a flexible data message. This enables changes in satellite health to be alerted to all users much more quickly than today. According to the satellite GPS block satellites broadcast one, two, three or four different data messages [4], [5], and [6]:

- original navigation message NAV on the C/A and both P(Y) code signals. This message is common across all GPS satellites, fixed in structure and length;
- civilian data message, CNAV, on the L2C signal (CM component), block IIR–M and IIF satellites. The CNAV data set is a higher precision representation and nominally contains more accurate data than the NAV message. This message is half–rate forward error correction (FEC) encoded using a 7–bit convolutional encore to decrease the bit error ratio (BER);
- military data message, MNAV, on the L1M and L2M signals, IIR–M and IIF satellites. The MNAV message structure is similar to that of CNAV. This message broadcasts higher precision ephemeris and satellite clock parameters than the legacy message, and there are plans to improve the precision of these parameters in the CNAV message as well. The frame/subframe structure is changed to a data message structure. This message improves the data security and integrity of the system and is designed to provide the flexibility of satellite and frequency diversity;
- navigation data message on L5C signal (I component). This message is broadcast by block IIF satellites (since August 2010) and it contains the same data as NAV and CNAV but in different format.

The United States is planning to add a modernized civil signal upon the L1 frequency within block III satellites. The data message CNAV–2 modulated onto the L1C signal (d component) will be subdivided into frames, which themselves will be subdivided into three subframes.

2.2 GLONASS Navigation Data Message

The navigation message transmitted by the GLONASS satellites within the navigation signal is purposed to provide users with requisite data for positioning, timing and planning observations. GLONASS satellites broadcast different navigation data messages on the C/A code and P code signals. These messages include immediate and non-immediate data. The immediate data are related to the satellite currently transmitting the data and are as following [4], [7], and [8]:

- enumeration of the satellite time marks;
- difference between onboard time scale of the satellite and GLONASS time;
- correction to the satellite frequency with regard to the theoretical one (due to the FDMA scheme addressed in GLONASS);
- the satellite ephemeris.

The non-immediate data include the almanac data:

- health of the satellite;
- coarse corrections to onboard time scale of each satellite relative to GLONASS time (phase almanac);
- orbit parameters for all the satellite of the constellation (orbit almanac);
- the GLONASS time correction relative to UTC (SU).

A new navigation data message will be broadcast in the L3 band (satellites block K and later). This may include integrity information and differential corrections.

2.3 Galileo Navigation Data Message

Five different types of data content have been envisaged for the Galileo messages: the positioning/navigation data, integrity data, the supplementary data, the publicly regulated data, and the data for Search And Rescue (SAR) operations [5]. These five different types define four navigation message types [4], [5]:

- FNAV, freely accessible, carried on the E5a–I signal, for Open Service (OS);
- INAV, integrity, carried on the E5b–I and E1B. These two channels transmit the same information in the same page layout, however with different page sequencing. Demodulating the navigation message of both allows for fast reception of data. Two types of pages have been specified for the INAV message: the nominal and alert page. This message is designed for Open Service, Commercial Service (CS) and Safety of Life (SoL);
- CNAV, commercial, centered E6B, for Commercial Service;
- GNAV, government, carried on both Public Regulation Service (PRS) signals, i.e. E1A and E6A.

Navigation data is broadcast on all message types except for CNAV. Ephemeris and almanac data is similar to that in the GPS legacy message NAV, while the satellite clock parameters are at a higher resolution for both the transmitting satellite and the constellation. Integrity data, including three levels of integrity alert and authentication data, is transmitted on both INAV and GNAV messages. The Galileo data messages include both Galileo System Time (GST)–UTC and Galileo–GPS time conversion data. At present (May 2011), the detailed information about messages CNAV and GNAV is not available.

3 Data Transfer and Formats

The transmission of data and differential corrections, raw measurements or position solutions from or to the user receiver can be based on various means of communication. Three formats, in different versions, internationally accepted and generally supported by all receiver manufacturers, have been specified for the exchange of satellite navigation data:

- Radio Technical Communication for Maritime Services (RTCM);
- Receiver Independent Data Format (RINEX);
- National Marine Electronics Association (NMEA).

3.1 RTCM Format

Many messaging protocols have been developed throughout the industry for dissemination of code- and carrier-based DGPS data between reference stations and user's receivers. The standards established by the Special Committee 104 of the US Radio Technical Communication for Marine Services (RTCM SC–104, or in short, RTCM), originally developed for differential operations in maritime applications, are today internationally accepted, and supported by nearly all DGNSS and nearly all DGNSS receiver types. Actually this standard defines the format of differential pseudorange corrections (PRC) transmitted by the ground reference stations or geostationary satellites (SBAS) to the user's SNS receivers.

The preliminary version RTCM from 1985, was replaced in 1990 by RTCM 2.0. This format provides pseudorange and range rate correction, PRC and RRC, respectively, and is sufficient for ordinary DGPS with an accuracy level of few meters or better. Version RTCM 2.1 (January 1994) additionally includes carrier phase data and hence provides the possibility to resolve ambiguities of the rover station and is the required standard for precise DGPS and Real Time Kinematic (RTK). Version TRCM 2.2 (January 1998) includes PRC for other SNS, GLONASS system in particular, version 2.3 (May 2001) includes antenna phase center variation (PCV) data [6], [9]. The last RTCM version 3 has been defined to increase the efficiency of information transmission and to increase the integrity of the parity operation. Version 3.0 messages are broadcast in variable length frames, this version parity scheme is much stronger than that used for version 2.3.

The RTCM standard version 2.3, the most frequently used now, includes 64 different messages types. The messages consist of a sequence of words with 30-bits each. The last six bits in each word are parity bits. The total message has a maximum length of 33 words. Seventeen selected message types in the case of radiobeacons transmitting DGPS corrections are presented in Table 1. The detailed description of all 64 message types can be found in specialised publications, e.g. [6], [10]. The number of countries and the number of radiobeacons transmitting these 17 message types of Differential GPS and Differential GLONASS corrections first of all for marine users are shown in Table 2. In 2011 DGLONASS corrections were transmitted by two stations (Yenikal'skiy and Zmeiniyy) only, both in Ukraine, but four stations have the status on trial and the next eleven are planned; all stations are situated in Russia. Seventy three stations are without the list message type.

Table 1. Differential GPS and GLONASS corrections, selected messages types [5], [10]

Message Type Number	Title
1	Differential GPS Corrections. Now replaced by Type 9 messages, but still used by some countries
2	Delta Differential Corrections
3	GPS Reference Station Parameters. Contains information on the identity and surveyed position of the active reference station in the DGPS station. Broadcast at H+15 and 45
5	GPS Constellation Health. This message type will notify the use equipment suite that a satellite that is deemed unhealthy by its current navigation message is usable for DGPS navigation
6	GPS Null Name
7	DGPS Radiobeacon Almanac. This message provides information of its broadcasting DGPS station and the other two or three adjacent DGPS stations. Broadcast at H+7 then at 10 minute intervals
9	GPS Partial Correction Set. This message type has been selected for broadcasting Pseudo range Corrections (PRC) instead of the Type 1 message. Two methods of transmitting the Type 9 message are possible
9–3	The first method of broadcasting PRC is based upon "Three-Satellite Type 9 Messages". This is denoted as Type 9-3 messages
16	GPS Special Message
31	Differential GLONASS Corrections
32	Differential GLONASS Reference Station Parameters
33	GLONASS Constellation Health
34	GLONASS Partial Differential Correction Set (N>1) GLONASS Null Name (N≤1)
35	GLONASS Radiobeacon Almanac
36	GLONASS Special Message
37	GNSS System Time Offset
59	Proprietary Message (Chinese stations only)

The number of ground beacons (stations) transmitting DGPS corrections (PRC) has been increased in last years considerably. In 2004 there were 208 beacons with status operational, 68 with status on trial, 12 planned, in 2011 these numbers were 274, 36 and 18, respectively. At present the beacons are situated in 42 countries, the greatest number of beacons operational are in USA (38), Japan (27), and China (21). In Poland two stations, Rozewie and Dziwnow, have now the status on trial and transmit four message types 1, 3, 7 and 16, the third station, Jaroslawiec, is as before without status [10]. Some stations transmit one message type only, e.g. all US stations 9–3, others several, e.g. all India stations 6 types: 3, 5, 7, 9 and 16. Two stations in Ukraine broadcast 14 types, 7 designed for GPS system and 7 for GLONASS [10].

Table 2. The number of radiobeacons transmitting selected message type of Differential GPS and Differential GLONASS corrections [10]

Message Type Number	Number of radiobeacons	Number of countries	Remarks
1	56	9	Brazil all 11, Norway all 12
2	23	2	Brazil all 11, Norway all 12
3	194	39	Australia all 16, Canada all 17, India all 19
5	93	12	Australia all 16, India all 19, Norway all 12
6	102	21	Brazil all 11, Canada all 17
7	184	33	Australia all 11, Canada all 17, India all 19
9	176	32	Australia all 11, Canada all 17, India all 19
9–3	51	2	USA all 38, China 13
16	189	33	Canada all 17, China all 21, India all 19
31–37	2	2	DGLONASS corrections, Ukraine only
59	5	1	China only

Conventional DGPS requires message types 1, 2, and 9 to provide meter accuracy. RTK operation relies on message types 18 through 21 to provide a centimeter accuracy. Reference stations transmit in the 283.5 – 325 kHz marine radio-beacon band, with coverage radii of up to 500 km. VHF and UHF band data links, cell phone systems, radio and television broadcasts, the Internet, and terrestrial radionavigation system Loran C signals are also used [2], [4].

3.2 RINEX Format

In 1989, W.Gurtner of the University of Berne defined the RINEX format to facilitate the exchange of the GPS data of different receiver types. RINEX data can be obtained from the reference station provider via Internet, via mobile and fixed phone, CD ROM, or other data storage devices, depending on the service [9]. RINEX version 2 was presented and accepted in Ottawa 1990, mainly adding the possibility to include tracking data from different SNS, GLONASS in particular, and SBAS. Several subversions of this version have been defined 2.10, 2.11 and 2.20 [11].

The upcoming Galileo system and the enhanced GPS with new frequencies and observation types, especially the possibility to track frequencies on different channels, ask for a more flexible and more detailed definition of the observation codes. Therefore new RINEX version – 3 must be created. This format consists of three ASCII file types [5], [12]:

- observation data file, i.e. information on the measurement session, receiver/antenna station, satellite system time, number and list of satellites in view during the session;
- meteorological data file, i.e. information on atmospheric status, such as temperature, pressure and humidity;

- navigation message file, which may contain the navigation message (satellite clock parameters, satellite health, almanac parameters etc.) of more than one satellite system (GPS, GLONASS, Galileo, SBAS).

The naming convention for this standard format is “ssssdddfyyt”, where the sequence “ssss” is the station name designator, “ddd” indicate the day of the year of first record, “f” session indicator, “yy” denote the last two digits of the current year, “t” indicates a file type: O – observation, N, G, L, P, H – GPS, GLONASS, Galileo, Mixed GNSS and SBAS Payload navigation message file, respectively, B – SBAS broadcast data file, C – clock file, S – summary file [11], [12].

As RINEX version 3.0 specifies 228 different observation codes for all various GPS, GLONASS, Galileo, and SBAS observable and signal-to-noise ratios, this format enables the combination of observations of different satellite types.

3.3 NMEA Format

The US National Marine Electronics Association (NMEA) proposed in 1983 the NMEA–0183 interface specification. This format is the standard used in real-time marine navigation to interface marine electronics devices, in particular for transmitting GPS information from the GPS receiver to hardware that uses the positioning as the input. Additionally today NMEA became a voluntary industry standard interface for GNSS receivers [5], [12], and [13].

The NMEA–0183 are data streams in the ASCII format and the data is transmitted in the form of sentences, each having no more than 82 characters. Every sentence starts with the dollar sign “$” followed by the address field, two-character-long talker (“GP” indicates GPS data, “GL” GLONASS data) and three-character-long sentence type.

Actually at least 54 NMEA sentences are used in GNSS receivers, some concern satellite navigation systems, sat fix, others navigation parameters (bearing, cross-track error, distance, heading, route, waypoint etc.), terrestrial radionavigation systems, time and date, etc. The content of some GNSS related NMEA sentences [14]:

- ALM – GPS Almanac Data contains GPS week number, satellite health and the complete data for one satellite;
- GGA – position fix data: time in hours, minutes and seconds UTC, latitude and longitude in degrees, minutes and hundred thousandth of minute, number of satellites used for position computation, dilution of precision coefficient, antenna height above geoid and the difference between ellipsoid WGS–84 and the geoid;
- GSA – GPS DOP and active satellites, the numbers of the satellites being used in the current solution, Position Dilution of Precision, Horizontal Dilution of Precision and Vertical Dilution of Precision coefficients;
- GSV – the number of satellites visible at given moment by receiver’s antenna, azimuth, elevation, and signal-to-noise ratios for each satellite. One GSV sentence only can provide data up to 4 satellites;
- RMC – NMEA has its own version of essential GPS PVT (position, velocity, time) data. It is called RMC, The Recommended Minimum.

4 Conclusion

- Some SNS apply satellite and frequency diversity concepts to decrease the time needed for decoding the complete navigation message and thus to decrease the time to obtain the first fix (TTFF).
- In each SNS, together with new satellite blocks, new signals and new services, new civil and military data messages were created. In the future one navigation message will provide more than one SNS service.
- RINEX is the international exchange format for the postprocessing of SNS and SBAS or near–online purposes, while RTCM format is used for the transmission of data corrections, in real time, in Differential SNS applications.
- As RINEX is now the most favoured format, all GNSS receiver manufacturers implement software for the conversion of their receiver–dependent format into RINEX.
- The new NMEA specification, NMEA version 2000, extends the single-talker-multiple-listener interface specification of NMEA–0183 to a serial data networking specification for marine electronic devices such as depth finder, nautical chart plotter, navigation instruments, engines and GPS receivers.

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Vehicle Tracking Using a Multi-scale Bayesian Algorithm for a Perspective Image of a Road

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Abstract. Tracking the vehicles in the short distance from the camera using the perspective view of the camera installed above the road requires considering the effect of perspective. Vehicles that are close to the camera are large and easily distinguishable on individual video frames. Moreover, the separation between adjacent vehicles is also high. However, tracking capabilities are deteriorated for longer distances of the vehicle from the camera. The article presents a solution for tracking the vehicles moving away from the camera, based on the image analysis at different scales in order to increase the range of the tracking system. The proposed algorithm utilizes a block matching technique using the correlation coefficients but the size of matched blocks varies for different video frames. Matching can be implemented in several variations depending on the choice of the reference blocks only in the previous frame or averaging of several frames. A particularly useful technique, used in the paper, is the spatio-temporal recursive Track-Before-Detect algorithm, especially for distant objects represented by a small number of pixels.

Keywords: Track-Before-Detect, Multi-scale video tracking, Intelligent Transport Systems.

1 Introduction

Tracking algorithms based on the video systems usually utilise a classical approach assuming the sequential process of detection of the vehicle, tracking and the assignment to a given trajectory. For this reason such systems belong to the class of multi-target tracking [1,2]. Utilising some limitations related to the vehicles' motion trajectory (movements are possible only on a specified plane determined during the calibration of the system), the location and velocity of the vehicles can be determined using only the data acquired from a single camera. Working quality of such system is dependent on a number of factors such as camera location relatively to the road and mutual obscuration of the vehicles associated with it. A typical working location of the cameras is the installation on a pylon or a building on a side of a road. The cameras are often directed perpendicularly to the axis of the road, especially if they are mounted directly

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over the road (e.g. with the use of some overpasses), usually at an acute angle to the road, because their aim is to observe traffic in their near neighbourhood, in particular the license plate numbers. the application of the cameras for the estimation of motion parameters from large distances is troublesome, because of necessary complicated image processing operations, limiting its applicability. The usage of such cameras together with some modern tracking algorithms allows the extension of the working range of the cameras and more importantly some existing systems may be used for this purpose. Unfortunately, the quality of acquired video frames decreases significantly, particularly the resolution of the tracked vehicles and their distinguishability against the background.

An alternative solution is the usage of some Track-Before-Detect (TBD) algorithms, assuming that the object is present on the consecutive video frames [3,4]. Performing the tracking the probability values are accumulated in each step, which are then used for the assignment of the object to the motion trajectory (for high values). A disadvantage of such approach is high computational cost of the TBD algorithm related to the necessary simultaneous tracking of many trajectories, even for an empty road without any vehicles.

The application of the TBD algorithms allows the proper tracking in the presence of strong noise [6]. Nevertheless, in such conditions an appropriate model of the possible trajectories and a large number of observations are necessary. In the non-recurrent TBD algorithms the trajectories may be constructed without any limitations. In most cases the recurrent TBD algorithm can be applied using the data acquired directly from the device, i.e. directly mapping the coordinates from the image into the input data.

2 Track-Before-Detect Algorithms

There are many existing Track-Before-Detect algorithms and one of the most interesting ones is the likelihood TBD [8], which is usually implemented as the likelihood ratio TBD die to some computational reasons.It is initialised by the probability value of the object being in a given state $p(t_0, s)$ divided by the probability of not being in this state $p(t_0, \phi)$. The likelihood values can vary within a broad range and, in contrast to the probability, their integral values equal to zero during the processing are not necessary. The algorithm can be described as:

Likelihood ratio initialisation:

$$\Lambda(t_0, s) = \frac{p(t_0, s)}{p(t_0, \phi)} \qquad for\ s \in S \tag{1}$$

For $k \geq 1$ *and* $s \in S$
Motion Update:

$$\Lambda^-(t_k, s) = \int_S q_k(s|s_{k-1}) \Lambda(t_{k-1}, s_{k-1}) ds_{k-1} \tag{2}$$

Information Update:

$$\Lambda(t_k, s) = L_k(y_k, s)\Lambda^-(t_k, s) \tag{3}$$

EndFor

where: t – time moment, s – state, k – step number, Λ – likelihood ratio, $q_k(s|s_{k-1})$ - state transition, q – Markov matrix, L_k – measurement likelihood.

Measurement likelihood can contain the processing characteristic of the input system [8] and is used for the input of the data. The result is expressed as the Λ value (from the prediction) or the current Λ^- value.

A similar method is the Spatio-Temporal TBD algorithm, where the information update formula mixes input data and predicted positions. The motion update formula utilises Markov matrix for the dispersion of probabilities (or likelihoods) between the current and future time steps. The new informations from measurements improve sharpness of the state space (probabilities or likelihoods). Depending on the value of the weight coefficient α the next prediction step is based mainly on the incoming data (α close to 0) or previous prediction (α close to 1). The basic algorithm can be described as [8]:

Initialisation:

$$P(k = 0, s) = 0 \tag{4}$$

For $k \geq 1$
Motion Update:

$$P^-(k, s) = \int_S q_k(s_k|s_{k-1})P(k-1, s_{k-1})ds_{k-1} \tag{5}$$

Information Update:

$$P(k, s) = \alpha P^-(k, s) + (1 - \alpha)X(k, s) \tag{6}$$

EndFor

where: s – particular space, k – number of iteration, X – input data, $q_k(s_k|s_{k-1})$ - state transition (Markov matrix), P^- – predicted TBD output, P – TBD output, α – weighting (smoothing) coefficient $\alpha \in (0; 1)$.

The tracking algorithm can be used directly, but the crucial aspect of the practical implementation is the limitation of the amount of the input data. One of the possible approaches is the usage of the background estimation for this purpose.

The background estimation can be applied in many variants, but the most typical ones are the utilisation of the exponential smoothing filters, long nonrecurrent moving average (MA) filters (implemented using the pipeline techniques), median filters and median filters with downsampling. The most efficient from the numerical point of view is the exponential filter but its disadvantage is

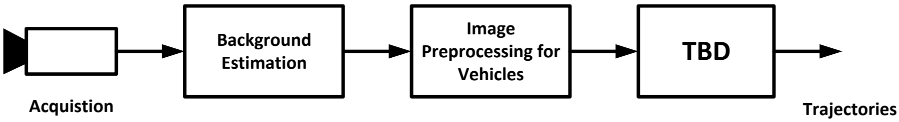

Fig. 1. The idea of the tracking system with the limited amount of computations and improved detection of the vehicles for the TBD

high inertia related to varying light conditions. The estimation of the background allows to determine roughly the size of the vehicle and its location utilised further for a faster initialisation of the TBD algorithm and increasing the separation between the vehicles and the background. The multiple objects tracking using this method is also possible but in this paper only the case of a single vehicle tracking is analysed.

3 Image Preprocessing for Vehicle's Tracking

The application of the correlation coefficient allows the utilisation of the numerical value without the necessity of thresholding, which introduces a noise into the tracking system. Such noise is the effect of the binarisation of the input data (1 stands for the presence of the tracked object in a given location and 0 for no object in this position). The images acquired by the video camera are greyscale or colour ones and the thresholding operation can also be used for them, causing the simplified construction of the system but lowering its efficiency, especially reducing the working range.

An alternative technology is the usage of the systems working with raw data, acquired directly from the measuring sensor (from the camera in this case) or the processed data obtained as the result of some algorithms which do not perform any binarisation. A typical approach is the usage of the two-dimensional correlation interpreted as the degree of matching of two images. Such operations used for the comparison of images (some other ones are Mean Squared Error, Mean Absolute Error as well as some modern full-reference image quality assessment methods [7]) are usually applied for the extraction of some relevant features of the image which cannot be determined without the knowledge of two images. Such operation allows the utilisation of the informations related to the tracked object from some other measurements for the increase of the object's searching effectiveness the based on some other ones.

For the images acquired by the video camera, the representation of the closely located vehicle on the image plane can occupy relatively large number of pixels, while some distant vehicles' representations are much smaller. Tracking objects, which move away from the camera, requires the comparison of the initial image of the object with all assumed possible locations for each possible scale (size) of the object.

The comparison operation using the assumed criteria (e.g. correlation) is used for two purposes. The first aim is to determine the location and the second one is related to the decrease of the object's size in a new space of the input data for the tracking algorithm. Bayesian tracking algorithms using the raw data work efficiently for the pixel-size data, where the vehicle is represented by a single point. During the tracking process the locations are blurred because of the predictor's working properties, so the appropriate data preprocessing is necessary. Direct input of the data, where objects are represented by several pixels is not desired, since the input data contain the informations corresponding to some details of the objects (related to its different parts e.g. some windshields or wheels). In such case the values of the signal can be both positive or negative in relation to the background for different parts of the same object (vehicle), so the total signal can be blurred by the predictor. The resulting signal in the tracking algorithm will be weakened and the tracking accuracy will decrease. Utilising the correlations of an object with the image for an appropriate scale, a significant limitation of the area of interest with maximum correlation values can be usually obtained.

Applying the multi-scale analysis and comparison the two general approaches can be used: scaling can be performed on the smaller image representing the vehicle or on the larger image of a road. In this paper the first approach has been used due to smaller distortions introduced by such operation.

The two-dimensional correlation is defined as the following operation using the two rectangular images (A and B)

$$r = \frac{\sum\limits_{m,n} \left(A_{m,n} - \overline{A}\right) \left(B_{m,n} - \overline{B}\right)}{\sqrt{\sum\limits_{m,n} \left(A_{m,n} - \overline{A}\right)^2 \sum\limits_{m,n} \left(B_{m,n} - \overline{B}\right)^2}}, \tag{7}$$

and can be implemented also for non-rectangular images. It is important for the vehicles' tracking, since depending on the camera's location and orientation the tracked vehicle can be observed from above, side view, front-side or back-side etc. at different angles. In this case a binary mask can be used, which defines the areas of interest and prevents the comparisons with the surrounding of the object. In such case the additional condition for all the summations in the Eq. 7 is introduced: $m, n \in M$, where M denotes the binary mask. The example of such limitation is presented in Fig. 2, where the mask obtained from the background estimation (white pixels) is used for the limitation of the potential area of interest and the correlation values with some other fragments of the scene are filtered out.

Scaling operation performed on the image corresponds also with the same scaling on the assigned binary mask and the number of allowed scales depends on the desired precision as well as the working range (usually several scales are used). In the paper 14 scales have been used experimentally starting from 1 (initial original image) with the step -0.05. The set of images in such scales as well as the appropriate masks are created for each detected image in the scene.

In order to utilise the correlation between the basic data and the consecutive video frames it is necessary to consider the influence of changes of the distance on

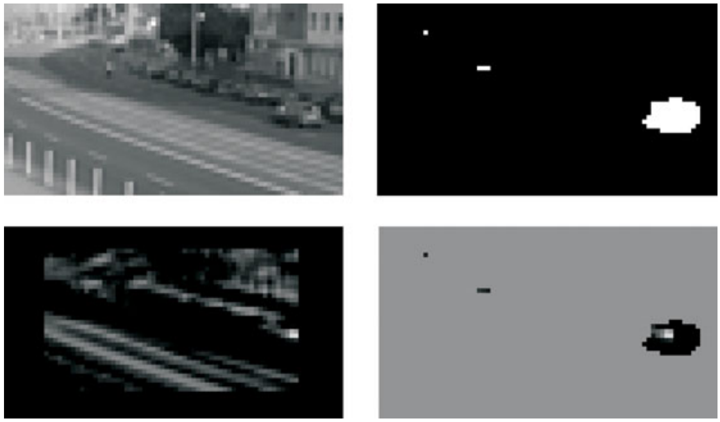

Fig. 2. Original image, mask obtained from the background estimation, correlation of the vehicle's model for the whole image and the same correlation for the masked fragment of the image

the image size. Since the correlation is calculated for the images having different resolutions (size), there may be the situation when the highest correlation values are obtained for the smallest size of the model (a vehicle represented by a few pixels only), while the model having the proper scale leads to lower correlation values with all the fragments of the video frame. Such phenomenon is caused by the presence of image distortions, especially in the nearest neighbourhood of the tracked vehicle, which can be a result of even small changes of lighting conditions. In such situation a set of highly correlated values are obtained for the smallest scales instead of a single one for the proper scale of the model.

This effect is especially strong for the large number of available scales, so in order to reduce this problem the solution based on the utilisation of two masks

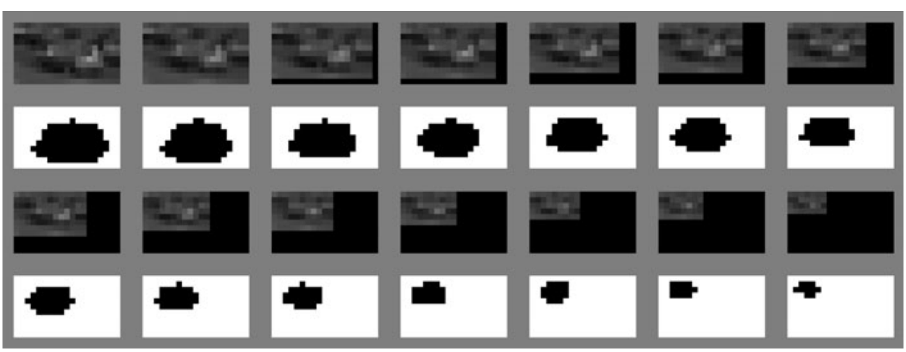

Fig. 3. Different scales of the initial image of the vehicle and the corresponding binary masks for an exemplary vehicle

is proposed. Both, the mask of the vehicle from the current base of the tracked objects (at different scales) and the current mask, originate from the background estimation algorithm. The mask taken from the base can be treated as a good estimate because of its acquisition at a small scale, but the current mask is only a rough approximation, especially for small objects. This mask is usually noisy, regardless of the possible usage of the floating numbers in the background estimation algorithm instead of typical 8-bit integers. Apart from the sensor noise and light changes, small objects cause the blurring effects as well as the local changes of brightness. This effect corresponds to the discrete character of the image (grid) and some limitations related to the sampling process. The maximum excitation of a single pixel may be equivalent to the 50% of excitation of two neighbouring pixels (causing the blurring and change of brightness) or even 4 pixels excited by 25% of the signal, depending on the position of the object relatively to the image grid. Using the simple thresholding of the differences between the current image and the estimate od the background in the presence of noise such blurred differences are often below the threshold level, so the proper mask cannot be determined. Typically, the size of the mask decreases before it disappears, and the tracking algorithms based on the mask cannot determine the proper motion trajectory because of such noise.

The above discussed reasons cause the necessity of using some other methods for object's searching with a small mask. The main problem is related to the high number of false matches, so the combination of mask fitting and multi-scale matching is necessary and the TBD algorithm can be used for the further improvement. The size of the mask from the base is compared to the current image mask in the location of the vehicle. For high differences the scale (mask size) is rejected from further processing due to too small or too large size of the mask. The results of the tracking (correlation range $\langle -1; 1 \rangle$ has been limited to $\langle 0; 1 \rangle$ for better visualisation) obtained using the proposed approach are shown in Fig. 4, where the highest correlation values are achieved for different scales decreasing according to the increase of the distance of the tracked vehicle from the camera.

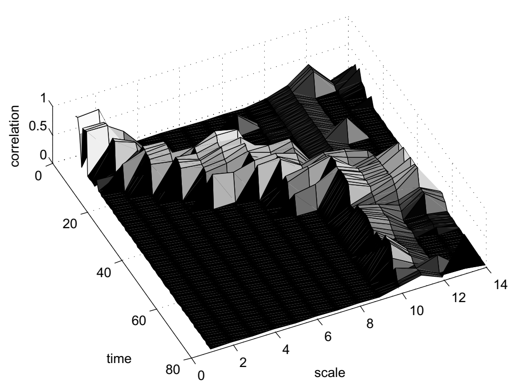

Fig. 4. Results obtained by the proposed approach

4 Conclusions

The algorithm presented is the paper can be efficiently used in the Intelligent Transportation Systems, which utilise vehicles' tracking based on the Track-Before-Detect algorithm. The main advantage of the proposed approach is the improvement of tracking distant objects represented by a small number of pixels observed from a perspective view. Due to changes of their size on the consecutive video frames the discussed multi-scale analysis is particularly helpful for proper tracking of objects moving away or towards the camera. It can also be considered as potential extension for the systems dedicated only for tracking objects observed from the side view.

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Model of the Integrated Vessel Traffic Control System for Polish National Maritime Safety System

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Abstract. Paper describes model of the Integrated Vessel Traffic Control System realizing fusion of data received from shore based station of the Ship borne Automatic Identification System (AIS) and pulse and Frequency Modulated Continuous Wave (FMCW) radars and presenting information on Electronic Navigational Chart. Additionally on the Observation Post is installed Multi Camera System consisting of daylight and thermal cameras showing automatically object tracked by radar or selected manually by operator. Model was designed, built and tested in the scope of research work financed by the Polish Ministry of Science and Higher Education as developmental project No OR00002606 from the means for science in 2008-2010 years.

Keywords: Vessel Traffic Control, data integration.

1 Introduction

The core elements of the Integrated Maritime Policy for European Union are:

- Establishing of the European System of Maritime Surveillance – ESMS; and
- Development of the Vessel Traffic Monitoring and Information System (VTMIS).

Now there are in Poland following elements of the above mentioned systems:

- Two Vessel Traffic Services in the Gulf of Gdańsk and on the fairway Szczecin-Świnoujście equipped with shore based pulse radars and VHF radiocommunication stations; and
- 11 shore based stations of the Ship borne Automatic Identification System (AIS), installed along the coast and connected into the national net of these stations through one national and three regional servers situated in maritime offices: in Gdynia – national and regional and in Słupsk and Szczecin - regional.

Polish Vessel Traffic Services and net of the AIS stations create fully independent systems. To comply with the goals of the EU Integrated Maritime Policy it is necessary to integrate them into one Vessel Traffic Monitoring and Information System, so called Polish Maritime Safety System (KSBM).

J. Mikulski (Ed.): TST 2011, CCIS 239, pp. 354–361, 2011.

Paper describes model of the Integrated Vessel Traffic Control System collecting data received from shore based AIS stations and pulse and Frequency Modulated Continuous Wave (FMCW) radars, performing their fusion and presenting information on the official Electronic Navigational Chart (ENC) issued and updated currently by the Polish National Hydrographical Service – Hydrographical Office of the Polish Navy. Additionally Observation Post constructed for testing purposes is equipped with Multi Camera System consisting of daylight and thermal cameras tracking and showing automatically object tracked by radar and/or selected manually by operator.

Model was designed, built and tested in the scope of research work financed by the Polish Ministry of Science and Higher Education as developmental project No OR00002606 from the means for science in 2008-2010 years.

2 Model of Integrated Vessel Traffic Control System

2.1 System Configuration and Features

Proposed model of Integrated Vessel Traffic Control System has a modular architecture and is subdivided into autonomous modules, which can be individually maintained, upgraded and/or replaced. It is an open-ended system with the possibility to integrate with external systems. The model consists of one Observation Post and one Control Centre. If required, there are abilities to connect to Control Centre several other Observation Posts. All elements of the system are linked through the LAN (Local Area Network). Fig. 1 shows functional diagram of constructed Observation Post.

Observation Post is located together with the Control Centre in the radar laboratory of the Faculty of Navigation of Gdynia Maritime University and consists of the following devices:

1. CRM-203 FMCW radar produced by Przemysłowy Instytut Telekomunikacji S.A. able to detect objects at maximum distance equal approximately 89 kilometres (48 Nautical Miles) and described in [1].
2. X band pulse NSC 25/34 Raytheon radar with the maximum range of detection equal approximately 44.5 kilometres (24 Nautical Miles);
3. Multi cameras system Sargas KDT-360 with display monitor comprising daylight and thermal cameras with the range of several kilometres, showing automatically object tracked by radar and/or selected manually by operator produced by the Polish company Etronika.
4. Stations of the Ship borne Automatic Identification System (AIS) (for choice):
   - Class A and B manufactured by SAAB;
   - Class B: TRUE HEADING; and
   - Class B T300 produced by Transas.
5. Computers with installed two ECDISs: Navi Sailor 2500 and Navi Sailor 4000 manufactured by Transas.
6. GPS receiver MLR.
7. Satellite compass manufactured by Furuno (to stabilise radar data).

The pulse and FMCW radars include plot extractors and tracker devices.

Optional, Observation Post may be equipped with its own hydro meteorological sensors and Radio Direction Finder (RDF) working in VHF band.

The functional diagram of proposed Control Centre is presented in Fig. 2.

The centre consists of server and operator's workstation operating under control of Red Hat Enterprise Linux 5 operating system. The photo of the operator's console is shown in Fig. 3.

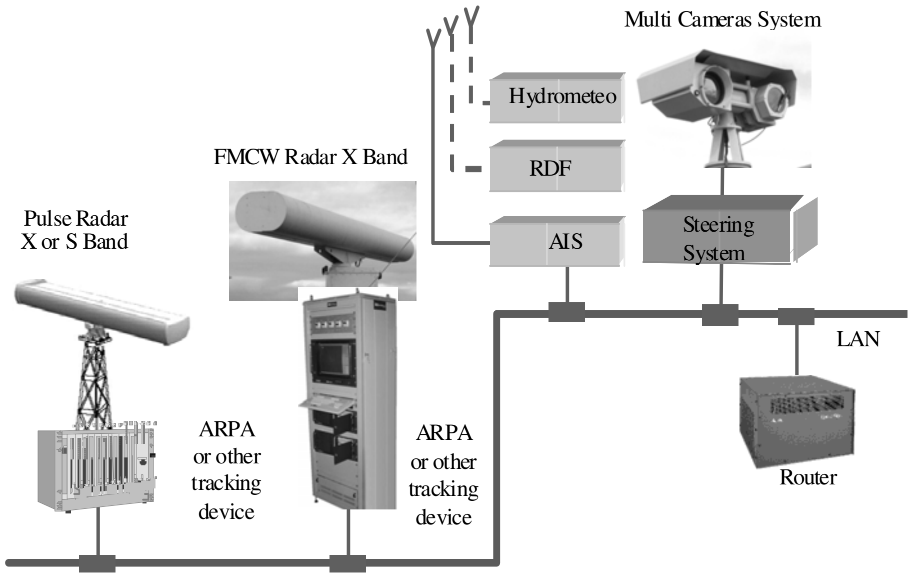

Fig. 1. Functional diagram of the constructed Observation Post

Control Centre receives data from:

1. Local Observation Post.
2. Maritime Safety Centre (MSC) of the Maritime Office in Gdynia located in the building of the Gdynia Harbour Master Office at the approximate distance of two kilometres from radar laboratory and connected with the Control Centre by fibre optical link.

There are following data available for transmission from MSC:

1. Digital data about objects tracked by X band pulse shore based radars of the Vessel Traffic Service (VTS) "Zatoka Gdańska".
2. Radar video signal from above mentioned radars.
3. Data from the Polish national net of the shore based AIS stations.
4. Data from hydro meteorological sensors installed in the VTS "Zatoka Gdańska".
5. Information about bearings for ships calling in VHF band received from Radio Direction Finders (RDF) installed onshore as an endowment of the above-mentioned VTS.

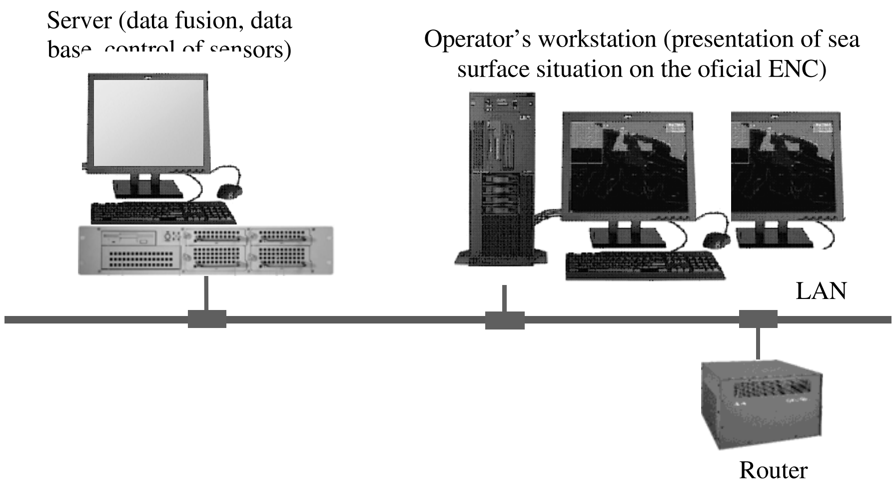

Fig. 2. Functional diagram of the constructed Control Centre

Fig. 3. Operator's console in the Control Centre

The Control Centre performs tasks as follows:

1. Presentation of information in the range of Control Centre operation about current sea surface situation. The process relies on verification and association of data collected from local and/or remote sensors.
2. Monitoring, collecting and updating of sea surface information within the scope of:
   - Tracking of point sea surface objects (ships and buoys);
   - Identification and classification of detected objects;

- Distinguishing between stationary and mobile objects;
- Warning about ships' entrances into areas temporarily or permanently closed to navigation and other areas defined by the operator;
- Warning about ships forcing anti collision and/or routes regulations; and
- Cooperation with others services.

3. Archiving and play back of recorded data.

As mentioned already all elements of the system installed in radar laboratory are linked through the LAN. Fig. 4 presents box for signals' commutation consisting of:

- NMEA buffer SIMRAD RS 5345;
- 7 port NMEA distributor ADU-102;
- 4 channel NMEA splitter;
- Four converters RS232 TO RS422;
- Two supply units; and
- Eleven 12 positions commutating strips.

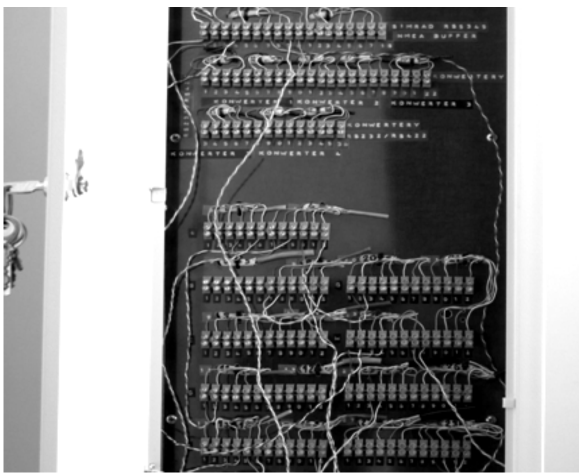

Fig. 4. Box for signals' commutation (inside view)

Described Control Centre is connected with the Maritime Safety Centre (MSC) of the Maritime Office in Gdynia by one mode fibre optical link working in Ethernet standard with speed 2 x 1Gbps and using Ether Channel protocol. Optical modules on both ends of the link work in LX/LH standard. Switch with 24 ports working with the speed of 10/100 Mbps is installed at the end of the link in the Gdynia Maritime University. Separating VLAN with VRF separation is created in order to secure data transmission and entrance to data stored in the MSC. Additionally MAC filtration of the addresses is used to secure against unauthorised enters. Transmitted data are coded in the NMEA standard with messages AIVDM/AIVDO. LAN switch installed in the radar laboratory is shown in Fig. 5.

Fig. 5. LAN switch

Control Centre utilises Dell Power Edge T610 server with four cores and 64 bits processors Xeon X5570, 32 GB of RAM as well as five 300 GB hard disks. Hard disks are operating under matrix system RAID 6. The Dell Precision T5500 computer has been applied as operator's workstation. This machine has 64 bits processor Intel Xeon W5580, 12 GB of RAM, two 300 GB capacity hard disks and graphical card NVIDIA Quadro FX3800. Hard disks in the workstation are operating under matrix system RAID 1.

Information received from local and remote radars and AIS are put to the database. Next, these data are subjected to fusion. Results of fusion are also written down to the base. Communication and control of the sensors, the database and the data fusion algorithms have been implemented in the server. Data from the base and the sensors i.e. radars, AIS and multi cameras system can be transferred automatically to external systems. Information from all local sensors and external systems are presented on two computer displays. Actual positions and movement vectors of targets detected by radars and received from AIS installed on ships are presented in the graphical form on Electronic Chart Display and Information System (ECDIS). The picture from multi cameras system is presented in the separate window. Archived comprehensive sea surface situation can be playing back in any moment.

Presented configuration of the model of integrated system and its functions can be changed. Therefore, modifications and development of manufactured vessel traffic control system are possible in dependence on needs and requirements of a customer.

2.2 Data Fusion

Fusion process used in presented system comprises following main stages (Fig. 6):

1 Unification of state vectors units of targets and bringing them to single timeline.
2 Association.
3 Determination of an updated state vectors.

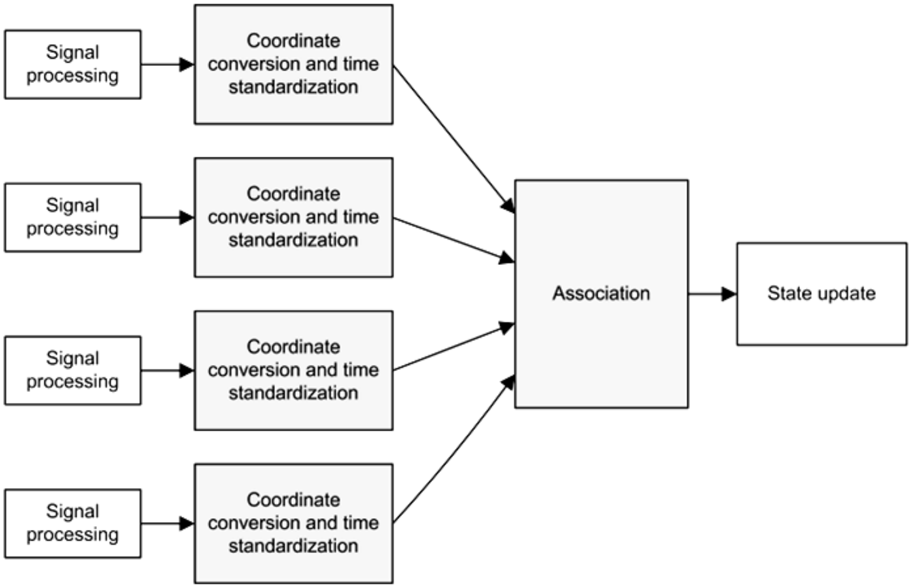

Fig. 6. Diagram of data fusion process

The state vector updates are assigned on the basis of calculated innovation vectors and association probabilities. The algorithm allows for flexible operation, depending on currant conditions (adaptive assessment of interferences) and quantity of information sources).

2.3 Sea Surface Situation Picture

Sea surface situation is presented on two displays, which show information from multi cameras system and from radars, AIS and external systems, in fully independent mode and after data fusion. Radar and AIS data may be displayed in graphical and digital forms. Fig. 7 shows example of information about detected and tracked ships equipped with AIS, presented after data fusion on the operator's display unit.

3 Conclusion

Paper presents model of the Integrated Vessel Traffic Control System designed and constructed in the scope of research work mentioned in the introduction. The system works and is tested. Results of conducted performance tests will be presented on the next conference.

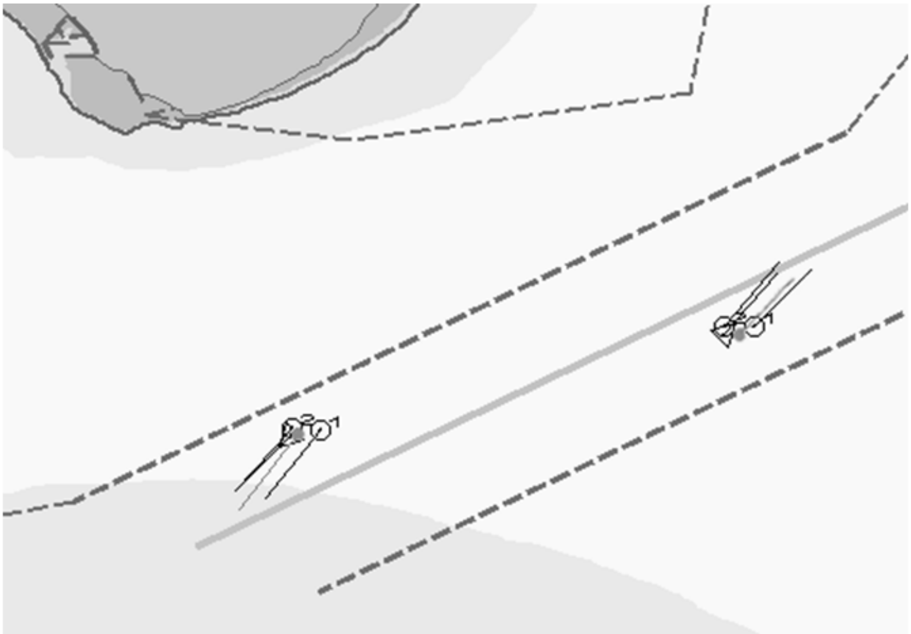

Fig. 7. Two detected and tracked targets (circle 1 – FMCW radar, circle 2 – pulse radar, triangle – AIS, point – objects positions and vectors of movement received after data fusion)

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Polish Research on the Subject of Electronic Toll Collection

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Abstract. Motor Transport Institute has developed functional structure of the National Automatic Toll Collection System (NATCS). It consists of the following elements: four intelligent on-board units (OBU`s), two control gates and laboratory model of National Automatic Toll Collection Centre (NATCC). OBU automatically calculates the amount of charge due, taking into account the vehicle category (admissible weight, number of axles), the emissions class and road distance. OBU is equipped with GPS, GSM and DSRC module, so it is interoperable with other electronic toll systems in the EU member states and meets requirements of directive 2004/52/EC and EC decision of 6 October 2009. The NATCS has recognized not only OBU Tripon – EU but also OBU from Toll Collect (Germany) and Passango from France which proved interoperability in the EU. The efficacy of automatic detection of number plates was 99.9%.

Keywords: NATCS, NATCC, GPS, GSM, DSRC.

1 Introduction

Motor Transport Institute has identified NATCS's functional structure, which consists of the following elements: Intelligent on-board device called TRIPON-EU, which was installed in 4 test vehicles, OBU device installation system using a chip card, two control gates (with DSRC modem and a vision tolling system), laboratory model of National Automatic Toll Collection Centre (NATCC), a proxy server for data exchange between headquarters and the OBU system via GPRS, control centre to manage the OBU devices allowing for management of OBU and analyses of data relating to the collection of tolls, analytical tools for DSRC, image analysis and classification of vehicles.

The on-board device TRIPON-EU (Fig. 1) is available in two different versions. The test system used the version mounted in a single casing collecting all components, including GPS and GSM antennas. This version is designed for installation on the windscreen of the vehicle.

The OBU device should store the following data: vehicle class, vehicle weight, axles or class of emission, registration numbers and contractual details. Data can be entered into the device using a chip card.

The GPS module used in OBU devices supports computing navigation *(*DR*, dead reckoning)* to improve the accuracy of positioning.

J. Mikulski (Ed.): TST 2011, CCIS 239, pp. 362–371, 2011.

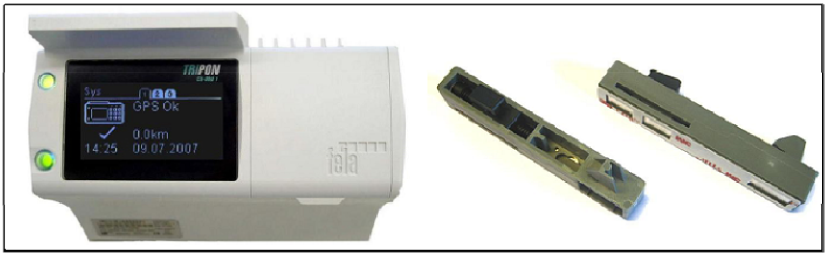

Fig. 1. OBU device and its mounting brackets [3]

GPS data (from satellites), supplemented by the results of computing navigation are used as an input for detection of on-ground facilities. Detected events are logged in the event file. The European EGNOS system can be enabled or disabled through the configuration file activated at the time of start-up. The device is designed to cooperate with Galileo.

The concept of toll control gates in the system tested in Poland is based on experiences of FELA company, collected during the operation of the Swiss system. The following devices are installed on control gates: DSRC locator to carry out transactions with the traffic lane controller (according to EN 15509 standard), vision system ANPR (automatic number plate recognition and photographic documentation (ANPR, only from the front), a local driver software for the registration fee collection.

2 Tests of NATCS

2.1 Test Team and Vehicles

Tests of the NATCS system (Fig. 2) including control of OBU devices, tolling segments at selected sections of roads as well as control gates were conducted in July and August, while vehicles passing through the control gates were registered from 1st July to 30th November 2010.

The tests of the system were conducted by Motor Transport Institute *(Instytut Transportu Samochodowego),* FELA Management AG and Autoguard SA.

The architecture of the system is in conformity with Directive 2004/52/EC [2] and Commission Decision of 6th November 2009 [1] as well as the CEN standards [5] and Road Charging Interoperability (RCI) model [6]. During the test four OBU Tripon EU units were examined, whose task was to detect all events associated with the collection of toll directly in OBU, as well as in the log file and display them on the screen. OBU is also meant to send log files to the proxy server and receive data from the server (data, status information and software updates.) For testing purposes four vehicles were added to the database: Volkswagen Golf – research vehicle of Autoguard, reg. no. WF 93311; Fiat Ducato, vehicle of Autoguard SA, reg. no. WF 4244E, total weight 1 968 kg, number of axles – 2; Volkswagen Crafter, vehicle of Autoguard SA, reg. no. WF 1831E, total weight 3 508 kg, number of axles – 2; Volkswagen Transporter, research vehicle of ITS *(Motor Transport Institute),* reg. no. WH 15904, No of axles – 2.

Fig. 2. Research Team and elements of the system [own work]

2.2 Test Route

Out of the several proposed test route options, the Płońsk - Garwolin, Garwolin – Płońsk route was chosen (Fig. 3).

It is the most diverse one that allows for checking the greatest number of elements of the system, including, in the immediate vicinity of the route, both control gates and allowing the use of even three actual segments of expressways:

- two segments of expressway S7 (planned route Gdańsk – Rabka with total length of 720 km): eastern bypass of Płońsk (a section of 4,7 km, opened for use on 3rd June 2009), western bypass of Nowy Dwór Mazowiecki (a section of 14,6 km, Zakroczym – Ostrzykowizna – Czosnów),
- one segment of expressway S17 (planned road on the Warsaw – Hrebenne route): bypass of Garwolin of 12,8 km length with two carriageways (each with two lanes and a 2,5 metre wide emergency lane and a 4 metre wide median strip, opened for use on 26th September 2007,
- some segments of the national roads: 61 and 637.

Based on the recorded data, transmitted by the vehicle in the form of messages, it was possible to recreate the exact route of the vehicle with the OBU device.

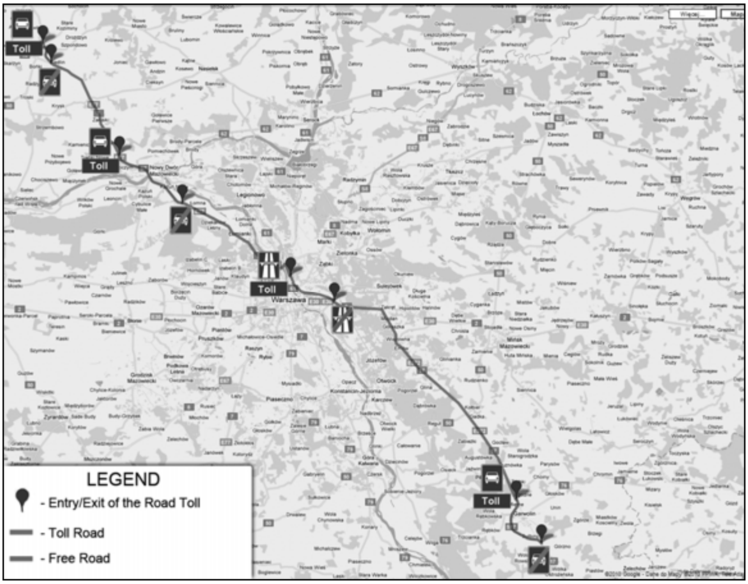

Fig. 3. Test route: Płońsk – Garwolin, Garwolin – Płońsk [own work with using the map from htpp.maps.google.pl]

2.3 Position Dilution of Precision and Satellites Number

One of the most important parameters determining the accuracy of measurement and transmitted in location messages is PDOP (Position Dilution of Precision) - defect in determination of position precision. PDOP is a coefficient describing the relationship between the error of user's position and the error of satellite position.

The value of any of the parameters equal to 0 means that at any given time measurement of position is impossible due to interference, weak signals from the satellites, too few visible satellites, etc. The smaller the value of this parameter (but greater than zero), the more accurate is the measurement. The following descriptions, signal quality, depending on the value of PDOP, are assumed: 1 (perfect), 2 - 3 (excellent), 4 - 6 (good), 7 - 8 (moderate), 9 - 20 (poor), above 20 (bad).

The following charts depict the distribution of the PDOP parameter obtained in the tests. The horizontal axis (X) depicts values for PDOP. The vertical axis (Y) depicts the number of measurements (in percentages) during which a given value of PDOP was obtained. The statistics were calculated based on 4627 measurements of position.

For the purposes of NATCS it was assumed that value of PDOP should be 90 percent of excellent (between 0.1 and 3), for more accurate calculations of position.

The presented graphs (Fig. 4) show that the tested OBU with the number of measurements were respectively 90%, of perfect values, and 8% excellent values. The number of results in the category of poor results (PDOP 9,9 - 2%) exactly matches the number of results corresponding to the absence of visible satellites.

As stated earlier, the values of the PDOP parameter are conventionally described depending on the value, hence: values greater than 0 and less than 1.0 are considered ideal, and from 2.0 to 3.0 excellent, and above 9.0 poor.

Analysis of the measurement data of the PDOP parameter and the number of satellites used during the test showed that more than 90% of the PDOP measurements were lower than 1, which should provide location accuracy with an error of no more than 6 meters. For 8% of the measurements the PDOP parameter was between 1 and 3, but 2 % was poor value (9.9), this happened at the time of activation of OBU and was associated with synchronizing the GPS receiver.

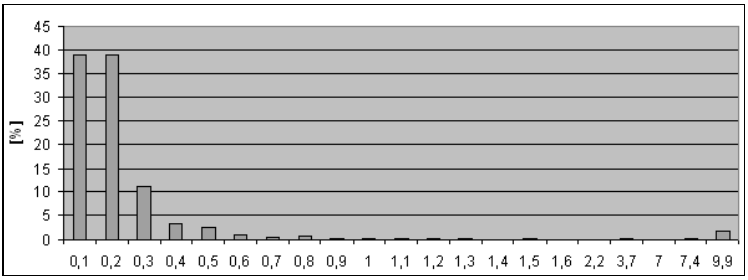

Fig. 4. Distribution of PDOP for all OBU [own work]

For the purposes of NATCS it was assumed that GPS receiver in OBU should track at least 5 satellites, for more accurate calculations and in the event of the loss of signal from one of them. The number of satellites used for measurements of all OBU devices is presented in Fig. 5, as follows: 5 – 10%, 6 – 17%, 7 – 25%, 8 – 22%, 9 – 16%, 10 – 7%, 11 – 2%.

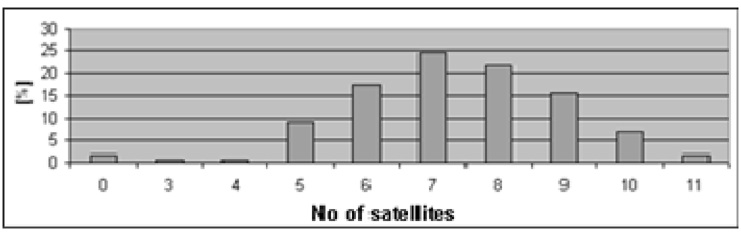

Fig. 5. Number of GPS satellites used for location measurement [own work]

Four OBU`s Tripon EU taken part in tests have got precision and accuracy and used for the purpose of location measurement value 99% from 5 to 11 satellites.

As part of the project, two DSRC gates with tolling system were prepared. This has allowed for testing of the following functions:

– operation of DSRC microwave devices
– operation of visual system ANPR system (automatic number plate recognition).

Data obtained from the passage of vehicles through the gates were stored in a separate database. Gates used for testing were described as follows:

- ITS Demo (UID=1000, 2),
- Autoguard Demo (UID=1001, 3).

Based on the tests, tables were developed for each of those gates:

- Image Records – contain records on photographed vehicles (possibly identified by ANPR),
- DSRC Records – contain records on passing vehicles detected by the DSRC system.

2.4 ANPR and DSRC Results

From 1st July till 30th November 2010, 2964 vehicles passing through control gates were registered n the database of the system. Not all vehicles were equipped with OBU.

During the tests at the ITS Demo and Autoguard Demo gates, using the DRSC system, passage of 24 test vehicles was recorded. During the tests at the ITS Demo gate as many as 667 photographs of passing vehicles were taken (e.g. Fig. 6).

Fig. 6. Registered vehicle, registration number WH 15904, taken on 15.07.2010 at 07.22:26, accuracy-0.960 [own work]

During the tests at the Autoguard Demo gate 2297 photographs of passing vehicles were taken. Example of the vehicle photo is presented in Fig. 7.

The registered vehicle was equipped with a French made OBU device - Passango (DSRC) and a German made Toll Collect (GPS / GSM). It was fully identified in the system as a user, which means that the NATCS system is interoperable and can work with both, systems of DSRC type as well as GPS / GSM systems.

During each and every passage the operation of control gates as well as the conformity of the DSRC data with the ANPR (automatic number plate recognition) reading was verified. For the purpose of the second stage the on-board OBU devices were replaced with new ones. Due to a mistake the devices were wrongly installed, however the system immediately discovered the error.

Also the operation of the control gates was tested – mainly with respect to the detection of various vehicle speeds. Thanks to this, it was possible to adjust the software and then to check the newly replaced on-board OBU devices with respect to the correctness of detection of vehicles coming up to the control gate at especially low selected speeds. The system detects vehicles travelling at speeds of 1 to 200 km/h.

Discrepancies between indications of impulses from the road or tachograph were verified – depending on the vehicle – and the GNSS readings. The verification was performed using the "Delta Tacho". Thanks to that it was determined that in the case of Volkswagen Transporter the tachograph readings were 2-3% lower than the satellite measurements, while in Autoguard's vehicle the road impulses were 2-3% higher than the satellite measurements. This fact shows that in the case of loss of GNSS signals, one can measure distance on the basis on devices checking if the passage of vehicle through a tolling point took place via the appropriate route.

Fig. 7. Picture of vehicle registration number WWY 07512, taken on 28.09.2010, at 09.25:53, accuracy - 0.980

Furthermore another parameter was checked - the correctness of detection of irregularities by the OBU on-board unit by disconnecting the tachograph signal, and then purposeful incorrect switching on of this signal while driving. The unit acted correctly and the red diode came on – thus showing a malfunction – instead of the green diode until the time of stoppage.

We also verified attempts to pull out on the route between the segments as well as attempts to drive via alternative routes and secondary passages through segments and gates.

In addition to testing the drives and checking the functionality, the efficacy of the gates was checked, recording all vehicles passing at the premises of MTI *(Motor*

Transport Institute) and at the premises of the AutoGuard company in various weather conditions and at various times of day. The efficacy of automatic detection of number plates was 98%. Errors in recognition related only to invisible letters ("lost") and not wrongly recognised ones. This was mainly due to the reflections of the sun, which indicates that an adjustment of parameters could eliminate this problem almost completely. The system control centre has a post for analysis of unrecognised registration number plates, which accurately detects the vehicle registration numbers, and thanks to this the efficacy of the system increases to 99.9%. In one case, a passenger car number plate was obscured by the semi trailer of the preceding vehicle, as a result of which the first two letters were not read. In this case, the right solution might be to change the camera angle.

During the test run and the other functional tests we verified the system by finding individual weaknesses that were reported as needing rectification. It should be emphasised that some of the improvements were implemented in real time - adjustment of parameters, fixing of minor errors. Other amendments required time – from one hour up to several hours to fix, such as remote modification of the vehicle data in the OBU or change of segment definition.

All objections were resolved on an ongoing basis, thus allowing us to trust the efficacy of such a system in practice. Contact with the operators of the system was fast and seamless. The testes also proved that any attempts to "deceive" the system or any atypical action resulted in correct responses served in the prescribed manner. The compatibility of the system and the OBU devices with the interoperability requirements of the European Union allows one to hope that the idea of a single device, single contract and single invoice is realistic.

The lack of a developed infrastructure - with a minimum of supervision and control infrastructure - and the ease and flexibility of changing the definition of segments and the addition or exclusion of alternative routes, classifications and remote changes in key parameters shows the superiority of the GNSS / GSM solutions over solutions requiring the communication infrastructure for each tolling point or segment, such as the systems based on direct DSRC communication.

During the test actual segments of expressways S7 and 17 were used. In addition, segments of roads No. 637 and No. 61 within the boundaries of Warsaw were classified as toll roads. The ability to define any classification of virtual segments is another element that shows the flexibility of the system, potentially also in terms of defining the same tolls for primary routes and alternative routes. In addition, the segments were defined in terms of individual directions (different number of segments, tolling points in various locations).

All the segments were identified correctly by the on-board devices, and there were no problems in this respect. Each segment consisted of three points, and in order for each one of them to count, all three segments had to be detected by the OBU device. As a result of this drivers who will cut through toll roads, or only pass through them, will not be registered in the system.

The tests were successful and confirmed the efficacy of the selected solutions in accordance with the assumptions of the project.

3 Conclusion

From 1st July till 30th November 2010, 2964 vehicles passing through control gates were registered in the database of the system. In addition to testing the drives and checking the functionality, the efficacy of the gates was checked, recording all vehicles passing at the premises of Motor Transport Institute and at the premises of the AutoGuard company in various weather conditions and at various times of day. The efficacy of automatic detection of number plates was 98%. Errors in recognition related only to invisible letters ("lost") and not wrongly recognised ones. The system control centre has a post for the analysis of unrecognised number plates, which accurately detects the vehicle registration numbers, and thanks to this the efficacy of the system increases to 99.9%.

Analysis of the measurement data of the PDOP parameter and the number of satellites used during the test showed that more than 90% of the PDOP measurements were lower than 1, and 8% had value from 1 to 3.

For the purposes of NATCS it was assumed that GPS receiver in OBU should track at least 5 satellites, for more accurate calculations and in the event of the loss of signal from one of them. Tests results showed that in the case of 99% of measurements at least 5 satellites were used for the purpose of location (the detailed results of satellites: (5 – 10%, 6 – 17%, 7 – 25%, 8 – 22%, 9 – 16%, 10 – 7%, 11 – 2%).

All objections were resolved on an ongoing basis, thus allowing us to trust the efficacy of such a system in practice. Contact with the operators of the system was fast and seamless. The tests also proved that any attempts to "deceive" the system or any none-typical actions resulted in correct responses in the prescribed manner. The compatibility of the system and the OBU devices with the interoperability requirements of the European Union allows one to hope that the idea of a single device, single contract and single invoice is realistic.

The researches clearly confirm that under the existing conditions (development of new technologies, Directive 2010/40 and the European Commission's decision of 6th October 2009), a tolling system, using GPS satellite positioning and GSM will be the best future solution for each EU Member State, particularly in terms of interoperability and flexibility when toll systems may be used for more categories of roads (or all roads) and each category of vehicle.

Tests of NATCS project has been a complete success. The system uses GPS/GSM technologies, but also recognises devices such as DSRC and OBU. During tests, the system recognised French made DSRC Passango device and a German made Toll Collect device of the GPS / GSM type, installed in a vehicle which did not participate in the test, but accidentally ran through the control gate. This implies that the NATCS system is interoperable and can cooperate with both GPS/GSM systems as well as with DSRC types of systems existing in other EU Member States.

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What Is Concealed behind the Hazardous Failure Rate of a System?

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Abstract. Quantitative safety assessment of safety-related control systems consists of many steps, with the creation of a valid mathematical model being the one of most important one. Assumption on constant failure rate of a system leads to numerous approximations that are made in the process of model creation. These approximations need to be coherent with the philosophy of safety assessment and must be discarded if they could artificially increase the safety level of the modelled system. Nevertheless, if probability of the hazardous failure and hazardous failure rate as safety measures are compared, currently used approximations allow to achieve inaccurate or even invalid results of the safety assessment. The scope of the paper covers exact and approximate approach to the safety assessment of a two-channel redundant system structure comprised of dissimilar channels. Outcomes and conclusions of the paper can be immediately applied in many forms of the quantitative safety evaluation.

Keywords: safety, safety assessment, SIL, hazardous failure rate, multi-channel system.

1 Introduction

In some applications a control system is required to perform not only control functions, but also safety functions. This kind of control system is usually referred to as a safety-related control system (SRCS). In many cases, a pure control function needs to comply with safety requirements as well, which renders it safety relevant.

Safety functions are determined by a risk analysis, which suggests technical measures meant to decrease an amount of risk related to a hazard. Higher risk requires higher safety integrity level (SIL) safety function to cope with the risk. The standard [1] defines four levels of safety integrity level – SIL1 to SIL4. These levels have quantitative meaning of a tolerable hazard rate (*THR*) related to every safety relevant function. If assumed that every hazardous failure of the SRCS causes hazardous state, then the SIL has a meaning of hazardous failure rate related to a safety function. According to the philosophy proposed in [1], the SIL is only quantified for hazards caused by random failures. As for the systematic failures, qualitative approach is employed instead.

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Required random failure integrity is mainly achieved by a redundancy applied to various decomposition levels of the SRCS [2] (a level of individual parts, level of system modules or an overall system level). Evaluation of random failure integrity is based on quantitative methods [1].

SRCS can perform one or many safety functions, depending on a specific application and realisation. The paper is, for the sake of clarity and simplicity, focused on the evaluation of the hazardous failure rate of the SRCS, not on its application-dependent safety function.

2 Introduction to a Hazardous Failure Rate of the System

Evaluation of the failure effects on the safety of the SRCS can be done by many (now already classic) methods. Markov chains are often used to reach this goal, given their ability to reflect great number of safety-affecting factors. Another identified methods used for safety evaluation purposes are reliability block diagrams (RBD), failure tree analysis (FTA) or their convenient combinations (e.g. RBD and Markov chains in [3]). The result of an analysis is usually obtained in the form of probability of the hazardous state of the system $p_H(t)$. In order to evaluate SIL of the system according to the standard [1], hazardous failure rate of the system $\lambda_H(t)$ needs to be evaluated instead. Generally, for $\lambda_H(t)$ we could write

$$\lambda_H(t) = \frac{\frac{dp_H(t)}{dt}}{1 - p_H(t)} . \tag{1}$$

The equation (1) is valid only if the $p_H(t)$ has properties of a probability distribution function. Therefore it has to meet the following conditions:

- it is right-continuous, $\lim_{t\to\alpha^+} p_H(t) = p_H(\alpha)$;
- it is monotone non-decreasing, $\forall\alpha < \beta \Longrightarrow p_H(\alpha) < p_H(\beta)$;
- limits $\lim_{t\to-\infty} p_{H'}(t) = 0$ and $\lim_{t\to\infty} p_H(t) = 1$ do exist;
- for each $\forall\alpha < \beta$ is the probability $Pr[\alpha < t \leq \beta] = p_H(\beta) - p_H(\alpha)$.

If the RBD or FTA methods are used, then the equation (1) can be directly applied to evaluate the hazardous failure rate of the system. However, those methods reflect only combinatorial effects of failures on the safety, disregarding their sequence. From their point of view the system can sojourn only in two disjoint states – operational and safe state or non-operational and hazardous state.

If the Markov chains are used to evaluate the safety (if effects of diagnostics on safety are evaluated, for instance) then a state-space diagram is comprised of more absorbing states (there are often two of these – a hazardous state and a safe state that is reached after a failure has been detected and negated). In this case, the $p_H(t)$ does not meet the requirements on probability distribution, because

$$\lim_{t\to\infty} p_H(t) \neq 1 . \tag{2}$$

If the (2) is valid, then some problems (dependent on system structure) are related to an evaluation of the $\lambda_H(t)$, as was elaborated in [4]. All these methods are developed with less or more extensive assumptions that simplify reality, which ultimately means that various methods can lead to different results of the analysis [5].

3 Evaluation of the $\lambda_H(t)$ – Two Channel Structure

Let us assume the SRCS with redundant 2-out-of-2 (2-o-o-o) structure. Fig. 1 shows its simplified block diagram. Furthermore let us assume that only units A and B have effects on safety of the system, therefore they are of our interest.

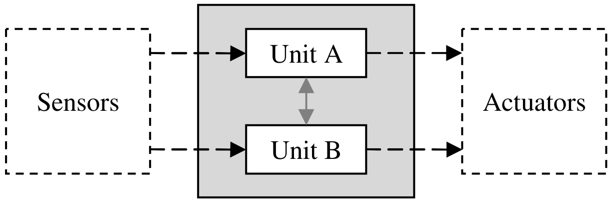

Fig. 1. Block diagram of the two-channel system. Safety analysis is focused on the highlighted logic block comprised of two independent units, although the proposed analysis can be extended to other parts as well.

This kind of structure can reach the hazardous state only if a hazardous failure occurs in both units. The probability of the both channels failing at the very same time is zero, so the hazardous state of the system can occur only if the first channel has a failure and the second channel would fail before the failure of the first channel could have been detected.

Following equations are valid for those two channels, if both of them have constant failure rates

$$p_A(t) = 1 - e^{-\lambda_A t}$$
$$p_B(t) = 1 - e^{-\lambda_B t}, \tag{3}$$

in which $p_A(t)$ and $p_B(t)$ is the probability of failure of the channel A and B, respectively, with the respective failure rates of the channels λ_A and λ_B.

3.1 An Exact Solution

If the both units A and B are statistically independent, then the probability of the hazardous state of the SRCS can be evaluated from

$$p_H(t) = p_A(t).p_B(t). \tag{4}$$

Given equations (1), (3) and (4) we can write exact solution to the hazardous failure rate $\lambda_H(t)$ of the SRCS (5), with the plot illustrated in Fig. 2.

$$\lambda_H(t) = \frac{\lambda_A.e^{-\lambda_A t} + \lambda_B.e^{-\lambda_B t} - (\lambda_A + \lambda_B).e^{-(\lambda_A+\lambda_B)t}}{e^{-\lambda_A t} + e^{-\lambda_B t} - e^{-(\lambda_A+\lambda_B)t}}\ . \tag{5}$$

It is required that the $\lambda_H(t)$ does not exceed a tolerable value given by the specific SIL (and its corresponding *tolerable hazard rate THR*) during the whole useful life-time. Therefore it is required to find the extreme values of the $\lambda_H(t)$. Those extremes can be found in boundary points (t = 0, $t = t_L$) or at the interval $t = (0, t_L)$. The SRCS is assumed to be operational during its useful life-time, which is approximately 15 to 20 years. So it can be concluded that $\lambda_H(t = t_L) \cong \lambda_H(t \to \infty)$.

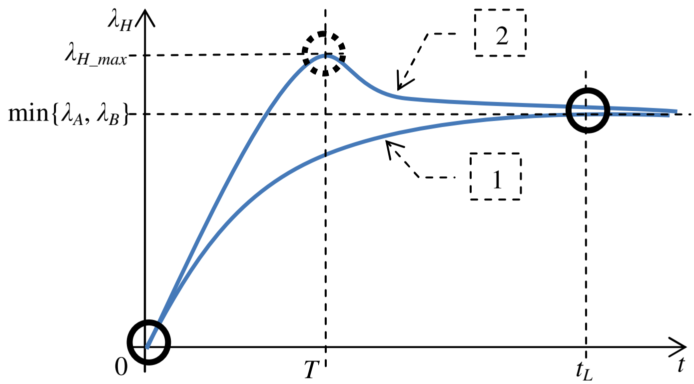

Fig. 2. Illustration of the specific properties of the hazardous failure rate of the 2-out-of-2 SRCS. The curve no. 1 is valid if $\lambda_A = \lambda_B$ and the curve no. 2 is valid if $\lambda_A < \lambda_B$. Note the peak value of the curve no. 2.

According to (5) we can write

$$\lim_{t\to 0} \lambda_H(t) = 0,$$
$$\lim_{t\to\infty} \lambda_H(t) = \lambda_A, \text{if } \lambda_A \le \lambda_B, \text{or} \quad (6)$$
$$\lim_{t\to\infty} \lambda_H(t) = \lambda_B, \text{if } \lambda_B \le \lambda_A.$$

The maximum of the $\lambda_H(t)$ in the time $t = T$ can be found by

$$\frac{d}{dt}\lambda_H(t) = \frac{\lambda_A^2 e^{\lambda_A t} + \lambda_B^2 e^{\lambda_B t} - (\lambda_A - \lambda_B)^2 e^{(\lambda_A+\lambda_B)t}}{(e^{\lambda_A t} + e^{\lambda_B t} - 1)^2} = 0. \quad (7)$$

If the SRCS is symmetric, which means that $\lambda_A = \lambda_B = \lambda$, then there is no solution to the (7) and $\lambda_H(t)$ is monotone increasing on $t = (0, \infty)$ with the maximum value of $\lambda_H(t \to \infty) = \lambda$ (Fig. 2., curve no. 1).

Diversity often serves as a SRCS's safety-increasing measure in multi-channel systems 0. Diversity could have hardware as well as software form (or both). Hardware diversification of the multi-channel system naturally causes the difference in the failure rates of the system channels.

If there are different channel failure rates, then the $\lambda_H(t)$ function has a maximum in the time T given by the solution of the (6), as illustrated in Fig. 2., curve no. 2. The higher is the difference between respective failure rates of the channels, the higher and the more skew the peak value is. For $t \to \infty$ the value of the $\lambda_H(t)$ is

$\lambda_H(t \to \infty) = \min\{\lambda_A, \lambda_B\}$. The effects of diversity on the both probability of failure $p_H(t)$ and hazardous failure rate $\lambda_H(t)$ of the system are pictured on Fig. 3.

The k coefficient is the ratio between the failure rates of the respective channels (8), while $k \geq 1$.

$$k = \frac{max\ \{\lambda_A, \lambda_B\}}{min\ \{\lambda_A, \lambda_B\}}. \tag{8}$$

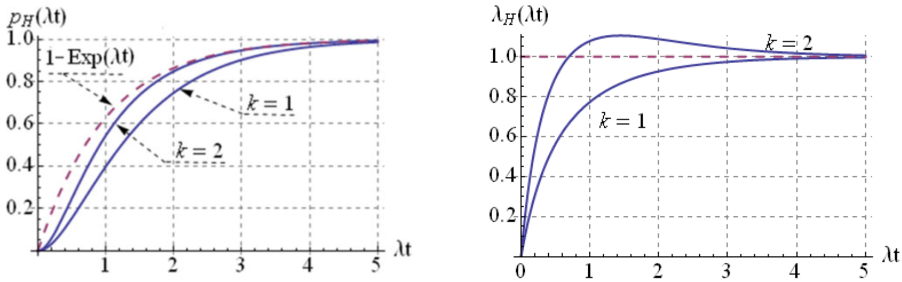

Fig. 3. The comparison of a probability of failure $p_H(\lambda t)$ and a hazardous failure rate $\lambda_H(\lambda t)$ of the two channel system with respect to diversity. Note that the exponential function 1 - Exp(λt) delimits the $p_H(\lambda t)$ from above for any value of k, nevertheless the same assumption is not valid in the failure rate domain (normalised functions are shown for comparison only).

3.2 Approximate Techniques

The standard [7] attempts to avoid different failure rates in the multi-channel systems through the means of "symmetrisation" (estimation of equivalent system with the same failure rates of channels), even though this approach can lead to wrong conclusions. In praxis, an approximate evaluation of $\lambda_H(t)$ based on Taylor series of the function $\left(1 - e^{-\lambda t}\right)$ is often used instead. For $\lambda.t \ll 1$ only first term of the series is important, therefore

$$\left(1 - e^{-\lambda.t}\right) \cong \lambda.t\ . \tag{9}$$

Then the equation (5) with respect to (9) can be written as

$$\lambda_H(t) = 2.\lambda_A.\lambda_B.t\ . \tag{10}$$

This simplification is acceptable from the safety point of view, because the values of the approximate function $\lambda_H(t)$ are always equal or higher than the values of the exact function $\lambda_H(t)$ (Fig. 4.).

It is obvious, that the reliability of the 2-out-of-2 system is worse than the reliability of the system comprised only of one channel. If the use of two-channel system is to be meaningful, then the hazardous failure rate of this system must be much lower in comparison with the one-channel system. This requirement can be met by, for example, periodic check of reliability performed by on-line diagnostics or periodic proof-tests [8].

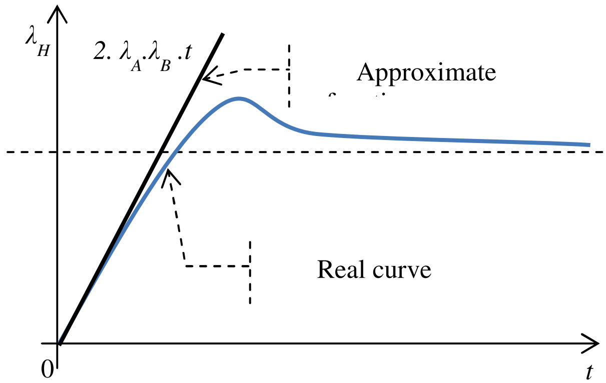

Fig. 4. An approximation of the hazardous failure rate by a linear function

3.3 Meeting the THR Requirements

According to the [8], the maximum time to detect a failure t_D and the maximum time needed to negate its consequences t_N are important when hazardous failure rate is evaluated. Required safety level (and its corresponding tolerable hazardous failure rate $\lambda_{HT}(t)$) can be achieved by constraining the maximum time needed to detect and negate a failure t_O (defined by (11)), as illustrated in Fig. 5. Usually it is true that $t_O \ll t_L$ and t_O could be estimated by the equation (12).

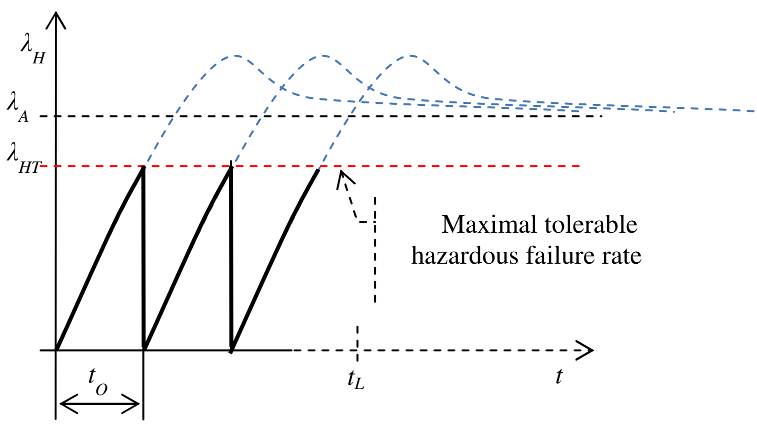

Fig. 5. Effects of the maximum time to detection and negation of failure with respect to the safety and tolerable hazardous failure rate

$$t_O = t_D + t_N. \tag{11}$$

$$t_O \leq \frac{\lambda_{HT}}{2.\lambda_A.\lambda_B}. \tag{12}$$

3.4 Estimation of the t_O in the Probability Domain

Even though it is not compliant with the standard [1], an another approach to the assessment of the safety integrity of the SRCS can be based on assumption

$$p_H(t) \leq p_{HT}(t), for\ \ t \in \langle 0, t_L \rangle, \tag{13}$$

in which $p_H(t)$ is the actual probability of the hazardous state of the analysed system and $p_{HT}(t)$ is the tolerable probability of the hazardous state. The t_L is the useful life-time of the SRCS. In accordance with the standard [1], the *THR* (*de facto* $\lambda_{HT}(t)$) is constant, therefore we can write

$$p_{HT}(t) = \left(1 - e^{-\lambda_{HT}.t}\right). \tag{14}$$

Inequality (14) express the principal requirement on safety, i.e. that during a useful life-time the actual probability of the hazardous state of the system must be less than or equal as the tolerable probability of the hazardous state (indirectly inferred from SIL). The requirement is illustrated in the Fig. 6, where the real $p_H(t)$ is in the time interval $t \in \langle 0, t_L \rangle$ approximated by the exponential function $p_{HA}(t)$:

$$p_{HA}(t) = \left(1 - e^{-\lambda_H.t}\right). \tag{15}$$

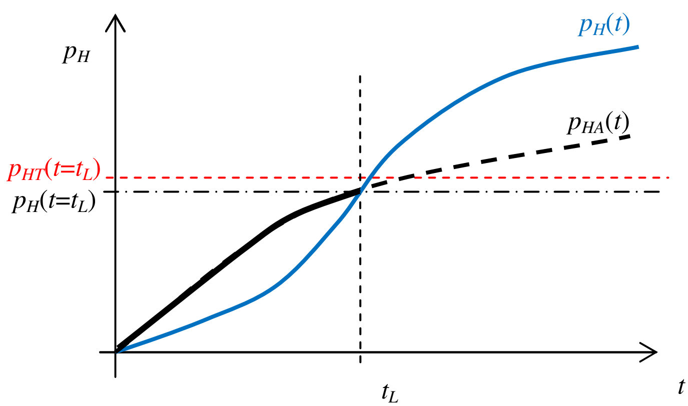

Fig. 6. Approximated actual probability of the hazardous failure of the SRCS by an exponential function pHA(t) for $t \in \langle 0, t_L \rangle$

We can apply the same approach on two-channel system with periodic reliability checks (on-line or proof testing). Now, the $p_H(t)$ needs to be approximated only during the time interval $t \in \langle 0, t_O \rangle$, as pictured in the Fig. 7.

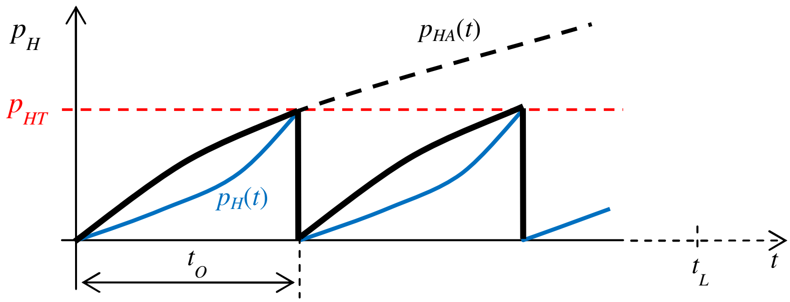

Fig. 7. Approximated actual probability of the hazardous failure of the SRCS by an exponential function $p_{HA}(t)$ for $t \in \langle 0, t_O \rangle$

4 Case Study with the Comparison of the Results

Let us assume the 2-out-of-2 system (Fig. 1) with the channel failure rate $\lambda_A = 2{,}5.10^{-5}h^{-1}$, $\lambda_B = k.\lambda_A$ and requirement on SIL4, which is equivalent to the tolerable hazard rate of at least $THR = 10^{-8}h^{-1}$.

The k indicates that a diversity has been applied to the system, so the Table 1 shows properties of the $\lambda_H(t)$ for various levels of diversity. It is shown that for $k > 1$ the function $\lambda_H(t)$ has local maximum in time $T \in \langle 0, \infty \rangle$.

Table 1. Determination of the peak value of the $\lambda_H(t)$ and the time instant of this value. The values in this table were evaluated for the 2-out-of-2 structure with λ_A =2,5.10^{-5} h^{-1}.

k [-]	λ_B [h^{-1}]	T [h]	λ_{H_max} [h^{-1}]	$\lambda_H(t \to \infty)$ [h^{-1}]
1	2,500.10^{-5}	-	-	2,500.10^{-5}
2	5,000.10^{-5}	5,775.10^{4}	2,764.10^{-5}	2,500.10^{-5}
3	7,500.10^{-5}	3,327.10^{4}	2,797.10^{-5}	2,500.10^{-5}
5	1,250.10^{-4}	1,811.10^{4}	2,817.10^{-5}	2,500.10^{-5}
10	2,500.10^{-4}	8,488.10^{3}	2,828.10^{-5}	2,500.10^{-5}
100	2,500.10^{-3}	8,046.10^{2}	2,837.10^{-5}	2,500.10^{-5}

As seen in Table 1, the peak value λ_{H_max} increases with k. Note that the limiting value $\lambda_H(t \to \infty)$ is always the same, regardless the difference between respective failure rates of both channels. This property should be kept in mind when analysing the safety of the non-symmetrical systems. Even when the massive application of diversity is necessary, the difference between channel failure rates should be as small as practicable.

For some SRCSs the maximum allowed time to detect and negate a failure t_O has to be determined so the system can meet the specified requirements on safety. There are more possible approaches to evaluation of the t_O, as was mentioned above in the paper. The Table 2 shows the results of various approaches of evaluation of the t_O

with respect to the required *THR*. In this case the required *THR* is 10^{-8} h^{-1} (which means safety integrity level SIL4) and failure rate of the one channel λ_A = $2{,}5.10^{-5}$ h^{-1} has been chosen. Various levels of channel diversification were explored.

Table 2. Determination of the maximum allowed time to detect and negate a failure, according to four different methods for various level of diversification. The results assume with λ_A = $2{,}5.10^{-5}$ h^{-1} and *THR* = 10^{-8} h^{-1} (SIL4).

k [-]	λ_B [h^{-1}]	t_O^1 [h]	t_O^2[h]	t_O^3[h]	t_O^4[h]
1	$2{,}500.10^{-5}$	8,0024	8,0000	16,0064	8,0000
2	$5{,}000.10^{-5}$	4,0009	4,0000	8,0024	4,8395
3	$7{,}500.10^{-5}$	2,6672	2,6667	5,3348	4,1728
5	$1{,}250.10^{-4}$	1,6003	1,6000	3,2008	3,7965
10	$2{,}500.10^{-4}$	0,8001	0,8000	1,6004	3,6205
100	$2{,}500.10^{-3}$	0,0800	0,0800	0,1600	3,5563

The values of t_O^1 are evaluated by the comparison of real $\lambda_H(t)$ function with constant *THR* value, while the $\lambda_H(t_O)$ = *THR* condition holds. The values of t_O^2 are evaluated by the approximated approach according to (12). Both exact and approximate methods of t_O evaluation are almost equivalent by comparison. However, the difference between t_O^1 and t_O^2 increase with decreasing difference between the *THR* and the channel failure rate, so if this is the case, then the analysis should be performed with caution. In the third case, the values of t_O^3 were evaluated in the probability domain, using the condition (13). In contrast with the previous two methods, the maximum allowed times to detect and negate the failure were doubled. This variation is not random though, it has origin in slightly different mathematics used in probability domain. It should be emphasised, that even though were these results obtained by a fair and regular method, it is not compliant with the [1].

At last, the Table 2 also shows values of t_O^4 evaluated with the equivalent failure rates of the symmetric two-channel system, according to the standard [7]. It is obvious that this approach is too inaccurate to be taken seriously during safety analysis, but it could serve as a fast estimate. On the other hand, all the t_O^4 values (save for k = 1) are higher than they should be according to exact approach (t_O^1), which is not acceptable from the safety point of view.

5 Conclusion

This paper summarises problems related to assessment of hazardous failure rate of two-channel redundant system followed by the safety evaluation. Founded on theoretical basis, it shows how the different approach to analysis can significantly affect the results, even though the analysis is performed with correctly used methods and with respect to standards. All methods used in the paper, along with conclusions,

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[1] Evaluated with respect to (5).
[2] Evaluated with respect to (12) without symmetrisation of channels.
[3] Evaluated with respect to condition (13).
[4] Evaluated with respect to (10) with the symmetrisation of channles according to [7].

can serve as an outline for analysis of any two-channel system. Further research in this field will be conducted with an aim of extending the theory on multi-channel systems, as similar problems are anticipated during a safety analysis of systems with another structure than 2-o-o-2.

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Technical Support of Traffic Control System of Slovak Agglomerations in NaTIS Project

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Abstract. A necessary requirement for the implementation process of NaTIS in Slovakia is the integration of functional ITS of main town agglomerations into the system. One of the basic components of town ITS is data acquisition from properly located detectors, transmission of these data into the control center and subsequent utilization for traffic control. In case of large agglomerations usually a high demandingness of sufficient telecommunication infrastructure emerges. The paper describes the major parts of NaTIS and of the proposed ITS philosophy of the town Presov. Further a technical solution design is analysed enabling videodata transmission from detectors placed to the control center via a hybrid communication interface. The designed interface with tested compression algorithm enables the usage of present commercial telecommunication networks for videodata transmission in real time.

Keywords: NaTIS, traffic control system, videodata transmission via xDSL.

1 Introduction

The mobility of inhabitants and degree of motorization was increased not only in developed countries but also in Slovakia. The result is increased traffic loading and overloading of existing urban road network. Problems are most evident in towns where there is growth in traffic congestions, traffic accidents and negative impacts on the environment. Intelligent transport systems (ITS) implementation is one of the ways to effectively use the existing road network in the towns and increase its capacity and safety.

ITS is inevitable within the state, thus in towns, to be built in coordination and consistently on basis of interoperable systems based on open and public standards. Design of urban ITS in Slovak must by in accordance with the "Support Programme for the development of intelligent transport systems - National Traffic Information System for Slovakia'' in accordance with the resolution of the Government of Slovakia No. 22/2009 dated 14. 01. 2009. The framework for implementation of the National traffic information system (NaTIS) was established within this Program.

J. Mikulski (Ed.): TST 2011, CCIS 239, pp. 382–391, 2011.

The part of the proposed system environment NaTIS is implementation of ITS in 11 chosen towns in Slovakia. For the purposes of this project Technical study document for each town was elaborated. The Technical study analyzes existing and expected situation, defines critical localities on the basis of this analysis, which is necessary to solve and defines a framework for solution and its technical characteristics, respectively different alternatives of solutions.

In compliance with the NaTISproject a Technical study of ITS for the Presov town agglomeration has been elaborated on author's' workplace. A part of the study is an ideological proposal of Traffic Control System (TCS). The paper offers an functional overview TCS Presov and its components. The detection system is based on video detection of moving objects and belongs to the basic subsystems of the proposed TCS. One of the main problems occurring during implementation of such systems is the insufficient transmission capacity of trunks established in towns [4], [6], [7]. In the article the design of hybrid communication interface and image information processing algorithm implementation is described. The designed algorithm enables utilization of existing metallic trunks and is able to eliminate the insufficient transmission capacity of communication technologies deployed by public operator (xDSL).

2 The National Traffic Information System in the Slovak Republic

The National Traffic Information System (NaTIS) presents the complex system solution for operation and administration of applications, systems for acquisition, processing, publishing, sharing, and the distribution of traffic data about actual traffic situation on Slovak roads. The creation of NaTIS system in comparison to actual trends in traffic research and actual state of traffic problems in the Slovak Republic was accelerated by poor solution of this problem developed in past. Thus, the implementation of NaTIS was necessary.

2.1 Realisation Domains of NaTIS Slovakia

To ensure the basic functionality of NaTIS Slovakia areas four realisation domains presented in the Fig. 1were allocated. Moreover, they could be built separately and in future connected to each other.

- **National Traffic Information Center (NTIC) -** central system for securing the acquisition of traffic data from various agent based information and telematic applications, processing, exchange, publication and distribution of traffic data,
- **Production and acquisition of information** - central evidence system of closed roads, system of planned road servicing, agenda system of oversize and dangerous cargo, etc.,
- **ITS of main roads** - extension of technological equipment and improvement of telematic applications on main roads (mainly, the I. class roads) that secure the detection of traffic flow characteristics, automatic traffic counting, queue detection, acquisition of the meteorological data and state of road surface.
- **ITS of city agglomerations**.

Whole system will be jointed to the Information system of Slovak road network model, whose creation was actively supported by Slovak Road Administration.

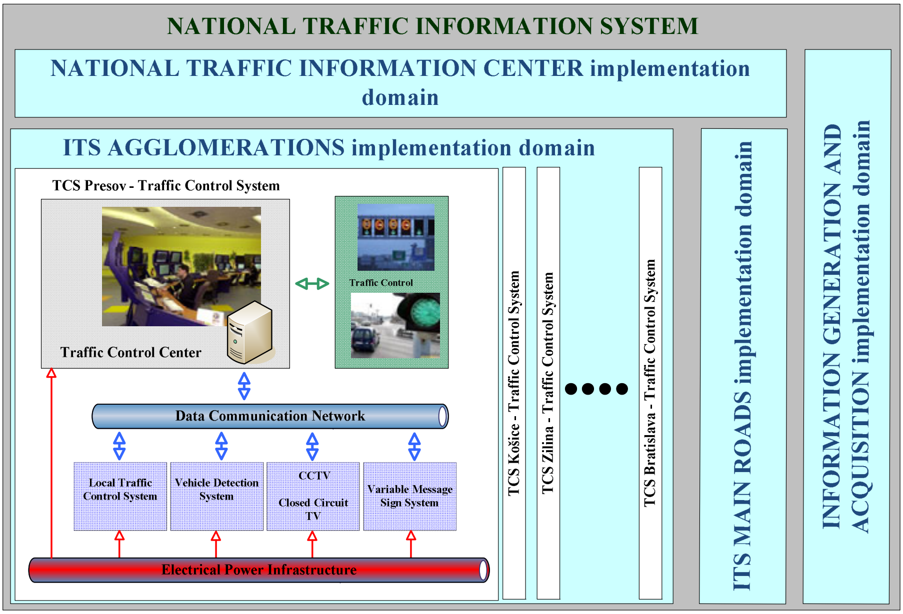


Fig. 1. Realisation domains of NaTIS, subsystems of TCS Presov

From the implementation of ITS in towns point of view, the essential part of NaTIS project creates the 4-th realisation domain that represents solution of integrated ITS systems for 11 chosen agglomerations in the Slovak Republic. Also, the third biggest town Presov was chosen too. In present time, there is not fully operated any integrated urban ITS system in the Slovak Republic. However, the necessary project documentation of urban ITS for all towns has to be ready by the end of 2011.

3 The Traffic Control System in Presov

An ideological design of the Traffic Control System (TCS) in Presov was developed as a part of the Technical study of ITS Presov [2] by experts from the University of Žilina in accordance with the process of ITS implementation within the frame of NaTIS project. The TCS Presov self is designed as an open system which enables integration of other systems, such as navigation system for local parking, urban public transportation etc.

The TCS Presov was designed on the basis of detailed analysis of external conditions (constructional condition and traffic load of the road network, capacity analysis, alternative routes, accident rate, climatic conditions, state of existing technology systems etc.) and a defined range of technological equipment to enable centralized management and influence of traffic flows on urban road network. The main goal of designed TCS Presov was above all capacity increase of the existing road network, traffic congestion reduction and transport safety increase.

These are the fundamental functions of designed TCS Presov:

- acquisition of traffic information and data,
- traffic control and navigation,
- operator monitoring,
- providing of information,
- supervision and repression,
- technological revision of operation.

3.1 Fundamental Subsystems of the TCS Presov

A complex traffic control system designed within the frame of Technical study of ITS Presov consists of three basic layers:

- **technological layer,** which consists of technological devices which monitor, inform and control the traffic situation according to directives of the traffic control center (traffic signal controllers, detectors, variable message signs, monitoring cameras etc.),
- **transmission layer** formed by active transmission and network elements serves for data transmission mediation between the technological and control layer (communication system for data transmission and control from traffic control center),
- **superior control layer** consisting of the control and visualisation system (components of these systems are concentrated in traffic control center).

The mentioned three layers – technological, transmission and superior – are for TCS Presov analytically divided into following subsystems (Fig.1):

1. Local Traffic Control System,
2. Vehicle Detection System,
3. Closed Circuit TV System for monitoring,
4. Variable Message Sign System,
5. Data Communication Network,
6. Traffic Control Center,
7. Electrical Power Infrastructure.

The most complicated problem which is solved within the frame of TCS Presov – method of detected image information transmission to the traffic control center via existing telecommunications infrastructure of public communication operator [3] - is described in following chapters in more details.

3.2 Vehicle Detection System in Presov – Videodetection System

A necessary foundation for traffic control is traffic data acquired from traffic detectors which mediate an image of traffic behaviour in a location requiring traffic-flow control. Primarily the input data for evaluation are the intensity, velocity and composition of the traffic-flow. The data detected are evaluated in such a way to not only provide information about the current intensity but also to predict formation of impulse waves or to identify accidents.

Traffic control within the TCS Presov is designed in two levels: tactical and strategic. For the tactical level the traffic requirements are determined by a detection system on local level of traffic node (crossroad), eventually multiple crossroads in coordination. Detection systems of road light signalling controller are being used.

On the strategic level the traffic situation is monitored on level of the dispatcher workplace central control system, namely by a detection system consisting of traffic survey devices divided according function into:

- Traffic Flow Analyzer (TFA) - traffic survey detector, which function is detecting of immediate characteristics of traffic flow to monitoring and traffic controlling in real time,
- Traffic Incident Detection Device (TIDD) - traffic survey detector, which function is in real time to identify of specified incidents in traffic flow.

VDS (Vehicle Detection System) is a system to collect traffic data from TFA (such as traffic volume, speed, share, time gap, etc.) or traffic incidents from DTID and provide them to Traffic Control Center for traffic management strategy. There are video detectors designed on 32 locations in Presov and these types of detectors cover both functions - traffic flow analysis and traffic incident detection, too.

The camera system and image information transmission within the TCS system have the highest demands on available or build transmission capacities. For the traffic control system according to TP 10/2008 a L1 technological network [1] has been designed, which consists exclusively from optical transmission lines. However the establishment of optical network for image information transmission between all video detectors and the center in such large agglomeration like Presov is too expensive. Therefore it was necessary to design a system utilizing the resources of present telecommunication infrastructure.

The problem of insufficient transmission capacity of such systems can also be solved with the help of the proposed hybrid interface, which uses the designed algorithm for video-sequence processing. The interface as well as the algorithm is described in following chapters.

4 Hybrid Communication Interface for TCS Presov Purposes

The designed hybrid communication interface [5] is based on assumption, that the data detected need to be preprocessed before transmission, subsequently transferred across public telecommunication network and after that decomposed into a form usable in the control center. Following requirements were defined for the interface and algorithm:

- high compression and decompression speed – to enable real-time coding and subsequent fast editing,

- highest possible compression rate – to accommodate the videodata flow to the ADSL system transmission capacity in upstream. However the record quality has to remain visually as accurate as possible in comparison to scanned original.

In this case for video-stream compression a method has been applied, which utilises the fact that the individual frames are similar to each other. The compression algorithm is then based on intraframe coding principle of video-stream.

4.1 Conception of Hybrid Communication Interface

The architecture of the interface designed for hybrid transmission systems (Fig. 2) joining open and closed communication systems contains a design and solution of adaptation unit and its two basic user blocks from the TCS Presov system technological network point of view:

- **Communication block** – serves for transmission of data concerning traffic process (processed information from sensors and actuators)
- **Information processing block** – this functional block processes analogue signals (sensors with analogue output, analogue video-flow from cameras etc.) into a form suitable for transmission over an open communication system.

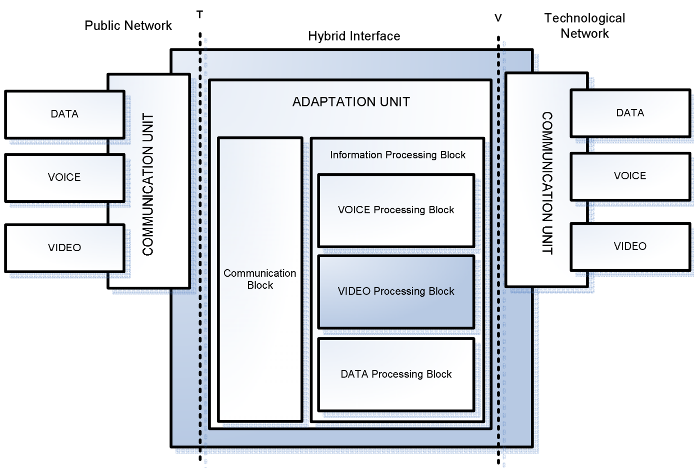
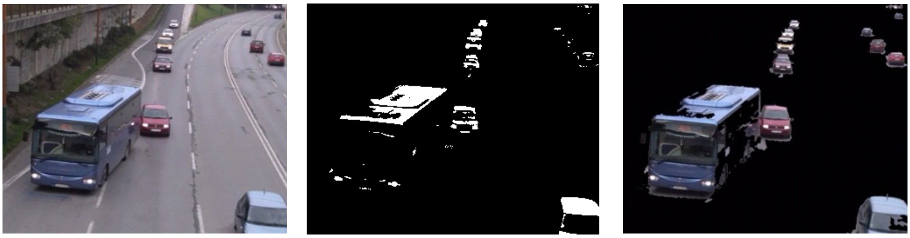


Fig. 2. The hybrid communication interface architecture [5]

4.2 VIDEO Processing Block

The idea of compression algorithm [5] is based on finding and subsequent separation of moving objects (differential objects) on the surface communication. These differential objects have to be identified and consequently separated from background using mathematical operations (in MATLAB programming environment).

The result of compression algorithm operation and the parts of differential objects creation are shown in Fig. 3.



a) b) c)

Fig. 3. The progress of differential objects creation within the transmitted frames a) Basic frame), b) Differential frame (objects identification), c) Differential objects (transmission itself)

Thus coding by channel coder does not include coding of full interframe, but only the differential objects of the individual frames (besides the keyframe). With this procedure a considerable decrease of data needed for transmission over a hybrid communication system occurs. A major advantage is the fact that the differential areas are in this case coded by a lossless compression there through eliminating their distortion. This way transmitted image information is suitable for further processing in the ITS control center (vehicle detection, vehicle velocity detection and so on). Description of differential objects transmission is in Fig. 4.

a) b) c)

Fig. 4. Description of differential objects transmission a) Basic frame, b) N differential frames, c) Basic frame

The search for changes in an image for different applications (especially ITS) requires design of special compression methods. The proposed compression procedure for ITS video-applications does not look at the image as a whole, but divides it into the background and the individual moving differential objects which are on this background. The idea of compression (on the HR-ITS side) and decompression (on the ITS control center side) is in blocks depicted in Fig. 5.

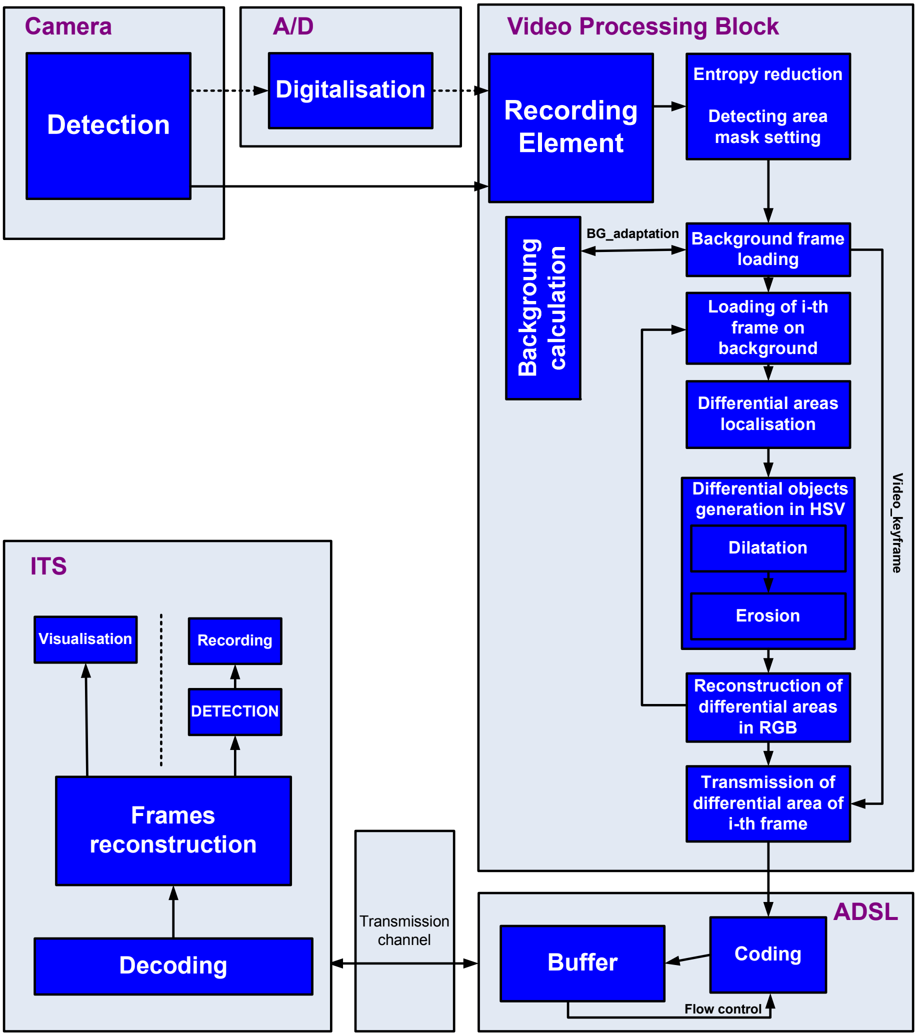
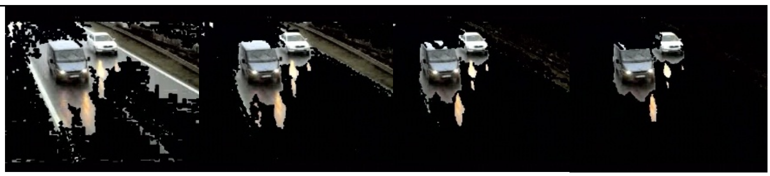


Fig. 5. VIDEO processing block – compression and decompression

4.3 Compression Algorithm – Real Operation

The optimised compression algorithm of Video processing block in ITS-ADSL interface has been tested on a real video sequence from a section of D1 highway in the town Presov. Table 1 shows the results of algorithm in dependence on Treshold parameter setting.

Table 1. Compression algorithm – real operation

Treshold	0,05	0,1	0,15	0,2
SSIM	91,42%	90,17%	89,66%	89,23%
Source data	0,3041 MB/frame 7,6025 MB/s			
Transmitted data(**Average data flow)**	0,0469 MB/frame	0,0183 MB/frame	0,0137 MB/frame	0,0112 MB/frame
Transmitted data (**Average data flow**)	1,1725 MB/s	0,4575 MB/s	0,3425 MB/s	0,28 MB/s
Compression ratio	6,48	16,62	22,20	27,15
Differential objects				

5 Conclusion

In this paper, the National Traffic Information System (NaTIS) developed for Slovak environment is presented. Moreover, one of the main parts is devoted to The Traffic Control System projected for Slovak town Presov. In detail, the algorithm for transport of videodata via narrow band communication technologies like xDSL as a part of Vehicle Detection System is presented too. This system was developed under several requirements and features, namely: automatic recognition of moving objects (foreground/background separation problem), true recognition of moving entities (truck, car, human, etc.), widely used and robust system in connection to possible traffic situations, invariant to light properties, temperature or season, processing in real time.

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Knowledge Based Decision Support System of ITS Standards Deployment

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Abstract. Successful implementation of ITS standards in praxis can be the engine for economic development. The biggest obstacle for deployment of ITS standards in praxis is their volume and high specialization. The project STANDARD shows that there it is possible to reduce a number of pages of standards without significant loss of content. Standards are transformed into extracts according strictly methodology. This idea is viable and brings significant effect in the form of a decision support system for a wide spectrum of users.

Keywords: ITS standards, CEN, ISO, ontology, decision support system, Aristotle square.

1 Introduction

As the actual development of the Road Transport and Traffic Telematics (RTTT) focuses on the mass implementation of intelligent transportation systems (ITS) also in European environment, it is necessary to create a common platform based on the ITS architecture and to ensure functional integration of single subsystems and their interoperability across Europe. Practically, the only way for integration telematics systems represents standardization. In the field of traffic telematics there are standards worked out by European technical commission CEN/TC 278 “Road Transport and Traffic Telematics” or international technical commission ISO/TC204 “Intelligent Transport Systems”.

The scope of activities of both committees is often similar and they develop some of working items in parallel manner according to Vienna agreement between CEN and ISO. Technical committees are divided into working groups (WG) processing numerous standardizations activities related to relevant ITS themes. During the existence of the committees some WG have been suspended or merged together. This means that the whole process is very dynamic along the dynamic development of ITS. The last meeting of TC 204 was held in Prague in April and the last meeting of TC 278 was held in Vienna in March this year. The present status of active workings groups is depicted in Table 1.

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Table 1. Actual status of working groups in CEN and ISO technical committees

ISO WG	Name	CEN WG	Name
WG1	ITS Architecture	WG1	EFC/ETC
		WG2	Freight, Logistics and commercial vehicle operations
WG3	ITS database technologies	WG3	Public Transport
WG4		WG4	Traffic and Traveler Information
WG5		WG5	Traffic control
WG7	Fleet management/Com Freight	WG7	Geographic data files
WG8	Public transport	WG8	Road database
WG9	Integrated Transport Information	WG9	DSRC
WG10	Traveller Information	WG10	HMI
WG11	Navigation		
		WG12	AVI/ERI
		WG13	ITS Architecture
WG14	In-vehicle systems	WG14	After theft recovery systems
WG15	DSRC	WG15	eSafety
WG16	CALM	WG16	Cooperative Systems
WG17	Nomadic devices		
WG18	Cooperative Systems		

It is quite a long way from the approval of a new work item to a completed standard for publication. It usually takes two or three years and the standard passes through several stages – preparatory stage, committee stage, enquiry stage, formal vote stage and the process is finalized by approval stage.

While some ITS application can be provided without standards generally accepted inside the European or world market, this is not the case for the majority of ITS services. As example of a relatively insular type of standards some automobile standards can be mentioned. A curve speed warning system or a lane keeping assistance system need to have sensors inside a vehicle, but they do not have to communicate with other vehicles or with infrastructure. Many ITS services can only be defined in collaboration. It is possible to mention electronic tolling, co-operative systems etc.

1.1 ITS Technology Standards Development Process

The editorial of Computer Standards&Interfaces, ref. [1], raises the question if the crisis of IT technologies is being caused also by non-sufficient support of appropriate standards. The relation between suitable standards and the necessity of coordinated development of technologies is still very important.

The Congress of the United States has published a report "Global Standards: Building block for the future" which addresses standards broadly but it spends considerable space on particular needs of IT standardization.

Being aware of the importance of coordinated efforts in the standardization of ITS across Europe, the European Commission has published essential document "ICT Standardization work programme 2010-2013", ref. [2]. The scope of standardization work programme is spited into 14 priority domains of which the domain 3 "Intelligent transport" is interesting in terms of this paper. Concrete actions are required in specific ITS domains starting from EFC, via digital mapping, co-operative systems to electric vehicles. The response of standardization committee TC 278 refers, on 44 pages, the scopes of standardization items, the work plan and milestones of the fundamental areas of interest, ref. [3].

This impulse has resulted in a great progress in new standards development. As an example of the necessary support to produce relevant ITS standards for the future market regulation is EU support to develop certification and testing conditions for EFC. For illustration of the volume of standards, in 2007 there were about 7 standards in the EFC domain created by WG1. The report of the convenor of CEN/TC278/WG1 to the ISO meeting in Prague describes more or less 45 items which are finished or under elaboration, ref. [4]. Nevertheless publication of standards guarantees neither their successful deployment nor the practical implementations.

1.2 ITS Technology Standards Deployment Crisis?

As follows from the short analysis in the previous chapter the elaboration of the standards supported by common European policy is relatively successful. It is possible to identify about 180 ITS standards at present (together with ISO, it is more than 310), some of them are being elaborated, some are under revision and a significant part of standards has been finished. They are focused on the different market applications, starting from CEN/TC278/WG1 “Electronic Fee Collection” (EFC) up to the ISO/TC204/WG16 “Wide Area Communications/Protocols and Interfaces” (CALM) communication standards as examples.

There are two basic problems limiting their successful utilization in real praxis. ITS standards are very complex (in general a standard often has almost 100 pages). There are more or less 17 000 pages of ITS standards, which is a huge quantity for comprehensive reading. The standards are frequently written in the Universal Markup Language (UML) or eXtensible Markup Language (XML) conventions and they need an advanced reader. Even for experts in ITS standardization it is often difficult to follow such a complex set of standards. Generally said, standards are not readable at all, it is a problem especially for investors and decision makers. Also for people who plan to propose a new public tender based on existing standards it is very hard to find relevant ITS standards at once.

The deployment of standards must not be the brake of a successful ITS implementation. This is the reason that “deployment” is very frequent word in ITS standardization process.

To facilitate this problem, Mr. R. Williams has published the book “Intelligent transport systems standards”, ref. [7]. This book has two primary objectives: “to list, summarize, and categorize ITS standards that currently exist, or were under development at the time of the writing, and to provide direction and guidance about where to look in the future to find relevant standards for ITS systems”. The book creates relations among different standards and provides short abstract of each of them in a verbal form.

The ministry of transport of the Czech Republic supported two research projects aiming at simplification of information search in sets of ITS standards. The first project ZNALSYS has introduced a new approach to deploy fundamental pieces of information included in standards as application oriented knowledge units. The basic difference to the known full-text programs is that this system works as a knowledge engine mining requested knowledge by the contents and formal semantics being pre-processed in the standards. It also uses different form of logical functions to be able to answer complex questions raised by end users.

The second tool for ITS standards deployment in the praxis, which is end user oriented, has been developed in the project STANDARD. The idea is simple and therefore effective – to enhance reading by reduction of a volume of each standard to a reasonable level of several pages of a concise text within a single document. A new form of document is called Extract. In addition, the project is developed as a web application enabling on-line looking for relevant standards and obtaining specific extracts.

Extracts are created syntactically by semantically oriented analysis of standards. It means that standards are transformed into the same formal structure containing semantic entities disclosing the reader the most important content of the standard. Semantic entities are to chain according to the particular expert elaborating an extract.

The reduction of pages of original standard into an extract was limited to 5 pages with focus to reveal fundamental information of original standard and its possible applications. 175 extracts have been elaborated in the frame of STANDARD project during three years. The web site allows general public or a specialist to find relevant extracts to concrete ITS application in a few minutes at present.

The mechanism of STANDARD project is described in the following part of this paper.

2 Size Reduction of Standards

The basic idea of standards volume reduction is mentioned in the previous chapter. To achieve the same level of results by elaboration of a number of standards by a few experts required to prepare and discuss the methodology. The methodology describes the complete process, starting by standards analysis and ending with description of procedures how to elaborate an extract. The experts are the members of Czech national standardization mirror committee to CEN/TC 278 and ISO/TC 204 and they have at least four-year experience in a standardization process. The completed methodology and the first few extracts elaboration were discussed at several meetings.

The process of volume reduction of ITS standards is possible to formulate with the equation

$$S(P_n, \Psi) \xrightarrow{\otimes} E(P_{\max 5}, \lambda\Psi) \tag{1}$$

The original standard S contains n pages P and information content is depicted as Ψ. The transformation S into extract E could have *max 5* pages. It is a strict regulation. The second important point determines that information content giving information concerning the scope of a standard should be reduced very carefully, in minimum. The parameter λ shall stream to 1, but in reality could be around 0.8. This number was repeatedly achieved by comparative tests of original standards and equivalent extracts provided by independent persons.

The task of reduction of pages without the loss of majority of information content is not valid generally, but standards are very proper for this process, because of strictly defined formal context structure which usually simplifies the extracts elaboration. An experienced expert needs only few hours (average 3-5 hours) to elaborate an extract of appropriate quality.

ISO DIS 12855 "Road transport and traffic telematics - Electronic fee collection - Information exchange between Service provision and Toll charging'' could be an example an extract elaboration to reach significant reduction of pages volume. The original draft of international standard has 107 pages and its extract has 5 pages only. Regardless the reduction to only 5,35 % of original draft pages the extracted information could give to an ordinary person or a specialist sufficient information what the standard says and for what purpose it should be used.

Another standard ISO TR 17452 „Intelligent transport systems - Using UML for defining and documenting ITS/TICS interfaces" has in original version 27 pages which are transformed into 4 pages. In this case the reduction of the text is 7 times into 15%.

The project has been based on the requirement of the Ministry to bring knowledge found in the standards to decision-makers and so to initiate using ITS standards in praxis in the Czech Republic. That is why the extracts have been made in Czech language only. Nevertheless, the complete English version of the searching tool is available on the web site http://www.silmos.cz/standard/en/ and could provide reader with crucial information concerning the outputs of the project.

To conclude this chapter it is possible to summarize basic features of transformation of standards into extracts:

– Extract is a document created by reduction of a standard to approximately 5 pages, prepared according to the methodology with respect to formal and content elements of the standard in such a way that it provides the experts with adequate information about the scope of the standard.
– Extract has become a new type of document exclusively created for raising awareness of existing ITS standards. To assure the consistency and unification of the form, context and content of the extracts a specific methodology for its creation shall be used. Extracts processors must be informed in detail about the whole procedure.
– Extract is a simplified text about a technical standard providing its reader of detailed information about the content of the standard. The aim of the extract is to deliver information about the intended use and application of the standard. The extract does not describe the full scope of the standard, nor replaces the standard itself, its purpose is to provide the specialist the possibility to make a good choice among the standards for his/her intention and guide him/her to buy and use the standard.
– Non experts, as investors or decision makers, could use extracts to define conditions of tenders by specifying relevant standards or raise higher level discussion with suppliers or communicate ITS also at political level.

3 ITS Extracts Searching Engine

The purpose of the project STANDARD is to provide a user with an on-line overview of ITS extracts that are properly classified and make them be found by several searching methods according to his/her needs. The goal of the search is to find relevant extracts or sets of extracts.

The results of the extracts search provide at first the number and the list of extracts being found; then the user chooses a particular standard to get more information, provided by their extracts. All the extracts contain basic information (the number, type of normative document, title, type of implementation to the Czech standardization framework, the classification number within the system etc.). The extracts are also provided with the possibility to get in touch with the author (Question to the author). There is also another tool which is under testing. Twenty standards, the "most important of that time", are provided with e-learning that is done by a particular web application.

This extensive database of extracts includes hundreds or even thousands of heterogeneous information in a form of knowledge entities. This heterogeneity of knowledge is done by wide spectrum of ITS standardization activities, see Table 1. It is not easy to discover information latently hidden in an extract.

3.1 Basic Searching Tools

There are several searching methods to discover semantic entities. The simplest is the fulltext search, which provides the search for a certain standard (group of standards/extracts) by identification of the standard (its number), part of its title or part of its extract´s text or key words. This simple tool is very well known and it will be not discussed more, because it is not able to provide targeted search. The full text search does not bring consistent results for a user who looks for a particular set of standards for a particular purpose in ITS (e.g. an ITS service, an ITS application etc.).

The other possibilities for users' search are: search by user categories, search according to the originator (WG) and search by domain oriented ontology. The first two choices are familiar to all involved in ITS standardization and they are a basic tool in the project. The ontology or similar tool use has been provided in the frame of the research part of STANDARD project and it is described as a particular matter in the next chapter.

Searching by user categories results from the following considerations: USERS are divided according to their particular interest in general or detailed information into four types:

1. Non specialist (general public),
2. Expert category: manufacturer, test laboratory,
3. Expert category: contractor/supplier,
4. Investor/owner.

For the type 1 non-specialist and for the type 4 investor/owner the search is done through simple questions, coming from the fact that these users have only very general information concerning searching information. As a surplus for investor/ITS system owner some variants of thematic classification are available. More advanced searching is available for the type 2 and 3 expert because the pre-defined semantic model is applied. The "Expert" category represents a user who is already familiar with the technical content of the ITS world and market profit of data model that leads him towards the relevant extracts immediately.

3.2 Object Oriented Searching Tools

The ability to search and fuse information from heterogeneous standards or extracts can significantly contribute to the discovery of added value knowledge that is unreachable using classical searching methods. In order to provide an efficient information mining from extracts a knowledge-based model is an optimal solution. Using an ontology approach, a coherent, consistent and non redundant knowledge model could be designed.

In information science, ontology is defined as a formal representation of knowledge as a set of individuals (instances, terms), classes (concepts), attributes, and relations between those concepts. Instance depicts the basic object and it is indivisible. In the sense of the paper an instance unit of text in an extract could be represented as a semantically uniform term. It is also possible to speak about hierarchical categorization which describes the same model as the ontology is.

In theory, an ontology is a "formal, explicit specification of a shared conceptualization", ref. [5], expressed as a shared vocabulary, which can be used to model a certain area. There are universal ontologies, as for example SUMO (Suggested Upper Merged Ontology). SUMO ontology creates high-level ontologies for different domains – finance, computers, geography, transport etc. and it is too generic to help us mining appropriate information from standards. A domain-specific ontology models describing given area of interests in more detail are used more widely.

Creating ontology is not a trivial problem generally and it is especially complicated in the field of ITS. This is the reason that ITS ontology is not being processed until now. The technique of elaboration of ITS ontology is described in ref. [6], but the praxis has shown huge complexity of this process and a simpler tool has been used in the frame of STANDARD project. The discussion with Korean delegation during ISO meeting in Prague highlighted necessity to start with it. The first step should be domain oriented ontology of cooperative systems. This supports a non-conflicting development of standards in this area, because CEN and ETSI are supposed to work out about 40 relevant standards.

The effort to categorize and to describe the people activities on similar and well formalized style has appeared through many centuries. In history a few philosophers tried to create a set of "universal knowledge about the world". From the present point of view they wanted to prepare a model of knowledge system. The first idea came from Plato and this idea was being developed by his scholar Aristotle (348 – 322 B.C) who published two books - Metaphysics and Categories. He tried to recognize basic features and segmented all activities into ten basic categories.

In the writing "Ars Magna" Ramon Llull (1232-1316) described logically combinative graphical system independent on language, culture and religion. It was made absolutely in the feature oriented system predetermining nowadays object oriented modeling. The effort to create universal description language was a part of the work of philosopher and mathematician Gottfried Wilhelm Leibnic (1646-1716). At the beginning of 17th century German mathematicians started to use the term "ontology", practically in the same meaning as we are using it now.

3.3 Categorization Based on Aristotle Square

The discussion within working team of STANDARD project has led to the solution that is possible to implement relatively quickly. This tool of categorization of arbitrary fact is so called Aristotle square of opposition, more generally Aristotelian logic. It is a simple diagram representing relations between four propositions which are logically opposed one another. The scheme of Aristotle square is in Fig. 1, ref. [9].

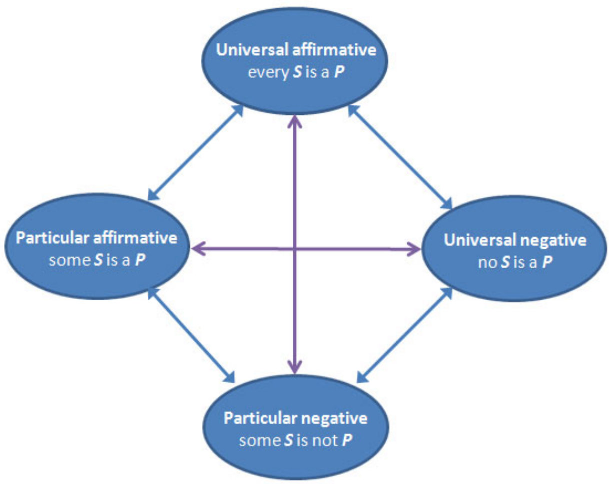

Fig. 1. Aristotle square of opposition

The description of categorical proposition, which contains two terms in general, subject and predicate, could be reduced to one of four logical forms:

1. "A" proposition is valid, if "every S is a P", name: universal affirmative;
2. "E" proposition is valid if "no S are P", name: universal negative;
3. "I" proposition is valid if "some S are P", name: particular affirmative;
4. "O" proposition is valid if "some S are not P", name: particular negative;

According to this scheme the Square of opposition delimits several propositions by their logical relationship (polarity). The use of the tool prevents creators from possible repetitions or overlaying of the categories. The use of the tool has brought 48 different categories classified within three groups of 16 categories. Each of the group is described by "**higher bipolarity**" and each of their elements, "**basic bipolarities**", is subdivided into four elements, (4 x 4 = 16). The three identified groups (higher dipolarities) are User and standard (formal categories), Transport and data (general categories) and Interface and communication (specific categories). For illustration the following table might help to fully understand.

The square of opposition elements are defined by quality (positive or negative proposition) and quantity (particular or universal proposition). The table below shows example of the matrix of the system of categories.

Table 2. Example of the matrix of categories

Higher bipolarities	Basic bipolarities	1	2	3	4
1. User and standard	1.1. User of a standard	non specialist	manufacturer, test laboratory	service (system) provider	investor/ ITS system owner
	1.2 Implementation of a standard to ČSN	not implemented	implemented by endorsement	implemented by English original	implemented by translation
	1.3 Type of a standard	standards for standards ("metastandards")	test standards	product standards	system specification standards
	1.4 Use of a standard in ITS	system design	software	hardware	system operation

To evaluate the applicability of elaborated data model is an interesting activity concerning frequency of use of terms/categories in a set of standards. More than 180 standards have been checked. Table 3 illustrates the resulting facts and underlines the need of a user to be more specific when looking for an extract. A user should combine more categories to get effective number of results.

Table 3. Illustration of numbers of matched results for specific categories of search

Category	Nr. of standards	Category	Nr. of standards
service (system) provider	140	DSRC	54
Data element	106	Hardware	42
investor/ ITS system owner	96	EFC	31
Communication	88	GNSS	22
Software	76	Data-structured language	14
In-vehicle assistant system	61	Driver	14

The web application enables ITS extracts search by combining the categories/terms. This way of search significantly reduces the number of extracts found and leads user to the target very quickly. Another category can be added at any time during the search to make the resulting output more specific. As example – the category "Urban area" raises 68 extracts, in combination with the category "DSRC" we get 24 extracts. To plug together "Urban area"+"DSRC"+"EFC" reveals 10 extracts (EN 12253, EN 12795, …, ISO TS 25110).

Each extract also identifies the way of the standard implementation; whether the relevant standard is implemented by translation, or in English with Czech comments or it is not implemented at all. The membership of the Czech Republic in CEN brings the obligation to implement all European standards (EN); ISO standards are implemented selectively. The implemented standards can be bought via national standardization organization (UNMZ).

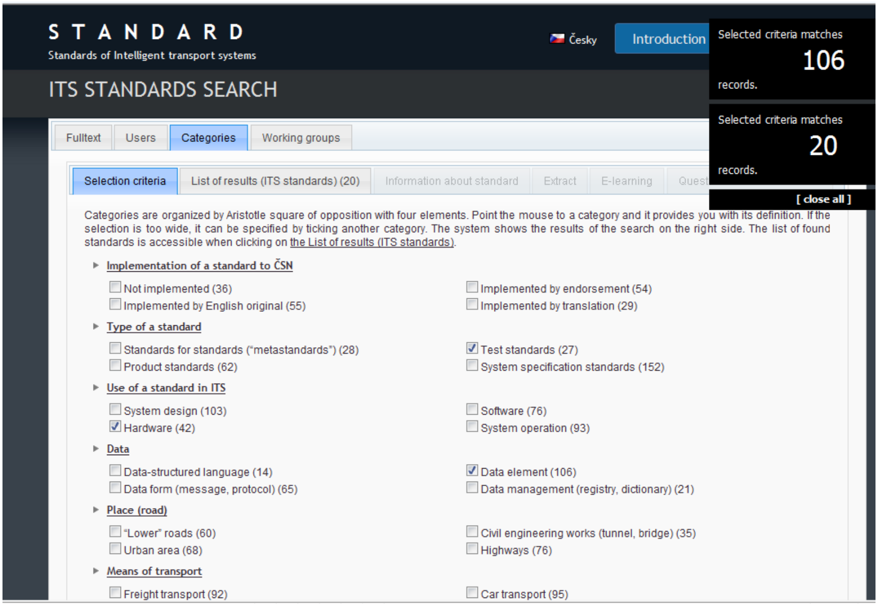

Fig. 2. Search by combining categories

4 Conclusion

Successful implementation of ITS standards in praxis can be the engine for economic development. There is not only a group of ITS standards but the technology of traffic, information and communication systems is covered by many more standards and so providing reference to other groups of standards is essential.

The biggest obstacle for wide use of ITS standards in praxis is their volume (about 20.000 pages) and high specialization (UML, XML, ASN.1…). Nevertheless there are other possibilities how to bring subject of standards to users and support their decisions.

The first one is the title and abstract of a standard as provided by the relevant normalization organizations (as CEN, ISO) on their Web sites. To get the precise content of a standard, and its subject, it is necessary to obtain the full Standard, although there is not enough information to decide, if this concrete standard could be beneficial.

The second one represents a very good possibility how to gain some deeper knowledge of standards, the book of Mr. Williams, ref. [7]. It provides a short annotation of each standard; standards are clustered into groups according to ITS services and the book also contains generic information about ITS.

The third possibility goes more in detail because it transfers a standard to its extract according to the defined procedure. The crucial thing is to reduce a number of pages without significant loss of content. The project STANDARD shows that this idea is viable and brings significant effect in the form of a decision support system for a wide spectrum of users.

The last and more advanced possibility is to develop a real knowledge system. This work is just being developed in the frame of ZNALSYS project, ref. [8]. The aim is to find out knowledge units automatically and linked them through metadata to a qualitatively-new knowledge, which is not explicitly done by single units.

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Technological and Economic Aspects of Intermodal Transport

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Abstract. Various trends such as globalization and the accompanying factors incited the technological and organizational development of intermodal transport. The economic deregulation of the transportation industry and transport market had a tremendous impact on the practice of intermodal transport. For intermodal transport to be sustainable it has to be efficient. The pursuit of intermodal transport development is sustainability especially from financial and environmental aspect. Therefore, intermodal terminals are to be planned and developed according to planned and accomplished sustainability. Intermodal terminal as crucial traffic infrastructure elements are designed to ensure adequate facilities for cargo handling, decreased occurrence of cargo damage, reduced transit time and have affordable dues to attract a maximum traffic flow. Benefits of intermodal transport has to be presented to transport decision makers through information, consulting, promotion, marketing and training activities and education as well.

Keywords: intermodal transport, economic sustainability, promotion canters.

1 Introduction

The main idea or concept of intermodal transportation is to improve the efficiency of the transport chain as well as the means of transport. The key is to use all economic and operational benefits (cost, speed, capacity, flexibility, etc.) of different transport modes and merge it into a single transport chain. The shape of intermodal transport system depends on transport demand, transport service quality and geographic characteristics. For intermodal transport to be sustainable it has to be efficient.

There are many different definition of the intermodal transport. For the purpose of his paper the definition given in 2001 by the UN/ECE (United Nations Economic Commission for Europe), ECMT (European Conference of Ministers of Transport) and the EC (European Commission) in Terminology on Combined Transport [1] will be used. Here intermodal transport is defined as: “The movement of goods in one and the same loading unit or road vehicle, which uses successively two or more modes of transport without handling the goods themselves in changing modes.” Loading unit used for the movement of goods in intermodal transport is intermodal transport unit or ITU. ITU refers to containers, swap bodies and semi-trailers suitable for intermodal transport.

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By extension, the term intermodality is used to describe a system of transport where at least two different modes of transport are used in an integrated way to complete a door to door transport chain. [2] In other words, whenever two or more modes of transportation meet for the purpose of exchanging cargo, whether directly or through intermediate storage intermodalism occurs.

2 Intermodal Terminal

As there are lots of different definitions of the intermodal transport, also the term intermodal terminal isn't standardized. For the purpose of his paper the definition given by the UNECE/ECMT/EC for intermodal terminal will be used: "Intermodal terminal is a place equipped for the transshipment and storage of ITUs." So it can be also stated that intermodal terminal is a place where two or more modes of transportation (air, waterway, rail, and road) meet to interchange freight, either directly or through intermediate storage.

Depending on the terminal characteristics like type of the connections that intersect the terminal (one or more pairs of modes), transshipment operations at the terminal, type of the cargo handled and ownership structure, it is possible to distinguish different types of intermodal terminal. Some of the types of intermodal terminal are: TOFC[1]/COFC[2] terminals, truck-rail bulk transfer facilities and rail-barge facilities.

Transfer at intermodal terminal can be direct and short-term storage. Direct transfer refers to direct transfer from one mode to another. While short-term storage transfer refers to unloading of a cargo from incoming mode on a platform, loading dock or in a transit shed, and after a short period of time loading of the same cargo on the outgoing mode. In both cases incoming and outgoing mode are different modes of transport.

Intermodal freight terminals may be either privately owned or publicly owned. Privately owned terminals cover virtually the entire spectrum of intermodal freight facilities, while publicly owned terminals tend to involve airports, seaports, and inland waterway facilities. Regardless of whether a terminal is privately owned or publicly owned, it may be available for the general public to use or it may be reserved for the exclusive use of either its owner or a specific customer. Most publicly owned terminals are provided for public use. Often, however, the terminal may be leased to a single carrier for its exclusive use. Many publicly owned marine container terminals, for example, are leased to a particular containership company or its terminal operating subsidiary. Of course, any business can ship its freight through such a terminal by simply choosing the carrier having exclusive use of the facility. Thus, restrictions on the use of an intermodal terminal may apply to carriers, shippers, or both [3].

Performance of intermodal terminal can be evaluated through: transport costs, transit time, energy use, characteristics of the shipped commodity (unit value, weight or density, quantity, handling requirements etc.) and type of the transfer involved. Different type of cargo requires different type and level of the service. For terminal

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[1] TOFC – Trailer on flatcar, also called "piggyback" is a concept of loading trailers and semi-trailers onto railway flatcars. This type of terminal typically has large areas for storing trailers and semi-trailers pending loading or unloading.

[2] COFC - Container on flatcar is a concept of loading container onto railway flatcars.

operators as well as transport organizer it is important to know: terminal capacity, transit time, cost of the transfer, quality of the service, available equipment at the terminal, physical layout of the terminal, terminal operating procedures, work hours, number of employees and their experiences, type of the cargo that can be operated at the terminal, type of transfer, percent of terminal capacity utilized at any given moment, timetable of different modes of transport i.e. degree of coordination between modes of transport, etc. Also for the transport organizer it is important to know the cost of transport via different modes of transportation, possible delays due heavy traffic, shortage of truck drivers or railroad crews, shortage of equipment and so on.

Calculation of terminal cost and performance of intermodal terminal are difficult to measure since there are constantly changing due to the dynamic and stochastic characteristics of transport system.

If performance of intermodal terminal is not organized and efficient enough it will become a source of congestion and delays. Also, for intermodal transport to be attractive good intermodal connections are required. This requires establishment of good air, waterway, rail and road networks. Planning of such transport infrastructure can be done only through financial support from both the public and private sector.

3 Disadvantages and Advantages of Intermodal Transport – Technological Aspects

One of disadvantages of intermodal transfer is that it increases transit time and chances of damage due to additional cargo handling. Adoption of new regulation that stimulate development of intermodal transport, and utilization of standardized equipment for unloading and loading of standardized ITU helps to overcome these obstacles. Good communication between multiple parties is also necessary to improve flexibility, to enhance capacity and to improve and retain service quality. Tracking the movement of goods helps to organize traffic freight flow.

Also, introducing ICT[3] technologies in intermodal transport, such as electronic data interchange (EDI), geographic positioning systems (GPS), and automatic equipment identification (AEI) systems helps to organize transport and makes the entire concept of intermodal transport simple and workable. As stated by Muller [4]: "Computerization touches every aspect of intermodal movements: rating, routing, control of containers, clearance, billing, reporting and all other functions. The container revolution produced an improvement in physical aspects, but the computer revolution makes the entire concept simple and workable, regardless of whether or not freight is containerized."

If the system is well organized and well-integrated in transport system various modes working together may provide the shipper best choice of service. One of the reasons for introducing intermodalism is [3]:

- multimodal transport is required if no single mode of transportation connects an origin with a particularly destination,
- “need or ability to move enough product to justify the use of the larger capacity mode and the added handling expense required to make the modal transfer [5]“,

[3] ICT – Information communication technologies.

- to avoid dependence by a single mode or carrier (to stimulate competition),
- to reduce cost, for example while using piggyback system truck carriers reduce tire costs, fuel costs, maintenance cost, insurance decreased, fewer drivers, better equipment utilization, etc. On the other hand in port-rail transportation usage of double-stack train concept (stacking two containers per railcar.
- faster transit times; this is the case in ship-rail routing.

Carrier may sometimes substitute one mode of transportation for another when it becomes expedient or necessary, for example, a truckload carrier may off-load its trailers from TOFC/COFC service and switch to long-distance trucking if a train is greatly behind schedule, air cargo carriers, can ship some freight by truck only. The most important thing for intermodal transport is efficiency, for the shipper it is important that the freight arrives at its destination undamaged and on time, often he doesn't care which mode or modes are used [3].

4 Impact of Internal and External Costs on the Performance of Intermodal Transport

There are internal and external costs associated with a movement through an intermodal system. Internal costs are operator costs that occur while providing intermodal service. These are the cost of collection, distribution, line hauling, transshipment of ITU, labor cost, energy cost, taxes, tolls/fees, etc. They occur as a result of intermodal transfer.

The internal costs of an equivalent road transport network are analogous to those of the road part of the intermodal network plus the collection and delivery parts of the system. The internal costs directly associated with the particulars of a consignment, such as depreciation, maintenance, repair, and insurance costs, are not included because they are assumed to be borne by shippers or recipients [6].

An external cost also occurs while providing transport. In intermodal service external costs are cost of congestion, traffic accidents, air pollution, climatic changes, water pollution and noise. External cost is social cost, the cost that generates burdens on society, and needs to be reduced. Impact of the external cost on the society is subject to condition such are: time period (rush-hour or no rush-hour) and location of the activity (populated or unpopulated area). To reduce external cost it is necessary to stimulate research and innovation of new technologies and regulations since efficient transport and economical growth are still obstructed by administrative regulations.

European commission main objective is to reduce greenhouse gas emissions with 60% by 2050 for freight forwarding services. One of the plans to do so is to stimulate intermodal logistics and transport. The Commission's goal is that 50% of the routes of logistics services of 300 kilometers or more should be carried out by rail or water in 2050. In order to do so, EVO[4] points out that a full liberalization of the European rail network is necessary [7].

[4] EVO – Efficiancy valuation organization – is non-profit organization creating measurement and verification (M&V) tools to allow efficiency.

Why is European Commission goal to route 50% of logistics service of 300 kilometers or more to be carried out by rail or water in 2050? The answer is demonstrated in several studies (Frindik, 2007; Gudehus, 2000; Reim, Uwe, 2007; Sta-tistisches Bundesamt, 2008; 2007; 2006; 2005; Vahrenkamp, 2005), where the lowest barrier for combined transport to be realized at the same or at lower price as direct truck transport is at maximum 300 km distance.

According to Walter [9] the distance average in 2007 in Germany for conventional rail traffic is only 275 km whereas in CT[5] the average distance is 493 km. This shows that CT needs longer distances to act competitively. So, potential for the CT can only be transports which happen at distances longer than 300 km [8].

5 Conclusion

Various trends such as globalization and the accompanying factors incited the technological and organizational development of intermodal transport. Taking advantages such as cost, speed, capacity, flexibility and other advantages of different transport modes allows the carrier to produce more efficient transport service. For intermodal transport to be sustainable it has to be efficient because it affects the entire intermodal freight transport chain. Introducing ICT technologies in intermodal transport helps to organize transport more efficiently and to produce quality service.

Shippers today are becoming less concerned about means of transportation and are more concerned about reliability, speed, shipment tracking, and total logistics costs. Quality of the service is becoming more and more relevant.

Intermodal transport can be competitive to road transport only if the distance between place of the origin and place of destination is longer than 300 km.

European Commission plan is that 50% of the routes of logistics services of 300 kilometers or more should be carried out by rail or water in 2050.

Good and reliable relationship among the various modes of transportation is one of the keys for introducing an intermodal service. For intermodal transport good efficiency of all modes of transport is crucial since changes or problems in one mode or in one part of the country can have a profound impact on other modes and other geographic areas. If performance of intermodal terminal is not organized and efficient enough it will become a source of congestion and delays.

Intermodal terminal are crucial traffic infrastructure elements and are designed to ensure adequate facilities for cargo handling, decrease occurrence of cargo damage, reduced transit time and have affordable dues to attract a maximum traffic flow. The economic deregulation of the transportation industry and transport market had a tremendous impact on the practice of intermodal transport.

The pursuit of intermodal transport development is sustainability especially from financial and environmental aspect. Therefore, intermodal terminals are to be planned and developed according to planned and accomplished sustainability.

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[5] CT - Combined transport - Intermodal transport where the major part of the European journey is by rail, inland waterways or sea and any initial and/or final legs carried out by road are as short as possible [1].

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Regional Observatory as a Part of Road Safety Information System

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Abstract. EU experience clearly indicates that it is necessary to inform and motivate the public on road unsafety to undertake specific preventive efforts, as well as making road users feel responsible for the state of road safety and seek to improve this state gradually to protect their health and life. The implementation of the Warmia-Mazury Road Safety Observatory project will not only be an excellent addition to the activities carried out under the Warmia-Mazury GAMBIT programme. It will also be part of a long-term process adopted, implemented and perceived by the EU as a priority, which aims to reduce the external costs of transport, in particular the costs associated with accidents in road transport.

Keywords: road safety system, safety information system, road safety observatory.

1 Introduction

The complexity of the phenomena of road accidents causes that the effective preventive measures should be conducted in a systematic way - a comprehensive, coordinated and orderly mannered with the involvement of a consistent set of approaches and appropriate technical and organizational tools. This means that it is essential to have an operating road safety system in place, which is capable of continuous improvement and reassurance that all actions for improving the road safety are identified and implemented. The road safety is an issue which is affected by many factors, and the final effect of limiting the number of accidents depends primarily on the most effective action. The current state of knowledge can clearly specify that the main condition, in principle, which forms the basis for a systematic, continuous process of improving road safety, is to create an appropriate basis for long-term action. The development of appropriate organizational structures, forms and methods of management and implementation of road safety activities in the sectoral approach conditions the establishment of such bases. One of the key areas in this sense is to build the Safety Information System [1].

The EU countries experience has clearly indicated the need to inform the public and incite their motivation for specific preventive measures. In this way the road users feel responsible for the situation of safety in the place where they live, and having regard to their health and lives, want this situation to improve gradually. The key to

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the development of such behaviour is the quality of procedures for informing the public about the situation, problems, planned activities, and to enable feedback from the public about what they expect. The communication with the public should be a dialogue, not merely a system of informing a party about the tasks for the other. Therefore, an information system on traffic safety in the region should benefit not only from the databases of traffic incidents, but also of other databases containing the data about the behaviour of traffic participants or used preventive measures.

Accurate knowledge about the causes, circumstances and places of road accidents and collisions is the prerequisite to take the correct action to improve the road safety. It is necessary to periodically collect the data on the behaviour of traffic participants, such as the degree of safety belts use, the share of vehicle drivers under the influence of alcohol or other drugs, or the percentage of drivers exceeding the speed limit. Moreover, it would be wise to collect the data about the preventive measures. All this data should be included in a single and mainstream provincial database on road accidents and preventive measures, and should be used by an information system on the road safety in the region. Similar databases should be created in districts and municipalities. Local authorities want help in gaining the knowledge about road safety. Therefore, the existing interest should be used to raise awareness and promote proven solutions. This information should reach out to the interested parties not only via training but also in the form of manuals of good practice, the publication of material on websites and through all kinds of brochures, reports on road safety.

The institutions handling the road safety issues at the national and regional level should be the sources of data in the creation of an information system. With a choice of information gathered from the institutions cooperating in the field of road safety, an integrated database of traffic accidents, a demographic database and a database of network and road traffic, one can get enough information to perform any kind of analysis, studies or reports. Already on the internet you can learn about the current state of the road safety in some provinces, the activities of the councils and the implementation of regional road safety program.

2 The Idea of Road Safety Observatories

The EU Transport Policy, established by the European Commission in September 2001, in the document called “White Paper. Time to Decide”, not only indicated the goal to be pursued by the programs to improve the road safety – both national and regional – but also showed the solutions, which implementation after the adaptation to local conditions, and accordingly on a smaller scale, would improve the structure of the road safety management system. One of them is the idea created by the EU project SafetyNET and its final product, which is the European Road Safety Observatory (ERSO) [2], [6].

This project involves building a network of road safety observatories throughout Europe. According to their recommendations a National Road Safety Observatory, working with a network of regional observatories, associated with ERSO, should be created in each EU Member State. In Poland, the Motor Transport Institute began the realization of this idea, which to the order of the National Road Safety Council has been developing the concept of operation of the observatory at the national level.

There is also an advanced work for the establishment of regional observatories. One of them – the Warmia-Mazury Road Safety Observatory – is almost completed. Eventually in Poland sixteen of them should exist. From the idea of integration of transport safety point of view, these observatories, initially intermodal, in the future could become an embryonic network of observatories of safety of the entire transport system, from a regional to the European level [3].

Tasks and objectives of the currently operating observatories of road safety in the world depend on the level of their activities: European, national or regional, however, the common features between these institutions can be distinguished. A road safety observatory is a scientific establishment, where systematic observations and research in the field of road safety are carried out and the draft guidelines and recommendations for establishing laws and institutions responsible for implementing the program to improve the road safety at a national, regional or local level are formulated. It depends on the safety management structure, adopted in the country. Particular emphasis is placed on the formulation and dissemination of knowledge, so that it is easily accessible and understandable not only for scientists and experts, but also to politicians and decision makers. One of the oldest and most experienced units of this type is the French Road Safety Observatory, working mainly for the Interministerial Road Safety Committee equivalent to the Polish National Road Safety Council. A broader Dutch system called "Safety Information System" is also very well known.

3 Safety Information Systems

By definition a Road Safety Information System is an organized set of people, procedures of data processing, databases, and devices used for collecting information on the road safety. The role of the system is to ensure constant and direct access to the collected data from different sources, a possibility of using this data and access to bases of knowledge on efficient methods of road safety improvement, and also to ensure constant information exchange between its users. Also it includes the data on key preventive measures like rate of safety belt use, speeding, etc [4].

Taking into account the key role of possessing the information it should be pointed out that the information system constitutes the base of effective improvement in road safety and concerns all the areas related to the issue. The lack of sufficient number of specialists who may assess the undertaken actions from the road safety point of view causes that it is worth considering how to provide a specialised knowledge to create objective and full picture of road safety and social and economic costs connected to it.

Road safety information systems exist in many countries. One of the most popular is the SIS (Safety Information System) used in the Netherlands. It may be presented in a form of pyramid with four levels. The bottom of the pyramid defines interventions, the policy of actions (policy, programmes, and measures, etc.). The changes caused by implementation of a new policy constitute the second level. The next one consists of description of road events and participants of those events on the basis of police registration. The top level of the pyramid contains the data expressing the social cost of accidents. There are causal relations between all four levels (Fig. 1).

The aim of this system is to help to create available information, which will be easily processed during developing sets and documents. The Dutch system has a computerised (Fig. 2) and written form (web page access and printed reports). This system may play an important role during designing, implementing and monitoring the policy on road safety as well as creating a concrete basis for cooperation.

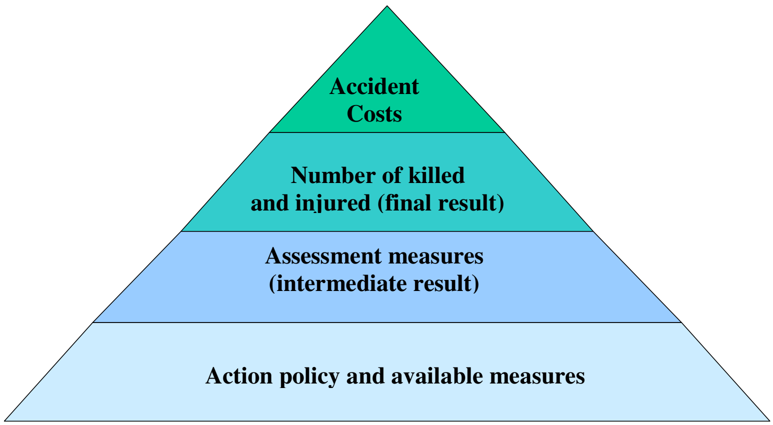

Fig. 1. Elements of SIS – the Dutch road safety information system [4]

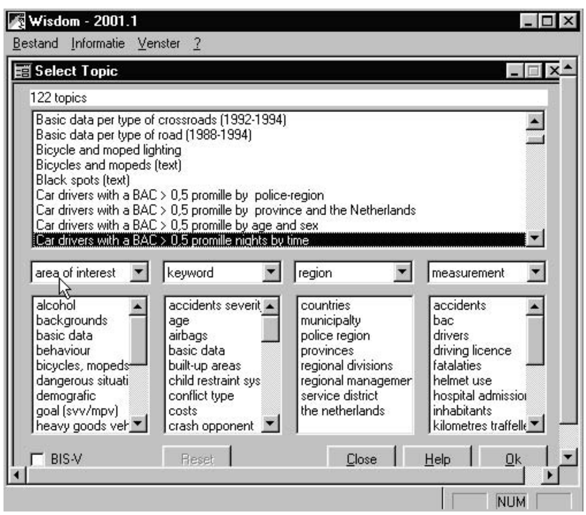

Fig. 2. Window menu in SIS enabling getting the searched data [4]

Starting the application SIS the user receives the data in which he is interested very quickly. On the first screen all available topics are listed. On the next one a detailed menu is available in a form of a table or text. The main screen contains a tool for data processing. This concept was accepted by the European Commission as the one fulfilling requirements for data distribution and knowledge about the road safety. It was recommended to create the internet version of the system to facilitate the access to every citizen of Europe as well as a hardcopy one which can be accessed by people not using the Internet. The system belongs to the Ministry of Transportation. It was built by a team of employees of Research Institute of Road Safety SWOV, which is responsible for system maintenance and operation to the ministry order. The users of the system are units of the ministry and other units on the central and local level. All information is free of charge [2].

4 Road Safety System in Warmia-Mazury Region

Since 2004, the Road Safety Improvement Program WARMIA-MAZURY GAMBIT is being implemented in the Warmia-Mazury region [5]. Its strategic goal is to reduce the number of road deaths by 50% till 2013. Thus, it is consistent with the objectives of the National Programme GAMBIT 2005 and a program to improve safety at the EU level. Also it fits the goals of Polish transport policy.

The analysis of road safety in the Warmia-Mazury region indicates that the strategic objective set was practically reached already for three years before the deadline. In the period 2004-2010 a 49% drop in the number of road fatalities has been reported. This is a proof that the strategy for road safety measures, supported by proper implementation is effective. The best foreign experience shows that the creation of appropriate organizational structures for management and coordination of efforts for road safety, at every level of management, is the key factor in achieving the best results. The creation in 2003, on the basis of the Regional Road Traffic Centre in Olsztyn, of the first national Regional Centre for Road Safety has turned out to be a very good investment and gave a possibility of effective and ongoing projects aimed at improving the key areas of road safety in particular, education and supervision of law enforcement – identified as the most effective, and the least capital-intensive activities.

Despite the undoubted success there is still some weak links in the operation of the road safety system. While the implementation of priority actions in the field of education and communication, surveillance of traffic or road infrastructure is relatively smooth and in accordance with the approved plans, it can be observed that there is a lack of an efficient road safety management system, with its all essential elements. One of these elements is certainly a professionally prepared and continuously updated road safety information system, which would operate on the basis of a regional road safety observatory.

The main objective of the establishment of Warmia-Mazury Road Safety Observatory (W-MRSO) is to establish a platform of knowledge about the road safety with particular emphasis on aspects typical of Warmia-Mazury region. This objective will be achieved through the preparation, launch and continued operation of the website developed and managed by designated specialists for this purpose.

This project represents the first phase of the Information System for the Safety of Road Traffic in the region, planned in the framework of the 3rd Operational Programme for the years 2010-2012. This action is consistent with the provisions of the National Road Safety Programme GAMBIT 2005 and the Regional Road Safety

Programme Warmia-Mazury GAMBIT. Also it fits into the objectives of the Integrated Safety System Project ZEUS developed by the Gdansk University of Technology on behalf of the National Centre for Research and Development. This project involves development of a system of information on the transport safety by building a network of regional road safety observatories. From this perspective, the W-MRSO may be regarded as the first of the effects of implementing a new concept of integrated transport safety system in Poland.

5 Assumptions for Warmia-Mazury Road Safety Observatory

W-MRSO will give its users wide and easy access to the information on the road safety issues and indication of the possibilities of improvement. Apart from didactic and informational role, the Observatory serves as a tool for:

- informing on the present situation of road safety,
- monitoring of execution of road safety programmes,
- facilitating the work of teachers, pedagogues, engineers, etc,
- facilitating the work with media representatives,
- serving the exchange of information between institutions working on the road safety improvement.

Creating the Observatory and its further operation depends mainly on the cooperation between institutions existing in the road safety system. Therefore the particular links will compose the whole of website operation and its representation. A cooperation of the following institutions is therefore required, during its creation and further operation:

- Regional Road Safety Council,
- Regional Road Traffic Centre – (the owner of the Observatory in the case of Warmia-Mazury region),
- Headquarters of Police, Road Traffic Department,
- Headquarters of Fire Department,
- National Road and Highway Administration,
- Regional Roads Administration,
- Health Service,
- Insurance Companies,
- Transport Institutes,
- Media, business
- other institutions and organizations.

Each of the institutions above should has strictly defined scope of activity and will be responsible for providing materials for updating the particular sites also in the case of interactive website.

The assumption of conveying the knowledge through the Internet is to ensure the access to a possibly large audience. However, to provide appropriate form, level and detailed outline of issues, the recipients were divided into the following groups:

- the experts working on the regional and local levels,
- local media,
- non-governmental institutions (insurance companies, foundations, etc.),
- individual recipients (children, youth, parents, teachers, driving instructors, drivers, etc.).

The defining and specifying of those groups is extremely important while developing and publishing materials on the website and promoting the Observatory.

It is assumed that the website of W-MRSO will consist of four major functional modules. The first three will contain information closely related to the region of Warmia-Mazury, while the fourth module will contain scientifically verified and generally accessible knowledge about the road safety issues. The following assumptions briefly characterize the operation of each module.

Module 1: Current information. This module requires frequent updates, since it informs on the most interesting and important events connected with the road safety activities in the region (and beyond). Its purpose is to provide access to information and support the coordination of regional efforts towards road safety. Here you will find links to all materials added to the page.

Module 2: Database on regional statistics. Providing users with reliable data on the level of road safety in the region is one of the main objectives of creating an observatory. The data collected in this module will be presented in different ways (in the form of maps, charts, tables), in accordance with the requirements of specific user groups. These can include hazard maps (of different road users), comparison of trends, and information on the size of the exposure.

In the first phase of the W-MRSO the data collection will match a standard annual report delivered by the regional police headquarters. In the future, this database will be able to be freely extended so as to cover not only the regional level, but also the municipal one.

Module 3: Knowledge base - from the perspective of the region. The knowledge is another important element of the created information system on the road safety. In the concept of W-MRSO it will have a twofold character: the knowledge base dedicated to the region of Warmia and Mazury (Module 3) and a universal knowledge base (module 4). It is assumed that within the framework of this module you will receive comprehensive information on major threats and safety problems occurring in the region (young drivers, pedestrians, children, speeding, etc.). Highlighting the regional specificity is a particularly important element here. Therefore, it is assumed that with the expansion of W-MRSO the emphasis on safety analysis in this area will become larger.

Module 4: Universal Knowledge Base. In addition to current and verified information about the state of road safety in the region, the W-MRSO website users will be also provided a wide range of news on the ways and means to improve safety. Therefore this module will contain information on the best experiences and good practices in basic system operations in the areas of: education, engineering and supervision. In addition, a list of key legislation relating to the road safety and links to other interesting sites, and ongoing and completed projects on specific security issues. The information appearing in each of the four modules is closely linked through a system of internal connections (links), so hitting the word "key" one will be redirected to areas, where more information and materials on the subject can be found.

6 Conclusion

The EU experience clearly indicates that it is necessary to inform and motivate the public on road unsafety to undertake specific preventive efforts, as well as to make road users feel responsible for the state of road safety and to seek to improve this state gradually to protect their health and life.

The implementation of the Warmia and Mazury Road Safety Observatory project will not only be an excellent addition to the activities carried out under the Warmia-Mazury GAMBIT Road Safety Programme – by creating a widely accessible sources of current and reliable knowledge about the dangers of road transport in the region. It will also enter in the long-term process, adopted, implemented and perceived by the EU as a priority, which aims to reduce the external costs of transport, in particular the costs associated with accidents in the road transport. This project should be a starting point for the implementation of regional road safety observatories in each of Polish regions.

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