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Contents

Centralized traffic management system as response to the effective realization of urban traffic fluency ............................................. 4
E. FRANCERIES, K. LIVER

Telemetric system for track measurement in rails vehicles without electric power supply .................................................. 11
T. HEJCZYK

Future of telematics applications as support for increased safety ..................... 17
A. KALAŠOVÁ, J. KUPČULJAKOVÁ

Road Line Traffic Control System - Experiences in testing operation ............. 22
D. KRAJČÍR, T. TICHÝ, M. SPĚVAČEK

The safety analysis in the open transmission standards in railway applications.... 26
A. LEWIŃSKI, A. TORUŃ, L. BESTER

„E-parking” an innovative system for monitoring and information on the occupancy of parking spaces in real time ......................... 31
K. LIVER

The problems with measuring distance in goods wagons ............................. 38
J. MŁYŃCZAK, M. ŚWIERNIAK, A. GWÓŹDŻ

Nonlinear background estimation methods for video vehicle tracking systems ... 42
K. OKARMA, P. MAZUREK

Increasing capacity of infrastructure for public transport co-modality and sustainability in cities ........................................... 49
A. PATLINS, N. KUNICINA, L. RIBICKIS

Integrated problem of ship route planning ............................................. 58
B. WIŚNIEWSKI, P. MEDYNA, J. CHOMSKI, M. MAKA
Centralized traffic management system as response to the effective realization of urban traffic fluency

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ABSTRACT
The paper is a form of mathematical description of the tool - a computer whose primary function is to manage liquidity through follow-up control of the traffic (in less than 1 second) to send signals to the drivers of management traffic light intersections of application is mentioned.

The purpose of this paper is to provide reliable knowledge in this area with particular emphasis on implementation of the criterion of maintaining traffic flow take account of any abnormalities that occur as a dynamic and random variables in the urban space.

KEYWORDS: intelligent transport system, IT

1. Introduction for ITS objectives
Conditioning economical and social aspects, each city wants to find solutions to organize the best circulation of people and merchandizes on the network of the metropolitan area.

But, what is the best solution and who to reach it?

40 or 30 years ago, the main objective was easy to understand, single and frequently oriented to make the traffic flow growing up and growing up again.

Today, ways of thinking the cities are different. It’s impossible to cancel and forget private cars, but a bigger “place” is requested for pedestrians, bicycles, public transports and lower level of contamination.

Quality of life in the cities is now the main objective of the responsible of the cities.

Requiring different priorities in relation with each local strategy an I. T. System must be able to give answer to several aspects.

- Increase traffic flow in some dedicated places
- Control traffic flow
- Manage public transport priority
- Control the contamination’s levels
- Create and protect pedestrian’s or bicycle’s areas
- Increase the urban security
- Use traffic lights to manage speed
- Inform the citizens
- Help citizens during travel to park their cars
- Create alternative in the ways of “moving in the city”

A good solution is a solution able to apply and assume several solutions
2. Traffic management in metropolitan area (Complexity of the network and liquidity flow)

Traffic flow crossing the network of the city is like water inside pipe. This network has to support conditions and rules. Physical and fixed parameters
• Street size
• Intersections complexity and basic capacity

Irregular events
• Dynamic evolution of traffic flow
• Perturbation and random events
• Incidents
• Each change on green time traffic light

Unforeseeable and permanents modifications of the network
• Pressure on pipe
• Permanents new balances

Consequences
Flow is not a regular one and traffic jams are the consequence of this irregularity and a frequently bad balance between offer (Physical capacity associated with green time) and demand (Traffic flow)

3. Measurement of efficiency or inefficiency

To make the evaluation of the efficiency or inefficiency of a network, traffic conditions and parameters, main criteria used are “travel time”, “waiting or stop time” and “quantity of flow able to cross city or area.

Several research have been done to give an expression of one synthetic criterion, the “Delay” representing the losing time between a free circulation without stop, without red traffic lights and a real travel respecting rules and traffic conditions.

First approach
• “May” Model considering free and regular arrivals
• Considering also a higher capacity than traffic flow in circulation

Figure 2 is representing the problem to be solved and in the red surface the value of this “Delay criterion”.

“Arrivals” are considering regular on a line of traffic lights and “departures” are considering zero when the traffic light is red and constant to maximal capacity flow when the traffic light is green.

The expression of the Delay is like following.

\[ R = \frac{q r^2}{2(1 - y)} \]

Where \( y = \frac{q}{w} \)
\( q \) - flow of arrivals
\( w \) - maximal capacity flow of departure

Second approach
• Loosing time within free movement
• “University of Bordeaux” Model considering managed arrivals by departure of precedent traffic light
• Taking in consideration loosing time for each beginning of green light

The figure 3 shows the representation of the new area for the Delay.

Within this approach the expression of the Delay is like following and depending of several cases in saturation conditions or not.

\[ R = N Decal + \frac{N(N + 1)}{2} \left( \frac{q_1 - q_2}{q_1 q_2} \right) \]

\[ R = N(Decal + TR) - \frac{1}{2} \int_0^{TR} 5(t) \, dt \]
Centralized traffic management system as response to the effective realization of urban traffic fluency

4. Evaluation and evolution of “delay” in case of bad balance between offer and traffic flow

For this evaluation, the following definitions are taken.
- “Traffic flow” : Arrivals on traffic lights
- “Offer” : Instantaneous physical capacity and green time on traffic light

Using a simulation process on a reference network with individual rules for each vehicle, the objective is to evaluate the Delay and the quantity of traffic flow crossing the network in several characteristic conditions.

Each simulation is done using the same protocol.
- Empty network is the beginning condition
- 5 cycles are used to put the network in charge
- Evaluation done during 30 cycles

First evaluation
- Fix green times on traffic lights
- Regular arrivals on each entrance point of the network
- Evaluations of the Delay and traffic flow moving the balance between arrivals quantities and green time allocated on each traffic light creating, step by step, a stronger difference within the optimized balance.

The Delay is growing up very quickly until reach 328,88 % when green times on traffic lights are 8 seconds far away the best balance in relation with traffic flow (Fig. 4.).

Using the same process of simulation and at the same time, traffic flow crossing the area is decreasing until it reaches -29,44 % when green times on traffic lights are 8 seconds far away the best balance in relation with traffic flow (Fig. 5.).

Those results show a strong sensibility of the efficiency of the network to bad parameters on green times for traffic lights.

Taking in consideration that traffic conditions are never regular and that the operational capacity of the network are permanently changing, those results show also the necessity to use a process able to adjust the parameters and green times with the best precision and speed in relation with the real conditions.

5. Centralized and Real Time I.T. System to react efficiently to the dynamic and random events within network and traffic flow

The GERTRUDE I.T. System is developed to be able to react instantaneously to the traffic conditions evolutions and to maintain the best balance between traffic flow and parameter’s regulation as frequently as possible.
The GERTRUDE I.T. System is able to apply the following process, one time per each second.

- 1 - Manage the acquisition of data from all sensors
- 2 - Data’s analyze and building of synthetic variables
- 3 - Define and calculate the best setting of regulation
- 4 - Send individual orders to the traffic light to be immediately executed by the controllers

Main objectives and functionalities
- Give an immediate answer to the random events
- React to the variations of traffic flow
- Reduce negative sensibility to events
- Maintain the 100 % efficiency of infrastructures

GERTRUDE: IT MEANS 4 TECHNICAL FEATURES
Gertrude Real Time is an expert system that combines statistical knowledge, macro-regulation, micro-regulation, and a very high standard of processing speed and precision.

Centralized Management
All the available information, concerning «macro regulation» but also «micro regulation», is sent to the Control Room. This Control Room therefore has full latitude to analyze, compare, calculate and synthesize the data. In nominal operation all the regulation intelligence is activated by the central system, thereby guaranteeing the global nature and cohesion of processing operations. This architectural principle allows, for example, the processing within the same algorithm and at the same time of a “bus” request for help and of a potentially contradictory saturation management operation, resulting in the best possible global decision integrating the precise traffic status of the moment and all the strategic orientations.

Real-time Management
So that the process may be as dynamic as possible and therefore as efficient as possible, data collection, analysis, command decisions, and traffic signal control are all carried out on a second-by-second basis. In this way the entire chain of the system is activated and the junction controllers receive the best adapted orders each and every second of the day.

Dissociated Management
With the aim of maximizing the system's ability to respond to the constraints and variations of the traffic, the traffic signals at each junction are individually controlled. Thanks to this technique it is possible to respond to traffic events, not by modifying the end-of-phase go-aheads or anything else, but by creating – where necessary – new traffic signal statuses, thereby providing a perfect response to the problem of the moment.

Parallel Management
To be able to apply different strategies according to the required objectives, the system is able to process several parallel processes simultaneously. This technique results in an acyclic phase in a traffic signal diagram, for example in order to give priority to a tram whilst maintaining the normal, coordinated running of the junction. The result is an extremely quick return to normal, reducing the effects of the tram priority to a minimum.

More efficient than a simply model's system, GERTRUDE real time is an expert system, which can react very quickly, each second with logical and combination rules that made the system complexly secure to react, with coherency, for each micro event.

6. Associated tools to reach the best traffic regulation

Main target: The quality of data’s analyze
- Know exactly the traffic conditions in real time
- Be able to build synthetic and strategic variables
- Model “Flow – Occupancy”
- Traffic charge on each “part of street”
The automatic process of data’s analyze used by the GERTRUDE I.T. System check permanently the coherence of information, looking for failures and always associating several information to build synthetic and secure variables to be used for the real time process to take and apply decisions.

Complementary statements
• Detect incident and abnormal situation automatically
• Calculate travel time in real time

7. Results for a Centralized and Real Time Intelligent Traffic System

Comparing the results of the first simulation and this new one, the objective is to evaluate the sensibility level of the GERTRUDE System in relation with bad preliminaries data (balance offer – traffic flow) compared with the equivalent results for a fix approach.

Second evaluation
• Dynamic green times on traffic lights
• Regular arrivals on each entrance point of the network
• Evaluations of the Delay and traffic flow moving the balance between arrivals quantities and green time allocated on each traffic light creating, step by step, a stronger difference within the optimized balance.
• Using the same reference network

Those results show with which proportion, the dynamic approach of the centralized GERTRUDE System reduce the impact of “eventual bad preliminary data” and adjust automatically the offer (Green time on traffic lights) in accordance with real traffic flows.

8. Global performance for the GERTRUDE I.T. System

Third evaluation
• Dynamic and random arrivals on each entrance point of the network respecting a gauss repartition around average value
• Dynamic green times on traffic lights managed by the GERTRUDE process
• Fix green times corresponding at average value of flow arrivals for the reference comparison
• Evaluations of the Delay and traffic flow comparing results with fix approach and dynamic one using the GERTRUDE Real Time Process
• Realization of several simulations making, step by step, growing up the traffic flow until reach and over reach the maximal capacity of the net work
• Using the same reference network

Those results show for this basic evaluation the level of performance reach by the GERTRUDE System reducing particularly the Delay of 19,10% in congestion conditions.

Those results show also that, bigger are the traffic conditions higher is the difference between the classic approach and the dynamic GERTRUDE process.
Since 10 years, an official and real evaluation is done each four months in the metropolitan area of Monterrey (Mexique) by the University Autonomous of NUEVO LEON. The average of those evaluation gives an amelioration of the travel time about 24,12% compared with the situation without the GERTRUDE System.

9. Scope of “activities” of the GERTRUDE I.T. System

Managing a city require to use global solution able to manage the traffic flow, but not only. Scope are present on figure 12.

In the same way, addition of technology is not enough. Technology must be in services to global strategy and politic decisions and introduce city’s responsible orientations and priorities must be possible in automatic decision process of the I.T. System.

A general study has to define answers on several aspects shown on Fig. 13.

In addition, the I.T. System must facilitate an evaluative life years after years.

To reach those objectives, the I.T. System must be built in specific way in accordance with city’s strategy and traffic limits and opportunities.

Engineering traffic studies are done to integrate all the characteristics of each specific network, including, traffic, areas, streets, intersections, to establish a traffic strategy integrated with the General Strategy of the city, particularly define the critical intersections or group representing frequently the origins of the traffic difficulties.

The introduction of hierarchy and main tasks for each intersection gives the structure for the organization of the automatic decision process, to be sure that the traffic strategy will respect the specificities of the city and his general strategy, as basic example on figure 15.

Hierarchic and priority tasks can be represented on the logic following tree, processing the real time activities of the I.T. System, respecting global coherency and strategy.
Basic Functions
- Influence by junctions on others
- Cycle
- Offset
- Split (Green Time)
- Order “Green – Red” directly on traffic light

Finally the GERTRUDE I.T. System practice a full real time process, including typical decision, each second to always maintain the best balance between offer and demand. The following algorithm resumes the organization of this real time process.
Telemetric system for track measurement in rail vehicles without electric power supply

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ABSTRACT
The article presents review of methods and devices for track measurement of rail vehicles in aspect of diagnostics and safety of use. Currently used solutions do not enable effective “on-line” measurement of mileage by wheelsets and vehicles’ axles in rail vehicles without electric power supply such as goods wagons and cisterns. Those solutions have limited functionality and have to use additional power supply (accumulators, generators, etc.) which significantly increase exploitation costs. A telemetric system for monitoring of wheelsets’ mileage as well as of their bearing temperature, based on original solution of odometer installed on the set’s grease-box, was suggested in the research. The odometer is powered from an independent source of energy generated through magnetic induction by coil and neodymium magnets. Reading of collected data is done with the help of a PDA equipped with an RFID reader as well as wired and wireless interfaces for data transmission to telemetric system and GPS.

KEYWORDS: wheelsets, axles, wagons, diagnostics, mileage, bearing temperature, lack of electric power supply, odometer, telemetry

1. Introduction

The safety of traffic control of rail vehicles requires continuous mileage’s monitoring of rail vehicles, wagons, and particularly mileage control of wheelsets, wheels and axles. Supervision should assure control of used materials. Depending on wagon’s mileage, the necessity of rim’s regeneration or bearing inspection based on previous bearing temperature measurement can occur, so that used material does not become the cause of train’s failure. To prove that it is not only a theoretical problem, it is enough to mention among other things a rail catastrophe in Viareggio on 29th of June 2009, where due to breakage of axle of a cistern transporting liquid gas 15 people were killed and over 50 were injured. As a result of this accident European Railway Agency as well as European Commission formulated recommendations and guidelines regarding axle and wheelsets diagnostics [1].

This measuring problem is especially hard to solve in case of exploitation of goods wagons which often transport dangerous loads and in contradistinction to railway-engines and passenger wagons are free of electric power supply. To provide correct wagons and wheelsets exploitation it is also necessary to have information about actual mileage of wagon and its wheelsets, even in the situation when it was dismounted and stored. The legislator lays [2], [3], [4], [5] a duty of rail vehicles’ mileage monitoring, which also determines validity of certificate of admission to rail traffic. However, in current regulations the method of calculation as well as technical requirements for the counter have not been specified.

The aim of this study is the analysis of currently used solutions in this field and suggesting the system which would monitor mileage of wagons and wheelsets with particular consideration of rail vehicles without electric power supply.
2. The analysis of existent solutions of kilometer counting methods and distribution of these data

2.1 Mechanical kilometer counters – method no. 1

Information about mechanical devices being kilometer counters was included in patent description in 1934. For this purpose appliances with ratchet and pawl mechanism were used driven by eccentric and driving the counter. The following solution was suggested by Siemens-Schuckertwerke. The first practical method of mileage measurement of goods wagons and its registration is mechanical counter. Devices from DIBA4000 series of Ditzinger trademark are based on this method. Those devices are built on axle in a way that enables its bearing. Thanks to non-centric placement and fixing they stay in set position toward turning wagon’s axle [6]. The fundamental disadvantage of these devices was low durability due to shakes and hits. The precision of such counters was worsening due to appearing vibrations. Readings of the counters achieved by this method were stored in the form of paper documentation.

2.2 Electromechanical tachometers – method no. 2

One of the ways of counting the distance is the method based on electromechanical counters e.g. Hasler RT/A type, which are installed in engine-driver’s cockpit [7]. It is not a direct way of measurement, however it allows to estimate the mileage of attached wagons based on the mileage of railway-engine during its work. Documentation can be done in the form of paper consignment note. There is also no possibility of electronic transfer of data “on-line” to central point of data collection, for example central data base including information about mileage.

2.3 Electronic tachometers – method no. 3

The method allowing for the mileage counting are systems built on electronic tachometers, where wagon’s mileage measurement is calculated indirectly, that is based on the readings of the counter of the currently attached railway-engine.

There are many types of electronic tachographs offered on the market, however the interesting one is e.g. Teloc 1500/2500 [8], which is a modern solution based on computer data recording from the ride with the possibility of wide analysis of collected information by means of a PC. The devices are installed on railway-engine. This way of ride’s acquisition and registration meets all the latest safety requirements as well as European Commission’s standards. Described above tachograph Teloc has a certificate issued by Railway Transport Office and fulfills all requirements of ERMTS and ETCS systems.

As an indirect measurement system it is not suitable for monitoring of wheelsets. Also due to required power supply ranged between 24 and 110VDC, unavailable in goods wagons. However, for further consideration it is possible to assume a change in tachometer’s construction which would allow its installation on every type of wagon or wheelset enabling direct measurement of their mileage. At that time it is necessary to provide electric power supply (batteries, generator coupled with wagon’s axle, etc.), it is possible to use for that purpose for example encoders installed on the lid of the bearing. The method is easy in implementation but at the same time expensive due to necessity of providing electric power supply, and in case of using accumulators it would cause significantly high exploitation costs.

On the market there are also present electronic tachometers which are designed to measure rotations with the help of magnets and REED-Relay. Their characteristic is a small compact construction, unfortunately they require battery power supply, which in case of the situation when a wheelset has not been used for a long period of time excludes its long-term use. Since the precision of the results in this method is influenced by accuracy in fixing the actual diameter of the wheel (which changes with the passing of time), it requires introduction of possibility of its flexible programming. It causes the need of expanding electronics and as result it increases consumption of energy.

2.4 Measurement of mileage based on GPS - method no. 4

The methods of kilometer control with the help of systems using GPS/DGPS depend on calculating the wagon’s mileage on the ground of summing up in time distances between points indicated by GPS. They use indirect system of calculation. The fundamental function of such systems is location of rolling stock on the map. These systems also often monitor other parameters of railway-engine’s work (e.g. status of railway-engine’s work and goods wagons attached to it, significant parameters of its exploitation, fuel consumption, engine’s driver log in and his time of work as well as fast access to reports, statistics and data sheets). There is also a function of full visualization of the track and stops history. This information is sent to Central Monitoring Unit in real time, for example with interval of 1 s. and back – from Central Monitoring Unit to the
objects with use of package of data transmission and infrastructure of GSM [9].

The standard accuracy of GPS from technical perspective gives precision of range of a few meters however the track calculation is loaded with much bigger error due to approximation curvature of the route with a straight line. The way of increasing accuracy of the measurement is usage of the system which works based on forward differencing method DGPS. In such cases, receiver located near the base station (with known and constant position) DGPS transmits to it differencing data (most often it is the difference between para distances calculated by BTS and real distances to the satellites). That way GPS receiver can correct errors coming from propagation of the signal between the satellite and the receiver.

Other error correction system is WAAS/EGNOS, similar to DGPS with the difference that corrections are sent to receivers by geostationary satellites. Moreover, specific countries have their own local networks of reference stations allowing for “on-line” or “post-processed” correction of the position fixed by GPS. In Poland such network is known as ASG-EUPOS (Active Geodesic Network EUPOS). The system allows for locating with the use of GPS-RTK with the accuracy of reading of 3 cm horizontally and 5 cm vertically. On the other hand, “post-processed” accuracy reading in POZGEO and POZGEO-D systems can range 1 mm.

### 2.5 System integrated with SEPE (Exploitation Work Registry System)

One of the methods of rail vehicles’ locating is using IT system integrated with SEPE (System Ewidencji Pracy Eksplotacyjnej - Exploitation Work Registry System). The system belongs to the same family as GPS described in point 2.4. Currently PKP Przewozy Regionalne uses System Zarządzania Flotą (Fleet Management System) – DS Locate by Data System. It enables locating and monitoring PKP’s rolling stock. Thanks to integration of DS Locate system with SEPE the tasks requiring manual work and high labour inputs were automated. DS Locate system works “on-line”, which means that all signals from vehicles are regularly sent in constant short intervals and additionally in case of unexpected event. SEPE application allows PR's controller to find position of a specific vehicle based on its serial number and train number. It allows also to obtain many more additional data about the vehicle (e.g. current speed, accurate time and location of the vehicle and possible delay). Data are archived. SEPE system allows the controller to manage the rolling stock in a dynamic way and to view current state of fleet “on-line”. The system has a complex functionality supporting fleet management. However, it does not enable mileage registration of wagons and wheelsets.

### 2.6 Numerical wagon documentation – method no. 6

Kilometer calculation is done based on shipping notes R7 and other documents prepared by traffic control staff. By reason of regulations which requires from rail transportation companies control of distance covered by rail vehicles and by the fact that goods wagons are not originally equipped with kilometer counters, enterprises use by their own means procedures which in most cases are based on analysis of shipping notes and other documents. However, these procedures are unreliable and inaccurate because of the need of manual updates and copying.

Full realization and registration of wagons’ registry rules are basic responsibilities of all PKP units employees who deal with management of goods wagons or using wagons. Its observance allows to avoid missing of wagons, result errors in railway stock work and loss of railway.

Even though transportation companies constantly improve the procedures of writing out, flow and archiving shipping documents (they include information about the length of covered distances), they still require a lot of time and staff. Fixing the mileage of wheelset (wagon, rail vehicle, etc.) based on assumption of distance from first to last station is only estimation and the results are not available in real time.

### 2.7 Conclusion

Collected information and knowledge about devices and systems registering rail vehicles’ mileage were analyzed from the perspective of possibility of implementing them in a large-scale in rail vehicles without electric power supply, which are mainly goods wagons caused by lack of such tools. The existing solutions listed above are usually unsuitable for direct implementation in case of wagons without electric power.
The basic element of the system is an odometer, that is a device allowing for the measurement and control of distance covered by wagons and rail vehicles. It has an original construction with independent local renewable electric energy source, based on induction of electromagnetic force in coil of kilometer counter placed in extremely low frequency magnetic field and resulting from rotation of neodymium magnets located in the wagon’s wheel. It is installed on grease-box of the wheel. Thanks to axle rotation it produces enough energy to power micro-controller counting the amount of axle's rotations and being able to register this value in non-volatile memory. Besides, the mileage it also registers current wagon’s bearing temperature and stores data about wagon which are necessary to prepare shipping notes. Reading and input of data are done from the controller in the form of PDA. Two-way data transmission takes place in the form of radio signal to/from the counter. Blocked diagram of the device is presented in Fig. 2 and its view in Fig. 3.

Non-contact data reading does not affect the reading because of dirt and non-volatile memory circuit is powered wireless by the controller at the moment of reading/registering of data. Energy needed for emitting electromagnetic wave is taken from the wave of the device that reads the data (so the vehicle does not have to be in motion) and it is implemented thanks to RFID technology. Because there are a few types of grease-boxes with different shapes and sizes, a series of types of odometer’s interfaces in different dimensions has been designed and produced.

3.2. Controller with application

The odometer cooperates with a portable PDA computer with colour LCD touchscreen, resistant to outside conditions and falls. It has been equipped with GSM module, GPS, RFID reader and USB. The device is intended for staff responsible for train check in or technical inspection. Thanks to appropriate software it is possible to make a fast wireless data reading about next wagons of the train (id numbers of a wagon, length, mass, brake settings, mileage, bearing temperature, etc.) and to update current data (load’s mass, type of load, person responsible for check in, remarks about technical shape of the wagon). The device is equipped with GPS, which causes that read data are always provided.
with accurate position of every wagon during check in. After reading of every wagon and railway-engine (railway-engines are equipped only with storage medium – TAG RFID, without sensors) the complete report is sent to database (GPRS transmission) in the centre of data collection. That report can be shared for print as mass memory USB in a shape of filled R7 form according to PLK standard. If the existing rail structure does not enable the use of computer and printer (A4 format) in places, where check ins are done and shipping notes are prepared, there is a possibility of equipping the railway-engine with printer with the function of direct print from the controller. On the controller, based on operating system Windows Mobile 6.1, an application has been made for odometer service and reporting in the format of 17 forms. It includes such functions as: logging in, system date, settings, railway stock control system, vehicle’s data, error notification, auto-diagnostics, info about engine-driver, manager, check in employee, system, list of numbers of wagons’ owners, their types and types of wheelsets, setting of break strength, etc.

3.3 The system structure

Different versions of telemetric system were considered and a few types of medium were installed between controller and transmission system. Regarding the physical aspect, two kinds of medium have been specified – wired and wireless. In case of physical connection by wire, it is understood as a connection with cable through USB interface to work station, connected with the rest of the system with data transmission network. Wireless medium is understood as package teletransmission network GPRS and optionally also WiMax, HiperLAN [10], TPSA network, Internet network and leased connections, as well as widely used standards of wireless communication based on infrared waves IrDa and standard 802.11 b/g, Bluetooth [11].

These standards have features which significantly differ regarding reach, emitted strength, radio frequency band (length of waves) and specification of physical and logical aspect of layered model ISO/OSI.

An important element of the whole system is information exchange from monitoring and management centre in the point of data collection. The central point of the system is electronic database and map server with Internet access (WWW). Authorized user has access to all read “on-line” data (R7 reports, location of the wagons on map, mileage and bearing temperature monitoring and submitting remarks about technical state of the wagons) as well as receives notifications (about upcoming main repairs and failures) and has access to all track and wagons history. Thanks to its functionality the system can be used as “blackbox” and have ability to register the date above. The structure of the system has been presented on Fig. 4.

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4. Conclusion

Thanks to presented work solutions there is a possibility of wide use of telemetric system to monitor and diagnose rail vehicles. In particular, the system is appropriate for mileage monitoring of wheelsets and axles as well as bearing temperature in conditions of lack of electric power supply in case of goods wagons and cisterns. The very important aspect of the system is the possibility of using it to monitor dangerous loads (e.g. cisterns), for it also enables GPS location of such loads and can handle the function of “blackbox” with a proper failure prediction. The system can be easily calibrated and can be adjusted to the needs of different carriers as well as it can be expanded while requirements evolve. Data transmission from controllers to the system can be done with the use of all modern wired and wireless medium, depending on the wish of the client considering also cost optimization for its access. The suggested solution of independent power supply of micro-controller circuit and its wireless data transmission with the use of wireless power supply from the PDA controller also allows for using this solution in other telemetric purposes, especially in situation of lack of access to electric power sources. Currently, the prototype of the system is being prepared for “on-line” tests.
TELEMETRIC SYSTEM FOR TRACK MEASUREMENT IN RAILS VEHICLES WITHOUT ELECTRIC POWER SUPPLY

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[12] Project no. 422/BO/A “Developing and implementing a device supporting diagnostics of rail platforms transporting dangerous loads”.

16

Archives of Transport System Telematics
Future of telematics applications as support for increased safety

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ABSTRACT

Communication between vehicles is very important element of accidents reduce. In this contribution is made accidents analysis in SR and is described all the available techniques for communication between various vehicles among themselves and with the infrastructure. The aim of this is to have a complete overview of all the possible communication techniques that the world of electronics and telecommunications has proposed in the last years that can be applied for accomplishing the task of enabling vehicles to communicate and interact with other vehicles as well as with the infrastructure.

KEYWORDS: Intelligent transport system, traffic accidents, safety

1. Introduction

Traffic is a key-factor in modern economics. Despite of this, there is a continual conflict between mobility satisfaction and increased delay. Nowadays, many specialists are trying to find out the reasons why some traffic events occur. ITSs are systems which help to make efficient use of road and urban communication network, using information, communication and directing technologies. They make basic conditions for high quality communication and information society that we are approaching also in our country. We have to remind that, according to current statistics 93% of traffic accidents are caused by human error.

Assistance systems are the main challenge. They are based on communication (data exchange) not only among vehicles themselves but also vehicles and infrastructure. These so called Intelligent Assistance Systems promise great benefits in the sphere of efficiency of transport systems and road safety. These benefits include mainly increase in the capacity of the road network congestion and pollution reduction, shorter and more predictable driving time, improving traffic safety for all participants of road traffic, lower operational costs of vehicles, better organization and management of road network.

2. Analysis of Traffic Accident Rate in SR

The Slovak Republic as a full member of the European Union respects the recommendations of the European Commission in the sphere of road safety and is trying to accomplish them. The development of transport in all its sectors is linked to the integration to the advanced countries and with developing of the society. Year by year in the road transport it increases the number of vehicles on the roads as well as new drivers and with this situation is associated lot of negative effects. The number of road accidents and their consequences increase in the aftermath to lack of conditions for the realization of transport education, low discipline, aggressive driving, violation of fundamental duties, and low legal awareness of drivers and other participants of road traffic. [1,2]
Traffic accident rate as a serious social problem requires a comprehensive and effective solution that shows features of a coordinated and aimed procedure by all stakeholders and institutions with a broad public support.

The year 2010 has been able to be assessed from the point of the consequences of road traffic accidents as one of the best since 2000. In 2010 we recorded 21,595 accidents. Overview of the last 10 years is shown in figure 1.

The number of casualties in traffic accidents in Slovakia in 2009 was reduced the most of all European Union countries. While in 2008 there were 558 casualties on Slovak roads last year it was 345, which has been the least in police statistics since their archiving since 1966. See figure 2.

There were died 112 pedestrians, 25 motorcyclists, and 19 cyclists on the roads excluded people in the cars. The promise of European Union to reduce the number of casualties hasn’t been met.

In Slovakia as well as in whole Europe, there are being constantly constructed new and wider roads, highways, tunnels, and urban bypasses. However none of it is enough because the level of congestion and accrue of traffic accident in the morning peak is everywhere the same. Experts are convinced that the solution or at least improvement of the transport situation in Europe can be otherwise and still cheaper than constructing new transport communications. An important way to improve safety and fluidity is the introduction of intelligent transport systems.

3. ITS Fundamentals

The number of casualties in Europe (40,000 casualties per year) due to road traffic is still unacceptably high, even if it has reduced significantly over the years due to safer vehicles and infrastructure and transport policy. Car ownership and its using have continued to grow steadily, and the resulting congestion in built-up areas and on main highways has become a significant overhead cost and burden for travellers, for economy and for environment.

Interest in ITS (intelligent transport systems) comes from the problems caused by traffic congestion worldwide. Congestion reduces efficiency of transportation infrastructure and increases travel time, air pollution and fuel consumption.

Intelligent Transport Systems and Services integrate information and telecommunication technologies with transport engineering under the support of other related industry, in order to provide for the existing traffic infrastructure an advanced system of control of traffic and transport processes – enhancing the transport performance, traffic efficiency, road safety, and comfort of transportation, etc. The main objectives of transport telematics are to offer intelligent services, which must be considered at several levels: for travellers and drivers (users), infrastructure administrators, transport operators (carriers), security and rescue system, financial and control institutions.

The basic components of transport telematic systems include the following fields:
- Electronic payments.
- Management of security and rescue measures.
- Management of traffic processes.
- Management of public passenger transport.
- Support at management of means of transport.
- Support of people’s mobility.
- Support of supervision over adherence to regulations.
- Management of freight transport and forwarding agents.
- Transport and traffic database.


Assistance systems are the main challenge. They are based on communication (data exchange) not only among vehicles themselves but also vehicles and infrastructure. These so called Intelligent Assistance Systems promise great benefits in the sphere of efficiency of transport.
systems and road safety. These benefits include mainly increase the capacity of the road network, reduce congestion and pollution, shorter and more predictable time of driving, improving traffic safety for all participants of road traffic, lower operational costs for vehicles, better organization and management of road networks. [8]

Cooperative systems for transmitting information in real-time use communication among vehicles (Vehicle-to-vehicle, V2V) and between vehicle and infrastructure (Vehicle-to-Infrastruc-true, V2I). They hold the promise of major improvements in the efficiency of the transport system, improve safety for all road users and increase the convenience that the mobility provides. The work on cooperative systems started in Europe in the fifth and sixth Framework Programme. In connection with the industry a consortium Car2Car has been set up [7], which promote a common progress of industry. The key prerequisites and the main objective of the Commission include the development of harmonized and interoperable system architecture, an architecture of common communications that can meet the needs of public and private sector, as well as the availability of suitable frequency.

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So, if cooperative systems are so effective and produce such benefits, one could ask why there are none today, in either vehicles or at the roadside. The answer is clear: the technologies that are needed to create applications where vehicles and roadside infrastructure can talk to each other directly are not yet fully developed and validated. Also, the main entities involved are not yet persuaded of the utility and benefits of investing in cooperative system.

Fig. 4 shows how cooperative systems can break the “vicious circle” of ever-worsening traffic problems by offering – for the first time – new ways for drivers and their vehicles to interact (and not just react) with a more intelligent infrastructure. And that new intelligence is due to new kinds of information that come, at least partly, from individual road users.

5. ITS and Slovak Republic

The Slovak Republic faces a lot of transport problems, which don’t come out only of the uncompleted transport infrastructure, but they concern many areas such as transport safety, impact of transport on the environment or quality of service, of which solution was not sufficiently secured in the past. The Slovak Republic adopted a project of an action plan, formulated in several areas which are aimed at:
- Optimization of the use of the latest road data and data access.
The synergy of combined applications and services in area of commercial transport.
Data security and protection of personal and commercial data.
Strengthening the effect of public authorities in the field of ITS.
A framework for integration and coordination of programs.
A framework for promotion of diversity and acceptance of ITS.

A supporting program of the development of intelligent transport systems - National System of Traffic Information - represents comprehensive solutions of intelligent transport systems based on information and communication systems and technologies in road transport in Slovakia. It is oriented to the use of a single system surrounding for the collection, processing, sharing, distribution and use of transport information in concrete information, guiding and telematics applications.

Basic system requirements are:
- Minimize the creation of congestion.
- Increase the efficiency of traffic that is expressed by saving time.
- Increase mobility and quality of transport services.
- Create space for an efficient multimodal transport.
- Make available information in real-time for passengers, carriers and users of communications.
- Improve productivity of commercial activity of transport processes in society.
- Reduce energy consumption.
- Increase the quality of the environment.

As mentioned recently, the growth of road transport is an attendant phenomenon of development, which manifests in a significant growth of negative impact of transport on the environment, growth in congestion in conurbation, and growth in traffic accidents common both for developed countries, and in conditions in the Slovak Republic.

Action Plan of ITS provides:
- Decrease transport congestion by 25% and increase the quality of travel.
- Increase transport safety by 25% and thereby contribute to the overall European goal to reduce number of death people by 50%.
- Reduce CO2 emissions by 10%, mainly in urban areas.

6. Conclusion

As transportation engineers, we are interested in knowing the schemes that can be applied to the field of transportation engineering to alleviate traffic problems like safety, congestion, environmental degradation and off late, energy consumption by the vehicles, to name a few. Intelligent Transportation Systems are undergoing a transition from demonstration projects to becoming a part of the mainstream set of options available to transportation planners. Hence, evaluation of ITS is one of the most critical and important steps to be taken before any ITS technique can be deployed. Safety has been recently emerging as an area of increased concerns, attention and awareness within transportation engineering. It has been extremely difficult to evaluate safety for new and innovative traffic treatments.

Modern transport systems for road networks include many different intelligent transport and telematics systems mainly built for traffic monitoring, control operation and electronic fee collection purposes. Furthermore, a wide range of sensors monitoring weather conditions, traffic status, vehicle types and their speeds are used to enable the applications mentioned above. The increase of data network capacity, processing power within the traffic control center (TCC) and development of sophisticated sensor fusion algorithms enables the concept of a single, consistent, central database which serves all applications and customized information distribution channels such as variable message signs (VMS) or wireless traffic information via the radio data system – traffic message channel (RDS-TMC). The maximum benefit for the stakeholders can be achieved if the services do not only use common databases, but contribute actively to it and share their complementary data in order to operate in a co-operative manner. Current FP6 integrating projects like COOPERS, “cooperative vehicle infrastructure systems (CVIS)” and “co-operative vehicles and road infrastructure for road safety (SAFESPOT)” are elaborating this co-operative system approach.

Acknowledgements

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Road Line Traffic Control System - Experiences in testing operation

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ABSTRACT
One of the most significant road structures completed in 2010 was the construction of southern part of the Bypass around Prague (BPAP), where technological equipment was designed and installed and Road Line Traffic Control system implemented. In the Czech Republic is this system is absolutely innovative and brings new organizational and regulation elements into operation. The system is primarily intended for traffic flow harmonization. It is based on usage of variable message signs to affect the traffic flow so the fluency, security and communication permeability is increased. Thank to automatic speed reduction by defined traffic data is traffic flow is more fluent, distances between vehicles are smaller and throughput of communication increases. RLTC system can identify traffic excesses on communication thanks to vehicle queue detection.

All algorithms were designed and tested under project of science and research of Ministry of Transport of the Czech Republic, project INEP, n. CG944-033-120 (inep.eltodo.cz). In current time testing operation on BPAP and on a part of D1 Highway is proceeded. System is monitored and all functionalities are evaluated for further debugging and adaptation of system for local conditions.

KEYWORDS: Road Line Traffic Control System, highway, traffic flow, harmonization

1. Introduction

Outstanding increase of traffic volume during the last years reflects in more often traffic congestions. Their sources are besides high traffic loads both incidents, which substantially increase the risk of traffic accidents.

Last year a long-awaited construction of the southern part of Prague Ring road was completed in the Czech Republic. This built has significant importance not only in terms of Prague city area, where significantly decreases traffic, but for entire state because of cross connection of important highways. Traffic forecasts predicted traffic load up to 60 000 vehicles per day at this important construction. For this reason the first Road line traffic control system in the Czech Republic was installed at the southern part of Ring road and part of D1.

General supplier of the technological equipment was ELTODO group, which has an experience with similar implementations. It supplied Road Line Traffic Control System, Tunnel control system and technological equipment in tunnels and highway technological equipment. Southern part of RRAP measures 30 km. during the construction was necessary to built 70 bridges in total length of 6,7 km, two road tunnels Cholupice and Lochkov with length 1937 m and 1661 m. Road Line Traffic Control System is installed in both directions on RRAP marked as motorway R1, between intersections with D1 and D5 highways and on D1 highway between intersections Mirosovice and RRAP.
Currently, we already have more than a half year operation and functioning of RLTC system on RRAP, thus in this article we can evaluate its first results.

2. Road Line Traffic Control principle

Road Line Traffic Control System (RLTC) was supplied for open route and cooperates closely with control systems of both tunnels. Based on measuring traffic flow parameters system affects flow fluency, increases communication permeability and security of traffic flow. Based on timely provision of information drivers may adapt their driving way and substantially reduce the risk of traffic accidents.

2.1 Range of functions

In cases when the situation requires, variable message signs (VMS) with warning symbols, prohibitory signs limiting maximum allowed speed or prohibiting drive of trucks outside of right lane are displayed on control profiles of RLTC system. Important parts of each control profile (RLTC Gantry) are detectors measuring volume, speed, traffic flow composition and other parameters. Based on these data system is able to perform these proceedings automatically, without system operator intervention.

Thanks to RLTC system it is possible to extend highway capacity during the peak hours and reduce creation of congestions, which often causes traffic accidents. During high traffic volumes “Stop and Go” waves occur, which are typical with high differences in speeds in the downstream sections. Consolidation of these speeds on the same level reduces accumulation of these waves together with increasing communication permeability. At lower speeds spaces between vehicles are minimized which leads to higher road capacity. The traffic flow harmonization is assured by Road Line Traffic Control system by reducing maximum speed using variable message signs (VMS) installed on control profile gantries, which are located on regularly spaced locations. Further RLTC system detects formation of vehicle queue and warns concerned drivers against these drivers using VMS. Another important feature is warning against meteorological states inconvenient for traffic and based on dangerousness traffic flow speed is reduced. In this case system collects data from meteosensors on the highway, which are automatically processed and evaluated. Of course there is a warning before accident, work or obstacle on the road, for example debris or animals. In case of restrictions on driving in selected lanes it is possible to activate light arrow, which ordered to leave the driving lane.

2.2 Control Algorithm

All algorithms were designed and tested under project of science and research of Ministry of Transport of the Czech Republic, project INEP, n. CG944-033-120, whose main solutionist is ELTODO group. During the
Traffic solution design algorithms were applied on particular conditions and in some cases were modified based on experiences from real operation.

Together with algorithms for evaluation of untypical traffic states was necessary to develop principles of application of single action on multiple sections simultaneously. Traffic precaution is applied on one particular profile or a group of profiles, but during operation there are situations, when it is necessary to combine more precautions together with preserving the rules of reducing speed on highways and avoiding to display speed steps on subsequent profiles. In order to avoid step changes of speed, which has negative influence on flow fluency, special smoothing algorithms were developed. Smoothing algorithms manage displayed symbols in consecutive profiles with regard to exact profile location on the route.

Finally, it is necessary to activate the maximum speed limits in time shifts instead of simultaneously. This provides so-called dynamic sequences, which reduces speed on requested level in the shortest time so that drivers actually moving on route are not forced to slow down sharply on low speeds. RLTC system doesn't forget on extreme event of driving in inverse direction. Although this is not very frequent, but may have fatal consequences. In case of detected inverse driving event, RLTC system automatically detected and evaluated this accident and slowed down traffic both on profile close to accident and on previous profiles. Operator both reacted to this state by finding accident source thanks to video surveillance by sending police patrol to the accident and supplemented speed symbol on gantry.

Information between these systems must be shared with regard on a good coordination of all precautions.

Road line traffic control system is connected to newly constructed supervisory centre SSUD Rudná, where proceeds uninterrupted surveillance of the completed part of the Prague ring road. Systems are monitored and during test operation are adjusted for having most fluent and safety traffic.

3. Results from operation

RLTC system is in operation more than half year and during this time its function is very carefully controlled and results are examined by representatives of both the National highway provider (ŘSD) and by our company. With regards to complexity of system and quantity of its functions number of parameters can be evaluated.

3.1 Traffic harmonization

Main parameters for traffic flow harmonization are speed and traffic volume. These parameters are showed in Fig. 4. RLTC system functionality is clear from upper bold red line, which shows adjustment of maximum allowed speed in time. From traffic volume graph is nicely visible day flow including morning and afternoon peak hours. Because of high traffic volume before eight o'clock was during morning peak hours the maximum allowed speed was reduced to 80 km/h and after volume decrease at 8:30 a.m. was increased.

From further detail speed evaluation in driving lanes explicitly results, that most of drivers respect actual traffic notation on VMS and differences between lanes are minimal. This is apparent from speed flow showed with orange spline in Fig. 4. Traffic is effectively homogenized and beyond ensuring smooth traffic flow and extended road capacity the risk of traffic accidents is substantially reduced.

3.2 Emergency situations

During the system operation also such situations happened, when system reacted to occurred situations much earlier than surveillance operator, who is warned on exceptionalities by this system. It sometimes happens, that drivers are forced to react to small traffic accident event by speed reduction. RLTC system automatically detected and evaluated this accident and slowed down traffic both on profile close to accident and on previous profiles. Operator both reacted to this state by finding accident source thanks to video surveillance by sending police patrol to the accident and supplemented speed symbol on gantry.
profiles by warning symbol on VMS. Thanks to this proceeding risk of another accident was substantially reduced by preserving traffic flow continuity and speeded up liquidation of incurred situation.

4. Conclusion

Although the RLTC system is brand new issue in the Czech Republic, despite the generally lower respect of Czech drivers on VMS road signs, we can see its big benefits. Homogenization of traffic flow by speed limits is explicitly positive and risk of traffic accident is further reduced by activating warning symbol on VMS. An important factor influencing the proper system functionality is operator, who confirms selected events and sets other setting directly into the system. Overall, we can say, that system performs its function, and significantly contributes to rising traffic flow fluency and safety. The trend of steadily increasing traffic volumes, both financial and time-consuming constructions of new highways, and finally increasing demands for transport security, we can assume, that telematics systems for increasing throughput and safety of routes will continue to be developed and improved.

Bibliography

The safety analysis in the open transmission standards in railway applications

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ABSTRACT
The paper deals with functional and safety analysis of transmission in railway control systems, especially fail-safe applications (Line Block System, Dispatcher/Interlocking, Cross Level Protection and monitoring remote control). An analysis of the data structure is presented with recommended protection mechanisms to determine the indexes of time used for safety proof. The typical standards used in safety transmission systems are A0-A1 (with additional data – e.g. time stamps and safety code-CRC), B0 (enciphered message containing user data, non-cryptographic safety code and additional data) and B1 (with additional data, non-cryptographic safety code, and cryptographic code). These methods correspond to the existing standards (EN-PN 50159-2, EN PN 50 129, EN PN 50126) and are recommended for safety transmission analysis in new railway control systems with public wireless transmission.

KEYWORDS: open transmission, wireless standards, BS EN PN 50159-2010

1. Conditions of safe data transmission
The exchange of information in railway control systems (RCS) using an open transmission must guarantee the safety of the transmission, in accordance with the recommendations for the required safety level SIL. In this case it is necessary to use for transmission the appropriate cryptographic standards and mechanisms. Requirements and recommendations are defined in the current standard EN 50159:2010 regulating such uses in the signaling systems. In an open transmission systems OTS, the data transmission between the systems participating in railway control process can be conducted using an open transmission, both via wired and wireless links, shared in the network with public access. This concerns all specialized radio networks (GSM) and the Internet. This means that the information is transmitted by broadcasting systems available to unauthorized users. Thus the transmitted data can be exposed to attacks such as:
- Intentional or unintentional masquerade of another system in the railway control system (RCS),
- Attacks in order to access the transmitted information or send processed packets to the system,
- Removing, modifying or redirecting the data telegrams,
- Changing the order or repeating telegrams,
- Delay of telegrams.
Therefore, the protection of transmitted data against such risks is the condition to access an OTS based system.

1.1. Types of telegrams

Basic methods of protecting the transmitted information in open transmission systems (OTS) in RCS systems are shown in Figure 1. This Figure shows the classification of groups of transmission telegrams and assigned to them cryptographic methods. Meeting these requirements is necessary in order to achieve the assumed level by an RCS system, the safety inviolabilities SIL.

- **A0** – authorized access only, the integrity code of data is required, the cryptographic safety code is not required.
- **A1** – unauthorized access is not excluded, the use of cryptographic safety code is required.
- **B0** – unauthorized access is not excluded, encryption is required, the use of cryptographic safety code is not required.
- **B1** – unauthorized access is not excluded, the cryptographic code is required, the cryptographic safety code is not required [5].

1.2. Methods of protecting the telegrams

The detailed structure of telegrams for the safe transmission with recommended safe protection mechanisms of data is shown in Figure 2. In the paper it was confined to two telegram types – A0/A1 and B0.

Type A0/A1 has been used in closed transmission systems so far, implemented mostly in Profibus and Ethernet standards. Type B0 is basically proposed by most manufacturers of RCS systems with an open transmission channel, and it concerns both dedicated radio links and wireless Internet. In the case of a closed transmission with protocols of A0 and A1 type the number of devices in the system is fixed and all participants in the transmission are known. Devices can be identified by the network addressing, so it...
has the character of physically closed, which excludes the threat of unauthorized access to the data, overhearing of transmission or inserting the extraneous telegrams.

The cyclic redundancy code CRC used to detect random errors is recommended to use as the data protecting code in those systems. Open transmission systems insert an additional threat to the system such as, for example, masquerade another system into a system of railway control or intentional modification of sending telegrams. To avoid this, it is necessary to use methods protecting against unauthorized access and which allow verification of data authenticity. In this field the standard recommends the use of cryptographic techniques, encryption methods and authentication keys. Telegrams using these techniques are identified as type B0, in which procedures of authorization using hash MD5 (Message Digest) and SHA-1 (Secure Hash Algorithm) are recommended. For verification of the data integrity, the redundant coding technique CRC (Cyclic Redundancy Check) can be used, which protects against random errors and allows detecting single or series of errors. However, the encryption of data using the block ciphers encryption with 128-bit symmetric key such as DES, 3DES (Data Encryption Standard) or AES (Advanced Encryption Standard) that allow to reject erroneous telegrams and protect against the decoding.

### 2. Time analysis of information flow

In order to determine the time and probabilistic indicators of data transmission in OTS systems, the analysis of execution time for individual functions to determine the integrity code, the encryption and decryption of data depending on the length of the telegram was conducted (assuming that a typical length of telegrams in the system is 16 Bytes) and for two bandwidths of 512 kb/s and 1Mbit/s. Most producers of RCS system assume type B0 of telegram, which uses cryptographic techniques with the secret key. The data is encrypted in its entirety including the integrity code. Such selection of telegrams protection results mainly from the use of wireless data transmission. During the encryption, the ensured confidentiality and integrity of the data affect the number of operations executed by individual algorithms (Fig. 3 and 4). In the AES encryption with a 128-bit key, the algorithm executes 10 rounds in order to transform each byte. This algorithm operates on blocks of data, which are 128 bits (16 bytes) long; therefore there is no need to collect more data, because each such block can be processed independently. However, for code CRC-32 the algorithm executes eight operations and protective properties of the CRC code depend on the size of the protected data block and the degree and form of the polynomial.

Figure 5 shows a comparison of two basic algorithms used in standard B0: CRC-32 and AES algorithms.

![Fig.4. Encryption algorithm AES-128.](image-url)

![Fig.3. Example of CRC32 encoding algorithm.](image-url)
For selected models of telegrams A0/A1 and B0, the time of information protection has been analytically defined (see Table 1) for the typical lengths of telegrams in the railway control systems.

The time of information exchange can be represented as the sums of the delays, which are mainly based on partial encryption / decryption and encryption and decryption of transmitted data:

\[ T_c = T_K + T_T + T_D \]  

where:
- \( T_c \) – the time of a single cycle of information exchange
- \( T_K \) – the time of data encryption
- \( T_T \) – the time of data packet transmission
- \( T_D \) – the time of data decryption

Examples of results of the time of a single cycle of information exchange \( T_c \) (telegram length 6 [B]) and the rate of transmission 512kb/s and 1Mb/s for each telegrams protecting feature are as follows:

Table 1. Average time of telegram protection

<table>
<thead>
<tr>
<th>Length of telegram</th>
<th>Type of telegram</th>
<th>A0, A1 CRC-32</th>
<th>B0, CRC-32(DANE)+AES</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 [B]</td>
<td>0.0812 [ms]</td>
<td>0.146 [ms]</td>
<td></td>
</tr>
<tr>
<td>20 [B]</td>
<td>0.305 [ms]</td>
<td>0.166 [ms]</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. The time of a single cycle of information exchange \( T_c \)

<table>
<thead>
<tr>
<th>Capacity of link</th>
<th>512kb/s</th>
<th>1Mb/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Functions protecting the telegrams</td>
<td>The time of a single cycle of information exchange ( T_c )</td>
<td></td>
</tr>
<tr>
<td>AES</td>
<td>0.103 [ms]</td>
<td>0.059 [ms]</td>
</tr>
<tr>
<td>CRC-32</td>
<td>0.092 [ms]</td>
<td>0.048 [ms]</td>
</tr>
</tbody>
</table>

In the analyzed model of B0 telegram, the generating of data integrity code does not make long delays; the biggest delays originate from the data encryption procedures. However, the best method of encryption is the AES with 128-bit key encryption, which guarantees a high protection. Systems working in an open transmission system significantly limit the number of supported devices; the delays result from data encryption procedures and from redundancy in the length of telegrams with encrypted data. The number of devices depends on the time cycle of a telegram and it can be defined from the equation of time of a single cycle of information exchange \( T_c \). A method for shortening the information exchange time in the system can be the pre-grouping of data for a large number of working devices, before coding process, integrity codes and encryption. For the analyzed variant of the OTS transmission system, the number of devices supported by the system allows to save determination of time in the exchange of information. Errors of the data telegram in the case of open transmission it rejection causes of telegram in its entirety and a temporary loss of transmission. The data is sent cyclically and the single error does not affect the system work. Assuming the probability of bit error for OTS transmission at the level of \( p = 10^{-4} \) (for the radio network), the probability of undetected error, e.g. for CRC-32 code, can be estimated based on equation (2), which for the telegram length of 4 and 20 bytes is: \( P(4)=9.6 \times 10^{-4} \), \( P(20)=3.2 \times 10^{-5} \), respectively.

\[ P_{np} = N_b \times p \times 2^{-b} \]  

where:
- \( P_{np} \) – the probability of undetected error
- \( N_b \) – the number of bits of information
- \( p \) – the probability of bit error for radio network

3. Conclusion

Using the open transmission systems in RCS systems cannot reduce the assumed level of SIL and the safety requirements defined for this system (e.g., section block, railway signalling system). In this analysis it has been assumed that the time of executed procedures (i.e. the determination of code integrity, encryption) is the sum for those of individual devices of the system. The pre-grouping of telegrams (with limited size) for more devices before executing procedures related to coding, determination of integrity code and encryption is the method that can effectively improve the efficiency of information exchange. This analysis allowed for the evaluation of various methods of increasing the safety of data transmission in the used OTS railway control systems, including in particular...
methods of ensuring the integrity and confidentiality of information. Based on the received results, the least time needed to execute the integrity code and CRC codes, these times are comparable. However, for the hash function the best algorithm was SHA-1. The fastest method of encryption is the AES and the most efficient is the DES cipher. The railway control systems are now computer systems with dispersed structure; in this case the reaction times of individual devices should be taken into consideration.

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ABSTRACT

The paper presents information of the project and the results of research on the problem of monitoring and management of information about occupancy of parking spaces in real time. The material draws attention the potential which, being properly used with adequate detection of the presence of selected technology and the desired transmission of information in graphic form for selected locations respectively in real time which will result in traffic that users will be more consciously decide on it’s journey with the appropriate leads on the possibility of to reach the goal, as well as surrounding their existing infrastructure and the possibility of using public transport.

The present level of knowledge and experience is realized in the framework of research and development project in score of ITS applications in response to the lack of consistency between multiple transport streams and the lack of their interaction on each other.

KEYWORDS: E-parking, occupancy monitoring

1. Project goal

Conducting research aimed at the use of their results in the economic activities of companies, consisting in the development and creation of Platform software - hardware which will allow the participant access to a range of information communication through which most will be able to optimally plan your journey to a specific location in the city.

Optimizing navigate congested city streets requires the collection in an appropriate way, many real-time data from large urban area.

Factors that determine the way of traveling:

- Commuting time,
- The ability to reach a maximum close to
- The price of this trip
- Knowledge about how to communicate in case of change of transport

1.2 Selection of public transportation

Unfortunately, public transport is exceptionally taken into account by a participant in the communication (the person who have they own private transportation ) due to the unpredictability of travel time and lack of information about the possibility of getting up close to the target.

The result of work carried out in the project will be an innovative approach to information management in transport and prepare the base for the commercialization of possible solutions, so that potential participants will be able to consciously choose for themselves the best way to reach the goal.
1.2 Scope of project

This includes conducting research, as a result of which they are to be developed and tested devices, algorithms, developed the software responsible for implementing various functional purposes. Implemented research results in the form of technology demonstrator will be tested on the basis of load scenarios in real operation.

The problem described in the remainder of the paper is a problem that occurs in all major cities. It should be noted that this issue is often downplayed or ignored. Its scale may be exacerbated especially when coming to the agglomeration a large number of tourists (tourist season) or a supporter during big mass events such as EURO 2012.

The proposed technology can significantly affect the solution to this problem by providing the right information at the right time and place for travelers.

1.3 Presentation of the management problems of free parking spaces

The issue of having knowledge of the free space to park (moduls chain of city streets) still has not been resolved to the satisfaction of users, this issue occurs in all large cities, as well as places for travelers (MOP) on the newly developed and existing highways.

Crowded center problem (people seeking free parking spaces) is also the problem of local governments that do not have the appropriate solutions that can meet the needs of the local community and support tourist services.

The very center - the market (conservation protection zone)

There is a lack of accurate information in real time, which have to get a driver from multimedia in the right place and time.

1.4 Design Goals

1.4.1 Purpose and characteristics of the research phase

The aim of research is to design and test various solutions proposed software-hardware platform as a basis for the Integrated Information System of Communication.

In their assumptions Platform should lead to improving the efficiency of infrastructure and transport management - road in heavily urbanized areas, and consequently:

- integrate management activities so far apart the two functioning modes of transport in one area - individual and public transport
- increase the safety of travelers, especially during high mass events, where the chaotic traffic of vehicles and people can cause serious communication problems (eg difficulties in getting ambulances or fire brigades),
- @ raising the standard of environmental protection by reducing pollution,

1.4.2 The project aims at product level

- to produce facilities, which will form the foundation of hardware of the platform (SHP),
- to plan a secure communication between them, develop their problem-free installation policy under the existing road infrastructure
- to develop, implement and test algorithms allow the insert a function of identifying the most advantageous and determinate mode of travel for the passenger / driver, which in future could be implemented as part of the application of products available from a mobile phone or mobile device.
1.4.3 The project aims at the results

Is to increase passenger satisfaction with the functioning of public transport by providing them information about the current position of vehicles and scheduled bus services during their appearance at a specific location (visualization on the map), making it possible to plan and optimize routes in real time. The result will also be introducing the possibility to choose by the driver who is approaching the city a way to travel further basis on current information collected online from the Platform.

1.4.4 The aim of the project at the level of impact

Is to reduce congestion in the city center (it is estimated that between 40% to 60% of the traffic inside the city is the driver who are looking for an individual vehicle parking space). At the same time will allow the commercialization of the results to produce applications for mobile devices, which allow to organize the traffic by transferring his weight in to the public transport.

On the one hand the number of individual vehicles is constantly increasing, urban agglomerations tend to continuous development, thereby increasing congestion in urban centers (down town). On the other hand, existing restrictions on the possible expansion of road infrastructure in the centers, forcing the search for new traffic control capabilities to allow a better use of existing infrastructure.

Currently managing the infrastructure in the cities are mainly focused on creating a fully functioning public transportation trying to provide to the users with “decent” time...
to reach their destinations. However, many elements that occur in the phase where we moving to a destination, does not depend on the participant’s of communication. This makes his displeasure, and in most cases comes down to choose an inefficient way of reaching the user planned destination.

2. E-parking / Architecture Solutions

Planned functionality and capabilities of the Platform presents the scenario described in the drawing. It shows part of the open road space controlled by the hub. Each parking space shall be supervised by hermetic sensor attached to the surface under the street.

Occupied parking spaces are detected by the hub, which connects to a payment system such as: parking meter and controls whether the fee was paid for the particular place. If no prompt is sent automatic to the appropriate services. A vehicle parked across the vehicle is identified as occupying two parking spaces and in compliance with the rules of the owner will be charged for two parking place.

The right of the oncoming vehicles, if only be equipped with satellite navigation systems (navigation system or navigation in the mobile phone) can be addressed by GPS to “approximate” parking space, allowing you to avoid driving through the surrounding streets “walking in a circle” searching free space for your car.

The driver of the vehicle waiting at the gate entrance to the reservation area can benefit from pay-option “guarded
parking place.” The system controls the amount of cars in the area and does not allow to occupy reserved seats. This means that in certain zones can be 100% to find a place, provided that a prior reservation.

The open system architecture based on the addressing used in the organization and building a LAN at any time will extend the scope of the system to areas not covered by the scheme. Modernity solution will consist, among others, for easy expansion of functions offered by the system, e.g. for loyalty programs.

2.1 Extensive research developed elements of the Platform

- constructions of sensors placed on the surface of the roadway and moving blocks of the road going along with the hubs are responsible for collecting information from sensors that are within their range,
- secure data transmission channels to prevent the introduction and removal of data from the system through mobile devices,
- prediction algorithms based on the current position of GPS data.

A characteristic feature of the Platform will be structure of linked planned measurement systems, visualization and audio to a computer system supervising and informing all participants of private and public transport. An important element will be the policy of attaching to the system of new types of devices scattered on the ground such as readers (cards), traffic sensors and other, which in future will be able to be used by applications which using the Platform.

2.2 The possibility of commercialization of the project

Group results of the project are the recipients of local government units, organizations, entrepreneurs who need information related to the state transportation system in a defined area (village, town, district ...) and institutions that are responsible for creating and overseeing the communication system.

With the introduction of the system will be possible to ongoing monitoring of free parking spaces designated in the streets and seats available for paid, unattended parking lots. Number of cars that are in daily use is increasing rapidly and the introduction of fees outside the ‘congestion charge’ or exclusion from the movement of inner cities has almost no ability to reduce car traffic.

The system could also find application in urban areas are preparing for EURO2012, where you will have quick and efficient deployment of vehicles, which will commute to games fans and tourists visiting the city.

3. Description of functionality and methods of data aggregation and presentation by the system

Unambiguous identification of a parking space will allow for rapid and remote configuration of paid parking zones, car park operator, depending on time of day, day of week or more circumstances, e.g. massive event.

All information about the changes and the current rates for parking will be available on the boards display and mobile devices. This allows the driver will be able to decide how far into the city wants to enter, which will lead to the level of fees or leave the car and use another kind of public transport.

Continuous monitoring of occupancy of individual sites by the system and the immediate transmission of such information to the appropriate services to a significant extent eliminate situations in which the offense occurs involving intentional avoidance of payment for parking by what will seal the toll collection system and increase return on urban parking spaces in paid parking zones. Possibilities to include measurements of movement or camera images creates opportunities for more specialized applications to enhance safety and convenience of road users.

In the basic variant, the system will be based on “quantitative approach”, which means analyzing, processing and correlation of information from sensors and payment collection systems. Number of occupied seats are in the “disposal” hub must match the amount of data derived from payment systems. In case of divergence relevant departments will be sent to the parking area (a specified quantity of sensor / parking areas), where the violations occurred.

In addition, an extended variant of the system infrastructure will be equipped with cameras, so that will be possible to record stickers / license plates of vehicles that defined parking spaces.

Correlating identified the registration number of the addresses of sensors will allow for precise indication of where the violations occurred.

4. Key system features

4.1 Functionality reservation in separate areas

Thanks to deployed on roads and parking sensors will be possible to create real-time maps of occupancy of individual sites. This will allow user quickly find free place
that are located in the vicinity of a moving car or at travel destination. Since each sensor will have a unique address, it will be possible correlation with the registration number of car parking space. This will include the introduction of a parking space reservation for a fee (separate areas).

It will be necessary for that purpose facilities such a parking space in a mobile blockade of leaving the ground, which at the time of booking a parking space for a specified period will be increased. This will allow the driver who made a reservation for a peaceful journey for him, waiting for a parking space. At a time when the vehicle will be located in front of the raised lock will need to send a message, eg SMS to the system, which associate with the current reservation request and leave the lock.

Reservations will be made at a predetermined time after which, in case of no person making the reservation, the place will be made available to other drivers.

The booking fee will be added to the mobile phone bill.

Integrating the system of mobile services will provide customers with advance information about the need for aid in case of approaching the end of the paid time. The system will automatically generate an SMS message to be sent to the phone, which was registered fee.

With the accumulated will be possible for example: flexible tariffs, which will make the amount of aid since it was introduced (in the case of payment of an additional period of standstill on expiry of your current ticket price for the next hour will be higher than in the case of payment before the expiry date).

At any time user of the vehicle will be able to use the „debit” in which the counting will take over the payment system of registration based in the specific parking spot. In this case, you will not need to remember the introduction of additional fees.

Registered users will receive an invoice or direct debit payments will be recorded on the invoices contained the mobile operators.

At the time of leaving the car in a parking space equipped with a lift-lock will be possible to send information to the system of „payment guarded,” which will result in raising the blockade. Thanks to this theft of the vehicle will be difficult.

If the fee for a parking space shall be paid by mobile phone, it will be possible to inform the owner of the phone that a parking space, for which he paid was released. If the owner is outside the vehicle, it can mean only one thing - stealing a car.

4.2 Functionality „Pay for a place that you became”

In the case of a single vehicle occupied by more than one parking space levy system will wait for two parking spaces on the same vehicle (assumed to develop an algorithm to detect the simultaneous occupation of several sites by a vehicle on the basis of data from sensors and possibly cameras).

If not paid the relevant fee in accordance with the cost of free spaces in to the system will send a message to staff supervision.

4.3 Additional functionalities

- continuous monitoring and records of vehicles that use public and private parking spaces,
- service ordering, issuing and activating cards allow parking spaces,
- building loyalty programs based on historical information, control the operation of moving lock,
- cooperation with mobile devices used by city departments and law enforcement to immediately provide information about the exact location of the offense,
- records management vehicles whose drivers have paid ranks based on historical information obtained from police and compare them with current data,
- cooperation with the police database of stolen cars,
- Internet access to the system, including the possibility of application for the parking card, and after confirmation of personal information, booking and purchase of „parking” in separate zones,
- Support of different ways to pay for parking site (transfer, credit card, online payment services offered by banks),
- choice of an algorithm using the best available space at a time or by pointing to a specific location.

5. Conclusion

Integrating these two streams of information - the amount of parking spaces and the level of mobility offered by public transport (at the moment these are separate subsystems managed separately) significantly changes the behavior of the user in traffic which significantly reduces the number of objects on their way to the district / city.

Paid parking zones created within the city of organisms are solutions of the individual and are not affiliated with other transport modes. Control and use of parking spaces located in the Motorway in Poland is mainly a problem solved organizationally but not technologically. Automation and process control parking is certainly needed for the organizers and those who are responsible for maintenance inside the city.

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The problems with measuring distance in goods wagons

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ABSTRACT
This article presents the current problems with measuring distance in goods wagons. The main problem where goods wagons are concerned is their lack of power supply. Owing to this, a distance-measuring system is hard to install. Meanwhile, the measurement of distance travelled and the service processes dependent on this measurement are becoming more and more important. Moreover, the railway accident in Viareggio on June 29, 2009 has resulted in increased interest in determining the accurate mileage of a wagon or, to be exact, of a wheelset. One has to realise, that a goods wagon is actually a combination of numerous elements (such as the body, the underframe, the carriage, the wheelsets, etc.) that can differ in mileage and can be exchanged between different wagons. This makes it necessary to register not only the mileage of the whole wagon, but also, at a minimum, of the carriage. This article is an attempt at outlining the current state of this issue.

KEYWORDS: distance measuring, odometer

1. Introduction

A goods wagon is a railway car, whose mileage measurement is technically problematic. The technical condition of the movable elements, including the influence of their operation, both time- and distance-wise on this condition, caused the minister of infrastructure to include a directive (concerning technical certificates) that can be interpreted to say that each wagon’s mileage should be registered.

The Directive [6] says:
… §3. The validity of the certificate is limited with time, which is equal to the mileage (in kilometres) of a railway car between its periodical repairs, but not longer than the date of the next periodical repair specified in the certificate, which stems from the maintenance schedule adopted by the entrepreneur. ...

As we can see from the above, we should attempt to ensure that every railway vehicle, including wagons, has the ability to register its mileage in kilometres.

Currently, such mileage cannot be determined for wagons not equipped with GPS devices (most wagons used by PKP).

2. Chosen aspects of goods wagon management

Railway carriers offer goods transport using numerous different types of goods wagons.

According to the general AVV agreement [1] concerning the use and replacement of goods wagons in international routes, their outer walls should bear an identification consisting of:
• an inventory number,
• an alphabetic interoperability code,
3. Wagon inventory

PKP CARGO S.A. utilises an EWAG system, which is used to collect and record wagon information. The application includes a numeric inventory of all wagons in operation, together with their history since manufacture, all current and periodic repairs, up until their disposal. The system also allows for registering the replacements of the most vital elements, such as wheelsets, as well as repairs, using codes for faults that happen during operation. Instruction [7] in chapter 8, “a wagon’s technical condition check-up” describes the method of registering incidents related to wagon repairs. Each removal of a wagon or its re-entry into the operating fleet is registered in the system, with the code of the cause of such removal.

Due to the lack of data concerning the mileage, the date of such incident is the main reference in the register. The mileage can be estimated based on R7 documents and by determining the routes taken by the wagon, in order to add up the distance.

4. Determining the mileage in goods wagons

Currently, statistical data concerning the wagon’s operation is used by PKP to determine the mileage of most goods wagons.

The mileage can be determined based on:
- periodical readings of the mileage meter
- the data in the wagon tracing systems based on GPS/GSM technology
- an analysis of the “List of wagons in a train” - R7.

Currently, the proportion of PKP wagons equipped with tracking systems or mileage registration systems is relatively small and includes mostly wagons from foreign carriers.

Due to this, the R7 analysis is most often used to register the mileage. The list includes such information as the starting and destination stations of every wagon in a given train. This data, combined with a table of distances, allows for estimating the mileage. It should, however, be noted, that both of these variables are imprecise. The table of distances gives approximate distances between stations with deviations that can be considered negligible when calculating short routes, but can become significant when summing up the total mileage. The second variable is the
wagon’s route. The R7 form lists the starting and destination stations, and does not mention the route that a wagon actually travels. This means that the shortest route is usually used to calculate mileage, while the actual route may be longer. The R7 list of wagons only contains wagons that are parts of complete and running trains. It does not, however, include any movement during manoeuvres performed to form a train, so the mileage during these manoeuvres is not included in the analysis.

This situation results in real mileages that can be approx. 4% higher as compared to the estimates.

5. Mileage monitoring system in data collection and processing - premises

A mileage registering device which collects data directly from the axle (with no intermediate subsystems such as radio transmitters and GSM/GPS navigation) should provide quasi-constant mileage registration with no faults.

Data should be collected by mainly using portable terminals carried by dispatch personnel in the stations. Such terminal should be able to communicate with a desktop computer using a cable or WiFi connection in order to transfer the data collected by the terminal to a central data collection point. Depending on the user’s preferences, such terminal could be equipped with GSM module, which would enable it to immediately transfer the data to a central location independently of stationary computers (this is important especially in the case of carriers with no extensive networks of offices in the stations, where the basic registration of wagons is often performed by the locomotive crew).

A further extension of this method of data collection using wagon-mounted devices would be to use pass-through gates in places where the wagons are operated, that would automatically read the data and transfer them to a central location.

An application providing access to the collected data as well as tools for processing them is required. Depending on the user’s demand, it would be advisable to create software interfaces between the data management application in the central location and the applications used by the carriers to register their wagons (e.g. EWAG used by PKP CARGO S.A.).

Apart from the basic functionality of the system, i.e. collecting data concerning registered mileages, the system could include a number of additional functions to extend this functionality. One example of this would be the ability to include other valuable information in the wagon-mounted device, such as: date of production, dates of repairs, wagon series and number, etc. Reading and processing this information would make it possible to depart from the traditional methods of registering wagons “on the spot” by automating, and thus speeding up the process. This would allow e.g. for automatically generating R7 wagon lists.

The second type of terminals, apart from the ones used to read the data, should also be able to save the data in a device. Such a device should allow for saving such parameters as wagon number, axle number, the diameter of the wheelset (updating this parameter is vital for the conversion of counted impulses into kilometres). Due to the importance of such changes, the access to the device and to the saving function should be verified by a PIN and checked against a database of authorised personnel. These terminals should be given to wagon receivers, repair shops or other personnel and institutions authorised by the carrier.

6. Goods wagons in the TSI specification - chosen aspects

The wagons should be labelled in order to:
- identify each wagon using its unique number, according to the “Railway traffic” TSI. The number is listed in the vehicle register,
- provide information required to complete a train, including the information concerning their braking weight, length including bumpers, their own weight, the speed table according to the load on different categories of routes,
- identify operational limitations for the personnel, including geographical and distribution limitations,
- provide appropriate information concerning safety to the personnel working on the wagons or participating in the rescue mission, including warning signs on powered traction and electrical equipment, lifting locations and safety instructions for particular wagons,

The vehicle should be able to transmit information between the stationary equipment and the vehicle.

Identification tags are not obligatory. If a wagon is equipped with a radio identification device (RFID-tag), the specification below should be used.
- two “passive” tags should be used, one on each side of the wagon, in areas specified in the drawing, in a manner that allows to read the unique id number by a trackside reader.
- if the trackside readers are installed, they should be able to read id tags on vehicles moving at speeds of up to 30 km/h and transmit the data to a ground data transmission system.
• physical cooperation between the reader and the id tag, the protocols and orders, as well as the diagrams for solving the collisions should conform to standard [8] type A.
• if the readers are installed, they should be located on entrances and exits where the train can be modified.

7. Vehicle identification

Each railway vehicle is assigned a 12-digit number (called a standard number) according to the scheme on fig. 3.

In each of the countries, the 7 digits designated to represent the technical characteristics and the serial number are sufficient to unambiguously identify any vehicle.

This number is accompanied by an alphabetic code:
• interoperability code
• a code of the country, where the vehicle is registered
• owner’s code
• technical characteristic code

Owner’s code (Vehicle Keeper Marking - VKM) is an alphanumeric code of 2 to 5 characters. The VKM is printed on every railway vehicle, near the vehicle number. The VKM marks the owner according to the register.

The VKM is unique in all countries included in the TSI and in all countries entering the agreement, which means that they have to implement the numbering and owner code system of the TSI.

The VKM shows the full name or an acronym of the owner’s name, in a form that is the easiest to decipher. All 26 letters of the Latin alphabet can be used. VKM includes capital letters, but the letters that are not initials of the owner’s name can be lower-case.

The vehicle’s ability to transfer information between stationary centres and the vehicle

Fig. 2. Locations of identification elements on a wagon
where: A1 and A2, respectively, signify the minimum and maximum distance from the top of the rail

Fig. 3. Goods wagon number structure

7. Conclusion

To ensure the accuracy of the data collected by a potential measuring system, the carrier using a mileage registration system should adopt a strict internal rule concerning the pairing of wheelsets and axle guards throughout the whole time between repairs.

In case of periodical repairs, when different wheelsets and axle guards are installed, the system has to be able to transfer the data concerning the current mileage to a data collection system, as well as an ability to be paired with a different registration device.

Currently, the mileage of wagons is not registered due to the lack of physical ability to determine such mileage. Due to the above, the EWAG application collects its data and plots them on the time axis, without pairing them with their respective mileages.

In view of the directive of the minister of infrastructure, the lack of mileage registration may be dubious to the Office for Railway Transport in case of carriers not meeting the formal requirement.

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Nonlinear background estimation methods for video vehicle tracking systems

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ABSTRACT

One of the major advantages of the video cameras’ usage for tracking of vehicles is to reduce the costs of Intelligent Transport Systems. However, this requires the development of software techniques allowing an automatic extraction of the vehicle or group of vehicles from the current video frame, which is possible by using the background estimation methods, assuming a fixed camera installed over or at the side of the road. Background estimation based on the linear image filtering algorithms can be performed by averaging a certain number of video frames. However, this technique is relatively slow, which complicates its use, especially in variable lighting conditions. The paper presents an alternative background estimation technique, utilised for its further replacement, based on the nonlinear image filtering algorithms.

KEYWORDS: background estimation, video tracking, Intelligent Transport Systems

1. Introduction

Video based vehicle tracking systems [1] are based on two types of cameras sensitive on the visible light or the infra-red ones. Regardless of its type one of the basic operations used for the reduction of the amount of processed data, as well as their transmission in distributed traffic monitoring systems [2,3], is related to the estimation of background and its elimination from each video frame captured by the camera.

The most typical approach to background elimination is based on more or less complicated motion detection algorithms. In the simplest case (called also the naïve approach) the neighbouring frames are compared with the use of the threshold and all the corresponding pixels which have the same colour are classified as representing the background. The main disadvantage of such approach in practical applications is its sensitivity to noise and changes of lighting conditions. In such cases, typical for the outdoor acquisition of the video signals e.g. for traffic monitoring purposes, the threshold should be adaptively changed or some more advanced algorithms can be applied.

A reliable estimation of the background objects should be not only weather-proof but also insensitive to some other disruptions e.g. related to some rapid local colour changes. The most typical reasons may be the directional light reflections related to the CCD thermal noise, influence of street and car lights, the presence of water on a road, leaves moving on the wind etc. [4]. Such rapid change of the background may also be caused e.g. by a vehicle starting from a parking previously classified as a non-moving element of the background (changes in the background geometry).

The influence of some other long term disturbances, especially those having rather global character, is usually easier to predict e.g. changes of light conditions caused
by street lamps, slowly moving clouds, sun, shadows etc. Another relevant element which should be considered is the influence of camera oscillations as well as the warm air motion caused by high temperature of the asphalt.

2. Background estimation algorithms

The basic method of background estimation (working as the differential detection) assuming the previous frame as the background works well only in the constant light conditions without any moving objects on the scene except the tracked vehicle. It is very fast and similar to some simple motion detection algorithms and some video compression algorithms which do not utilise any motion vectors. Some additional limitations are related to the object’s speed and the camera’s frame rate as well as the threshold. Since the differences of corresponding pixels’ colours between two neighbouring frames can be either positive or negative the dynamic range of the resulting image increases, or the absolute value can be used.

Another approach is based on the averaging of the specified number \( t \) of frames [5] and can be expressed as:

\[
B^{AVG}_{t}(u,v) = \frac{1}{t} \sum_{i=1}^{t} I_{i}(u,v)
\]

where \( u \) and \( v \) denote the pixel’s coordinates.

This method is slow and memory consuming so it can be modified towards the moving (running) average (MA) or the exponential smoothing filter [6]. The MA filter can be described as:

\[
B_{t,MA}(u,v) = \frac{1}{N} \sum_{i=0}^{N} I_{i}(u,v)\]

or in the recurrent form as:

\[
B_{t+1,MA}(u,v) = B_{t,MA}(u,v) + \frac{1}{N} (I_{t+1}(u,v) - B_{t,MA}(u,v))
\]

where \( B \) stands for the estimated background and \( I \) is the input image.

In some systems the weighted average of the each pixel’s recent history is used, where the most recent frames have higher weighting coefficients. Another modification can be based on the additional selectivity so pixels which have been classified as the foreground can be ignored in the background model in order to prevent the corruption of the background by the pixels logically not belonging to the background scene [7].

One of the most relevant limitations of the classical linear methods of background estimation is troublesome choice of threshold. It is typically based on a single value, not dealing with some multiple modal background distributions.

Another interesting idea is based on Gaussian average with fitting the Gaussian distribution over the histogram with running average update. For the multimodal background distributions the Mixture of Gaussians approach can be used, but there are also some problems with initialisation and update over time. Since, some of Gaussian distributions model the foreground and some others correspond to background, there is a need to divide them into such groups [7].

3. Experimental evaluation of algorithms

3.1. Initialisation of the algorithms

Background estimation can be applied with the use of the exponential smoothing filter IIR (Infinite Impulse Response) of the first order, characterised by inherent stability, expressed as:

\[
B^{EXP}_{t}(u,v) = \alpha \cdot B^{EXP}_{t-1}(u,v) + (1 - \alpha) \cdot I_{t}(u,v)
\]

The initialisation can be done using two approaches:

\[
B^{EXP}_{t=0}(u,v) = B^{EXP}_{t=0}(u,v) = \begin{cases} 0 & \text{or} \\ \frac{1}{2} \cdot \text{Range} & \end{cases}
\]

where \( \text{Range} \) denotes the dynamic range of the image depending on its type (0-1 for the normalised images represented by the floating point numbers or 0-255 for 8-bit unsigned integer notation typical e.g. for 24-bit RGB images).

According to the formula (5) the background estimate is initialised by the black pixels, so the convergence can be achieved after the time necessary for obtaining the luminance level of the brightest pixel of the background. Such time can be calculated using the step response of the filter. The modified initialisation (6) can be used for the acceleration of the convergence due to the choice of the middle level of luminance as a starting point for the algorithm.

The chosen value of the parameter \( \alpha \) should be large (close to 1), since the input image usually has the range 0-255 and the estimation update with the component \( (1 - \alpha) \cdot I_{t}(u,v) \) should be large enough to suppress the noise (preferably represented as a floating point number).

The results of the background estimation using two different initialisation schemes are illustrated in Fig. 2 for five chosen frames (no. 1, 1000, 2500, 4000 and 5000).
Images on the left side illustrate the current frames, while the middle and the right columns illustrate the results of background estimation using the initialization by the luminance equal to 0 and 128.

3.2. Median-based estimation

Considering some disadvantages of the linear filters, mainly their sensitivity to impulse noise, some nonlinear algorithms may be used instead of them. Such filters, mainly the median ones, are robust for rapid local changes of luminance values, which are typical for moving objects over the static background [8].

The basic median algorithm can be described as:

\[ B^{(MD)}_{i}(u,v) = \text{MEDIAN} \left\{ I_{i}(u,v), I_{i+1}(u,v), \ldots, I_{i+N}(u,v) \right\} \]  

(7)

where the pixels with the same coordinates \((u,v)\) from \(N\) neighbouring frames are sorted and the middle element of the sorted vector value is chosen as the result. For the even number of elements \((N)\) in the sorted vector (frames) the result is the average of the two middle values, so such filter can be treated as partially averaging filter. In order to increase the processing speed and reduce the influence of noise, the median filter with temporal downsampling can be used, where some frames are not used. In such case the impact of the vehicles moving on the scene is significantly reduced, since they occupy different areas of the image in the frames used for the analysis. Such filter is described as:

\[ B^{(MD)}_{i}(u,v) = \text{MEDIAN} \left\{ I_{i}(u,v), I_{i+M}(u,v), \ldots, I_{i-1}(u,v), \ldots, I_{i+(N-1)}(u,v) \right\} \]  

(8)

where \(M\) is the number of omitted frames.

Comparing the results of the background estimation using median filtering the advantages of using the temporal downsampling can be easily noticed. Illustration of such differences are shown in Fig. 3, where the original frames are shown in the left column, the results obtained for “standard” median filter in the middle, and the effects of using the median filter with temporal downsampling (with \(N=11\) and \(M=5\)) in the right column.

Obtained results can be verified by a human operator.
using subjective evaluation or utilising some automatic image quality assessment methods. Nevertheless, some of the metrics are well correlated with human perception of distortions and similarity of images but are not reliable for the error estimation purposes.

### 3.3. Automatic verification using image quality assessment methods

Two typical approaches to image quality assessment are subjective evaluation and using objective measures. Subjective evaluation requires performing some tests based on filling the questionnaires by the observers what allows calculation of the Mean Opinion Score (MOS) and some further statistical analysis. For this reason its application to image or video processing applications is seriously limited because of the necessity of using time-consuming evaluation by observers.

Much more desired method for computer applications is objective evaluation based on preferably single scalar value related to the overall quality of the image. Such automatic measure can be used e.g. as the optimisation criterion in many digital image and video processing applications. A good example can be lossy compression where it is often relevant to decide whether e.g. 1% better compression ratio introduces artifacts causing serious reduction of the quality.

Some classical image quality measures [9] such as Mean Square Error (MSE) and some similar ones e.g. Peak Signal-to-Noise Ratio (PSNR) are poorly correlated with Human Visual System so recently some new metrics have been proposed. Nevertheless, some traditional measures based on the analysis of single pixels without their neighbourhood are still in use, especially for the detection of changes between two images, especially in the applications where the human perception is not critical.

All such methods belong to the group of full-reference methods, which require the knowledge of the original image without any distortions. Such approach is typical for the optimisation of many image processing algorithms, where the knowledge of the original image is assumed. In this paper the “ideal” background image is also assumed as known, since the image of the road without any moving vehicles or long-term average can be used for this purpose. Nevertheless, in practical applications, especially for a high density city traffic the acquisition of such “empty” background frame is often impossible.

Application of “blind” image quality assessment methods [10], where the original image is not necessary, is quite complicated task and is not analysed in this paper. Such no-reference methods are rather specialised and insensitive to many types of distortions, so their main application area is limited e.g. to the estimation of the amount of noise, quality prediction of the JPEG compressed images [11] or blurred ones [12,13].

In this paper two full-reference metrics have been used for the verification of the background estimation algorithms. The first classical method is the Peak Signal-to-Noise Ratio (PSNR) defined as:

\[
PSNR = 10 \log_{10} \left( \frac{k^{2}}{\sum_{x,y} (I(x,y) - D(x,y))^{2}} \right)
\]

assuming that \(Q\) is the reference background image, \(B\) is the current estimation and \(k\) denotes the dynamic range (255 for the 8-bit image or 1 for the normalised one).

Due to poor correlation of classical metrics with the Human Visual System (HVS) some new image quality measures have been proposed in recent years. The first one [14] is the Universal Image Quality Index (UIQI), further extended [15] into Structural Similarity (SSIM). This metric is probably the most popular modern approach to automatic image quality assessment. The local SSIM index for the fragment of the image (typically 11×11 pixels) can be calculated as:

\[
SSIM = \frac{\left(2 \cdot \bar{x} \cdot \bar{y} + C_1\right) \left(2 \cdot \sigma_{xy} + C_2\right)}{\left(\bar{x}^2 + \bar{y}^2 + C_1\right)\left(\sigma_x^2 + \sigma_y^2 + C_2\right)}
\]

where \(C_1\) and \(C_2\) are small constants preventing the division by zero chosen such that they do not introduce significant changes of obtained results (recommended values are ). Symbols \(\bar{x}\) and \(\bar{y}\) denote the mean values and \(\sigma^2\) stands for the variances (\(\sigma_{xy}\) is the covariance) within the current window (\(x\) and \(y\) are the original and distorted image samples respectively). This measure allows creating a quality map of the image using sliding window approach and the overall scalar quality index for greyscale images is obtained as the average value of the local indexes using the Gaussian weighting (windowing) function. The size and type of the weighting function can be changed [16,17], influencing the properties of the metric, but these changes are not significant for the tests conducted in this work.

The PSNR and SSIM metrics discussed above have been used for the comparison of the obtained estimates with the reference background image. The results are presented in Figs. 4 and 5 respectively.

Analysing the results presented in Figs. 4 and 5 the advantages of the median approach can be noticed in the first time period because of it fast convergence to a good estimate of the background. Unfortunately, there are some negative peaks present in the plot, caused mainly by the moving large vehicles, where the length of the sorted vector within the median filtering procedure is too small. In the long-time period the background estimation obtained by the exponential smoothing filter is better, so the combination of both methods could be used. The median estimation with temporal downsampling should be used for the initial part.
and then the switch to the exponential filter should be done. The only problem in practical application is the appropriate choice of the switching moment without the knowledge of the reference background image.

The comparison of the results obtained for two different lengths of the sorted vector (11 and 31 frames) are illustrated in Figs. 6 and 7.

Since the median-based approach leads to faster convergence, it can be used for the initialisation of the exponential smoothing filter, which is more accurate due to using more frames and floating-point representation of data, similarly as in the High Dynamic Range (HDR) imaging. The idea of proposed hybrid background estimator is illustrated in Fig. 8. It can also be described as the following formula:

\[
B_{\text{HYB}}^{\alpha}(u,v) = \begin{cases} 
\text{MEDIAN} \left( I_{1}(u,v), I_{2}(u,v), \ldots, I_{N}(u,v) \right) & : t < T \\
\alpha \cdot B_{\text{HYB}}^{\alpha-1}(u,v) + (1 - \alpha) \cdot I_{t}(u,v) & : t \geq T 
\end{cases}
\]

The comparison of obtained results by means of the image quality assessment metrics over time is presented in Figs. 9 and 10.

---

**Fig. 4.** Peak Signal-to-Noise Ratio (PSNR) values for consecutive frames of the background estimation using four various filters.

**Fig. 5.** Structural Similarity (SSIM) index values for consecutive frames of the background estimation using four various filters.

**Fig. 6.** Peak Signal-to-Noise Ratio (PSNR) values obtained for two median filters with temporal downsampling and different number of used frames (N).

**Fig. 7.** Structural Similarity (SSIM) values obtained for two median filters with temporal downsampling and different number of used frames (N).
4. Conclusion

Background estimation and subtraction algorithms are still an active research area [18,19] especially in the applications related to the video surveillance systems. The analysis presented in the paper illustrates the disadvantages of some typical methods, so one of the most interesting alternatives is their combination, allowing better initialisation using the nonlinear median-based filtering with temporal downsampling preventing from the influence of noise.

Omitting 5 frames using the temporal downsampling approach with the frame rate 25 frames per second, the time period corresponding to the boundary frames is 2.2 s and 6.2 s respectively, what is a reasonable choice for the city ITS solutions and has been used in this paper.

The best results can be obtained using the exponential smoothing filter initialised by the median filter with temporal downsampling.

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Bibliography

NONLINEAR BACKGROUND ESTIMATION METHODS FOR VIDEO VEHICLE TRACKING SYSTEMS


Archives of Transport System Telematics
Increasing capacity of infrastructure for public transport co-modality and sustainability in cities

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ABSTRACT
The article describes public transport co-modality for sustainable development of a public transport system. New strategies are needed to make the city public transport more efficient, more accessible and more sustainable. There are some concepts described in the article. The concepts are illustrated with practical examples – how it is possible to increase the capacity of infrastructure and what has been done in the city of Riga for public transport sustainable development. Key benefits of each concept are also described. A more efficient use of city space, allocated to transport improves the overall performance of all the passenger transport system. The paper presents the concept of aid – a base graph approach to calculate the territory assigned to the particular stop of public transport for the cost optimization. Efficient planning and better use of infrastructure, as well as passenger-friendly interchanges and good traffic management, allocated to public transport, bring the public transport system towards sustainability.

KEYWORDS: infrastructure, sustainability, city transport system, public transport, co-modality, aid – base graph approach

1. Introduction

The social importance of urban passenger transport is indisputable. Moreover, the external effect generated by urban passenger transport is not confined to the city, and has an impact on the socio-economic development of the region and even of the country. The urban passenger transport is an essential component of any economy because the population need for public transport is very high.

Public passenger transport plays a leading role in municipal transportations in Riga. They are served by 54 bus, 20 trolley-bus, and 11 tram routes. The public transport system includes also taxis, trains in the city, and recently developed a system of public bicycles.

In recent years, characterized by a high rate of motorization of the population, the social significance of public transport has been increasing. Negative consequences of the increasing number of private cars on the streets include traffic jams, pollution, security problems, and lack of parking places. Such problems are solved in the world by upgrading public transport, development of the street network, taking into account the provision of its priorities, and selected lanes based on the structure and the technical level of the vehicles.

The team of Institute of Electrical Engineering and Electronics has a broad experience in the development of new technological solutions as well as in providing the expertise to the Transport Department of the city of Riga council on public transport services.
The recent developments comprise solutions for recuperation of braking energy of trams, the use of an ITS solution [1], the design of bi–directional DC substations [2], the formulation of ITS concept for the city of Riga [3], and the technical expertise in the Transport Department of the city of Riga council, including preparation of new ideas as student proposals for an international competition of Transport department, as well as development of decision making procedures for transport via participation in COST 356 project [4].

2. Concept of sustainability

The allocation of indicators to the three pillars of sustainable development, i.e. to its economic, social or environmental dimension is well known [4]. Of course, in many cases this distinction cannot be clearly made, as several indicators represent more than one dimension or it is not easy to unequivocally assign them.

An extension of the DPSIR-approach has been recommended by Niemeijer and de Groot [5]: They pledge to use an enhanced DPSIR framework, a so called ‘eDPSIR’, that does not consider individual causal chains, but looks ‘…at causal networks in which multiple causal chains interact and inter–connect’.

The DPSIR indicator framework is an extension of the PSR model developed by the Organisation for Economic Co-operation and Development [7].

The balance between the requests for transportation, transport costs, quality of service [8], including environmental impact is a classical logistic task relevant to the transport service. Normally the changes in transportation in the cities are relatively slow, due to the specific of requests for transportation and high cost of infrastructure.

In the case of very strong minimization of transport budget due to the crisis in Latvia, the need for calculations and modeling of sustainable transport system is very important, in order not to break the balance described by the DPSIR model.

3. Public transport services in Riga

The company “Rigas satiksme” provides public transport services in Riga, offers various types of transport for rent, as well as manages the parking lots of Riga municipality. From May 1, 2009, only electronic payments are accepted in Riga public transport. The company “Pasazieru vilciens” provides local railway transport services. From this year the e-tickets are used in both transport companies.

According to statistical data, public transport of “Rigas satiksme” [9] carried 133,399,525 passengers in 2010 [9]. So an average passenger flow per vehicle per day in 2010 is calculated using formula:

\[ X = \frac{P}{V \cdot Y} \]  \hspace{1cm} (1)

where:
- \( X \) – an average passenger flow per vehicle per day in 2010;
- \( P \) – the number of passengers carried by “Rigas satiksme” in 2010;
- \( Y \) – days in the year 2010 = 360.
- \( V \) - the number of vehicles used by “Rigas satiksme” in 2010;

\[ V = (T + t + B) \]  \hspace{1cm} (2)

where:
- \( T \) – the number of trams used by “Rigas satiksme” in 2010;
- \( t \) – the number of trolleybuses used by “Rigas satiksme” in 2010;
- \( B \) – the number of buses used by “Rigas satiksme” in 2010;

So, we have on average: 339 passengers per vehicle per day carried by “Rigas satiksme” in 2010.

Statistics of “Rigas satiksme” about ticket control in 2010 in Riga public transport say that there were 58,941 fare dodgers in 2010 in Riga public transport system. It is by 2,406 fare dodgers more than in 2009, when there were 56,535 fare dodgers. Just to compare: there were 471,583 ticket checkups in 2009, which is 664 less than in 2010.

Recently the company “Rigas satiksme” made a decision to strongly reduce the available services, which significantly affected the quality of service. This decision was taken based mainly on administrative and financial criteria, however, the assessment of the service quality and of the balance between requested services and available resources was not sufficiently addressed.

There is a numerical example for the calculation of sufficient number of services proposed.
4. E - ticketing

The Riga public transport (bus, trolleybus, tram, and railway) operates an electronic payment system, or e-ticket (e-talons). Every time, when entering a public transport vehicle, a passenger has to apply his/her e-ticket to the validator until the ticket's validity period and the number of remaining trips are displayed on the validator screen, the green signal lights up and a short signal sounds. Validators are located inside public transport vehicles, next to every door. In case of having no e-ticket, a passenger has to buy a one-time ticket in a public transport vehicle.

The understanding of the transport infrastructure is one of the important points for further planning. An efficient transport flow planning may improve the transport situation. It can reduce costs and travel time. For the effective transport infrastructure planning it is necessary to have the knowledge base of the current situation on the streets. Based on the received data of the current situation a deep analysis can reveal gaps and weak infrastructure sites, which need considering for early decisions.

The electronic payment system, which is based on contactless technology, recently introduced in the Riga public transport, consists of VPE 415 – card readers, which check electronic tickets, transmit the data about passengers checking-in to the driver computer and continually exercise control. A VPE 415 card reader is shown in Fig. 2.

The use of e-ticketing system is the basis for development of future optimization scenario.

5. Method of the calculations

The time, costs and quality of the service parameters are used for task optimization.

Time vs quality of service indicators parameters are defined by formula 3. The main variable and the parameters will be used next in the analysis.

\[
    d_{in} = \frac{1}{2} \text{Var}[D_{in} - D_{(i-1)n}] = \frac{1}{2} \left\{ \text{Var}[D_{in}] + \text{Var}[D_{(i-1)n}] - \text{Cov}[D_{in}, D_{(i-1)n}] \right\} \quad (3)
\]

where: \( \text{Var}[\ldots] \) and \( \text{Cov}[\ldots] \) - determines the difference, if \( D_{in} \) and \( D_{(i-1)n} \) values are not correlated

A legend of reliable service is shown in Table 1.

The delay time is one of variables in calculating the level of service. The delay time depends on many factors: firstly on the number of passengers embarking and disembarking, secondly on emergencies on the road. Formula 4 shows the delay time calculation, dependent on the length of the vehicle and passenger volume. The calculation of traffic accidents will not be taken into consideration here.

\[
    D'_{in} = d' + \Delta_d \cdot d'_{in} + \Delta_w \cdot Wxw_{in},\quad (4)
\]

Single-door vehicle, if \( d'_{in} > 0 \) or \( Wxw_{in} > 0 \)

Single-door vehicle, if \( d'_{in} = Wxw_{in} = 0 \)

Double-door vehicle, if \( d'_{in} > 0 \) or \( Wxw_{in} > 0 \)

Table 1. Accepted parameters and variables of reliable service

<table>
<thead>
<tr>
<th>Meaning</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger occupancy during trip</td>
<td>The average number of passengers</td>
</tr>
<tr>
<td>i, at the moment when the</td>
<td>coming to a stop n</td>
</tr>
<tr>
<td>vehicle leaves stop n</td>
<td>Trip time if difference between</td>
</tr>
<tr>
<td></td>
<td>the departure time from stop</td>
</tr>
<tr>
<td></td>
<td>k - 1 and the arrival time at</td>
</tr>
<tr>
<td></td>
<td>stop n</td>
</tr>
<tr>
<td>The delay, which is designed</td>
<td>The delay during trip i to stop</td>
</tr>
<tr>
<td>to R_k</td>
<td>k, includes the time which is</td>
</tr>
<tr>
<td></td>
<td>necessary to accelerate and</td>
</tr>
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<td></td>
<td>slow down (D_{in} = 0 if it</td>
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<td></td>
<td>does not stop at the transport</td>
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<tr>
<td></td>
<td>stop n)</td>
</tr>
<tr>
<td>The delay time part includes</td>
<td>The number of passengers</td>
</tr>
<tr>
<td>the time which is needed to</td>
<td>boarding vehicle i to stop k</td>
</tr>
<tr>
<td>accelerate and slow down (b =</td>
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</tr>
<tr>
<td>0 if it does not stop at the</td>
<td></td>
</tr>
<tr>
<td>transport stop n)</td>
<td></td>
</tr>
<tr>
<td>The number of passengers who</td>
<td>Insignificant time delays in</td>
</tr>
<tr>
<td>got out of vehicle i on stop n</td>
<td></td>
</tr>
<tr>
<td>Insignificant time delays in</td>
<td></td>
</tr>
<tr>
<td>disembarking</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 2. VPE 415 card reader
Source: [9]
Double-door vehicle, if \( d'_{\text{in}} = Wx_{\text{in}} = 0 \)

Formula 4 assumes that the embarking and disembarking passenger flows in two-door vehicles will differ from the flow in single-door vehicles. Knowing the number of entries and exits, it can be expected that a significant uncertainty will not happen.

The following factors affect the delay time:

- payment form
- arrival characteristics
- the conflict between the embarkation and disembarkation
- potential free space between vehicles
- the traffic characteristics
- passenger performance.

The boarding time of passenger:

- \( \Delta_d = 1.5 \text{ sec} \) - pay the conductor
- \( \Delta_d = 2.5 - 3.0 \text{ sec} \) - in cash - with residue
- \( \Delta_d = 5.0 \text{ sec} \) - with residue
- \( \Delta_d = 6.5 \text{ sec} \) - automated machines

Disembarking passengers:

- \( \Delta_w = 1.5 \text{ sec} \) - without baggage
- \( \Delta_w = 3.0 \text{ sec} \) - small baggage
- \( \Delta_w = 5.0 \text{ sec} \) - big baggage

The delay time of the stop:

- \( d' = 2.0 \text{ sec} \) - paying to conductor
- \( d' = 5.5 \text{ sec} \) - possibility of free space (the vehicle can easily leave the stops, does not interfere with other traffic)
- \( d' = 7.0 \text{ sec} \) - have no possibility of free space.

The second key variable is the journey time. The term “travel time” includes the following data: travel time from the outgoing point (origin) – a vehicle waiting time – travel time in transport – the time to destination.

The introduction of preference criteria \( Z[4] \), based on statistics available, is proposed for the calculation.

### 6. Catchment areas

The calculation of catchment area for a given origin-destination stop, the results of the accessibility study and rail journey times are taken into account. The so-called “preferential” catchment areas are based on the criterion of minimising the generalized travel time, which includes the time required for the actual rail journey, the time taken to reach the station of departure and the arrival at the final destination, plus the parking time (time to find a space to leave the car). As exemplified in Figure 3 [10], a given residential area is included in the catchment area of station 1, if it fulfils the following two requirements:

- The time required to reach stop A is less than the time required to reach stop B.
- The quality of service (preference of passenger) for stop A is more than that of alternative stops.

Let’s display a public transport route network as the graph, where peaks of the graph are stations, but the routes between nodes are considered as arcs of the graph. The public transport system will consider a public transport hyper graph, where Riga (Latvia) tram 4 route from the “Botanic Garden” stop to the “Grēcinieku iela” stop \( P_{tr} = \{ P_{tr1}, P_{tr2}, \ldots, P_{trn} \} \) and trolleybus no 9 route is \( P_{tb} = \{ P_{tb1}, P_{tb2}, \ldots, P_{tbu} \} \); hyper graph peaks in this case will be “Botanical”, “Slokas Street” and “Grecinieku street”.

The example of a public transport system hyper graph is shown in Fig. 3.

The following map shows the existing network of tram stops in Riga for tram No 4 areas.

This means that, in the same area, the catchment areas for different transport modes could be identified by preference (quality of service and price of journey).

The model is as follows:

With: \( Z[1] (P_{tr1}) \), probability of residential area i to choose stop \( P_{tr1} \),

- \( Z[2] (P_{tr2}) \), probability of residential area i to choose stop \( P_{tr2} \),
- \( Wx(P_{tr1}) \), number of useful direct connections of stop \( P_{tr1} \) for residential area i,
- \( Wx(P_{tr2}) \), number of useful direct connections of stop \( P_{tr2} \) for residential area i,
- \( t(i P_{tr1}) \), time of residential area i for a given trip via stop \( P_{tr1} \).
A. Patlins, N. Kunicina, L. Ribicks

5. Data use

The following subsystems will be considered: 1) power system (Se); 2) transport system with vehicles (St); 3) set of passengers (Sp).

Vehicles functions, an intelligent agent system for their implementation and the enforcement of intellectual equipment are described below. Set Sp of passengers in time moments in transport system St with vehicles St1, St2, ..., Stn ∈ St, with their functions Sfn, which provides an interface to the Advanced Traffic Management Systems, Advanced Traveler Information Systems, Advanced Public Transport Systems, Advanced Vehicle Control Systems, Advanced Rural Transportation Systems, Commercial Vehicle Operations, taking into account the environmental impact of Wv.

The following designations will be used in this article: Se – the power system; St – the transport system with vehicles St1, St2, ..., Stn ∈ St; S diretkt – the minimum of vehicles, which is necessary to provide the passengers transportation; Ste – the consumption of power resources of vehicles with its components Sε1, Sε2, ..., Sεn ∈ Ste; n=1,2, ..., Sp – the set of passengers with subsets Sp1, Sp2, ..., Spk ∈ Sp; k=1,2, ..., t – the time, t1, t2, .. ti – moments of time; Ptr={ Pτ1, Pτ2, ..., Pτn} the set of tram stops n=1,2, ...; Pτ={ Pτ1, Pτ2, ..., Pτu} the set of trolleybus stops u=1,2, ...; D – the distance (roots); d – nodes/stops of transport network d1; d2; ... dm ∈ D; Z^p – priorities of passengers; W – the environment; Wv – the influence of environment; W^l – feedback (transport control system); Wk – the input of the transport system (resources, passengers); Wp – the output of the transport system (resources, passengers); A^p – the set of intelligent agents (intelligent agent network) with subsets A^sτ1, A^sτ2, ..., A^sτm, A^sp1, A^sp2, ..., A^spm, ..., A^supra ∈ A^p; m=1,2, ..., A^supra – Supra intelligent agent; Dp – distributed data bases; Wd – distributed Web server (servers); ∃Sn ∈ Spk S(Sn, Spk) -> min, (exists when Sn, as for each Sp - S(Sn, Spk) exists; Target function S(S) -> min, S ∈ S diretkt .

For the areas around railway nodes or nodes of hyper graph the principle [11] shown in Fig. 3 is applied.

8. Numerical example for the calculation of sufficient number of services

There is a wide range of statistical data from e-tickets: personalised e-tickets, non-personalised e-tickets, and smart-tickets with necessary products.

Fig. 4. Example of existing stops fragment for tram No 4
Source: [9]

Fig. 5. The analysis of average travel time and demand potential units
The integration of railway transport in the Riga city public transport control is important for passenger’s service, using the existing recourses. However, the integration of transport control systems has just started, being developed for 3 years. A bus control system – ASOS – was the first implemented system. The use of a transport control procedure for co-modal transportation of passengers in the city of Riga is very important. An example of telematic tools application for the city of Riga is well-described in [8]. The dynamic control of transport modes in a pre-defined time interval and a composite final control procedure for each transport mode and the traffic harmonisation aimed at transport arriving on time and the harmonisation of railway and public transport traffic, maximally using the existing infrastructure capacities by defining transit flows in transport nodes (hyper graph nodes). An effective tool of research for problems of optimum control is the principle of a maximum by Pontryagin’s Maximum Principle representing a necessary condition of optimality in such problems. The procedure consists of two main parts: an operating procedure, in this case the routing of passengers’ flow, and the object of control, in this case the passenger transport. The objects of control divided into three levels, means of transport, a vehicle, or all the system of city public transport etc., can be considered. The operating kernel since the occurrence of control problems has undergone evolutions from an elementary regulator to modern information systems – intelligent transports system.

Validation of the existing origin-destination. The current transportation surveys depend on sample surveys – vehicle number plate survey, roadside interview survey, site visiting survey, cordon line survey. However, the smart card data has complete survey data for all the travel. In addition, it’s very easy to obtain some special data, such as in-vehicle persons.

Transport service system establishment. The current demand forecasting is based on historical data more than a year ago. However, the smart card data is up-to-date data acquired at least a month ago. The data is not forecasted data but the actual data. Using the smart card data, the transit demand can be analyzed and the schedule can be optimized.

Transportation policy before-and-after assessment. Researchers may develop the transit assignment and schedule optimization models with the smart card data. These models may be utilized to pre-assess projects, such as new railroad construction. The smart card data includes these items irrespective of the region and operator. Each smart card has a unique ID and a passenger’s travel information can be detected as a set of stops and stations. With these sets of stops and stations, passengers’ also travel routes can be calculated. Depending on the smart card type, some of them include the privacy protection. According to the privacy agreement, the private information is excluded from this research [12].

Transaction ID is to form a trip chain by linking each trip segment of various modes and lines. Transaction ID enables to generate trip chains from each trip segment. For example, it’s available that “One passenger takes line N of mode B from origin A, and transfers to hyper graph node at the place of A, and arrive at the place of C.” The origin and the destination correspond to stops or stations that passengers visited, so one can get precise origin-destination data compared to the existing transportation planning. Stops or stations are approximate passenger’s actual (real) origin-destination, in the catchment area. However, the data used had the limitation that did not record each trip, but only from personalized e-talons.

In the Riga area, the public transport fare is constant and does not depend on the travel distance, but in the future it can be adjusted to the travel distance. To measure the distance on a vehicle, passengers bring their cards close to the card reader on the vehicle (or station) at their getting on and off. This means the limitation described previously can be solved. The travel distance data is available in the smart card system.

### 9. Real database building

The key point of Real DB database is to build the entire passenger trip chain data from segment smart card data. Real DB database can be built from all segments of bus, trolleybus, tram trips, so a Real DB database user is able to analyze the transit DB and route. The raw data processing to build a Real DB database follows these principles [12]:
- make sets of segment data by the same smart card ID and Transaction ID,
- sort the transfer order within the same transaction,
- generate a unit of Real DB data as shown in Figure 5,
- build a database of Real DB data.

#### Table 2. Smart card data items [12]

<table>
<thead>
<tr>
<th>Data Items</th>
<th>Items details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smart card ID</td>
<td>Each smart card’s ID (passenger ID)</td>
</tr>
<tr>
<td>Departure date and time</td>
<td>Departure time of a current vehicle (train)</td>
</tr>
<tr>
<td>Transaction ID</td>
<td>Each passenger’s travel ID</td>
</tr>
<tr>
<td>Mode code</td>
<td>Current mode's ID</td>
</tr>
<tr>
<td>Number of transfers</td>
<td>Number of transfers is a trip chain</td>
</tr>
<tr>
<td>Line ID</td>
<td>Current line-ID (line number)</td>
</tr>
<tr>
<td>Operator ID</td>
<td>Company operator ID</td>
</tr>
<tr>
<td>Vehicle ID</td>
<td>Current boarding vehicle’s ID</td>
</tr>
<tr>
<td>Passenger class</td>
<td>Passenger class ID (general, student, aged, handicapped etc.)</td>
</tr>
<tr>
<td>Boarding time</td>
<td>Boarding or transfer time (sec. units)</td>
</tr>
<tr>
<td>Boarding stop ID</td>
<td>Stop (or station)’s ID of boarding or transfer</td>
</tr>
<tr>
<td>Alighting time</td>
<td>Alighting time (sec. units)</td>
</tr>
<tr>
<td>Alighting stop ID</td>
<td>Alighting stop (or station)’s ID</td>
</tr>
<tr>
<td>Alighting fare</td>
<td>Additional fare charged proportionally to total distance</td>
</tr>
<tr>
<td>Date and time</td>
<td>Travel date and time</td>
</tr>
</tbody>
</table>
The summed data is calculated by the sum of each segment smart card attribute value. The sum of time used for transfer can be calculated by the sum of time gaps between the time of alighting and the next boarding time acc. to the time order.

A unit of Real DB data [12]:
- Smart card ID;
- Boarding stop (or station) ID where the transfer order is 0 (the first boarding);
- Alighting stop (or station) ID when the transfer order is maximum (the last boarding);
- The number of passengers that own the card (generally 1);
- The sum of each trip segment distance within the same transaction ID;
- The sum of each trip segment time within the same transaction ID;
- The sum of each trip segment fare within the same transaction ID;
- The number of transfers;
- The sum of each time used for transfer (within a trip chain).

The trip chain data is very helpful to analyze the transit information and to estimate the demand. A spatial analysis and transit project assessment can be performed with geographical data and tools. With the Real DB database, the transit assignment models can be developed. In addition, the schedules optimized to the real demand are also derived. Further algorithm research, however, is needed. Especially, the Real DB data is a kind of actual data, not estimated data. It’s very powerful to calibrate coefficients of each model’s demand estimation, transit assignment, and schedule optimization [12].

The planned timetable with a driving record and the rate of delay can be calculated. The mode share can be derived by a mode’s total passenger-km divided by all mode’s total passenger-km within the time slot and the DB. In the DB analysis, the basic analysis of the above figure, as well as valid routes of certain DB, an average transfer time by the route, a comparison with the road network path, a railroad share by the route, a passenger assignment rate by the route, are available in Real DB.

Generally, each index might be analyzed by the time slot, the region, the passenger class, and the mode. The data integration analysis is also available for the indices. Besides, the research on the data integration of transit data and highway traffic data is needed.

The passenger class is divided into general, student, disabled person, the aged matching to the smart card classification. It is aimed at analysing the trip/travel pattern by the passenger class and at suggesting appropriate service strategies for each class. [12].

### Table 3. Transportation indices derived from the smart card data [13]

<table>
<thead>
<tr>
<th>Class</th>
<th>Index</th>
<th>Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fare</td>
<td>Avg. fare per passenger</td>
<td>Total fare charged divided by total passengers</td>
</tr>
<tr>
<td></td>
<td>Avg. number of transfers</td>
<td>The number of all trips divided by total passengers</td>
</tr>
<tr>
<td></td>
<td>Total income by line</td>
<td>Total fare of a line's passengers</td>
</tr>
<tr>
<td>Transfer</td>
<td>Avg. transfer time</td>
<td>Transfer time: the time gap of previous alighting and current boarding</td>
</tr>
<tr>
<td></td>
<td>Avg. transfer cost</td>
<td>Transfer cost: additional fare for transfer</td>
</tr>
<tr>
<td>Volume (Passengers)</td>
<td>Passenger by the OD pair</td>
<td>Sum of all passengers through all modes from one stop (origin) to another stop (destination)</td>
</tr>
</tbody>
</table>

### 10. Environmentally sustainable transport

The environmentally sustainable transport can be defined in two ways:
- as the application of environmental sustainability to the transport sector or to elements of this sector
- as the environmental pillar of sustainable transport, which makes the definition of the concept of sustainable transport necessary.

There is no generally accepted definition of the term “sustainable transport” (like its synonyms ‘sustainable transportation,’ ‘sustainable travel’ and ‘sustainable mobility’). The expression is often used in order to describe all forms of transport which minimise the environmental impacts, such as the public transport, car sharing, walking and cycling, as well as technologies such as electric and hybrid vehicles and biofuels.

While the conceptualisation of the sustainable transport using the ‘three Es’ of environment, equity, and economy is widely accepted according to [14,15], the problem with this...
Increasing capacity of infrastructure for public transport co-modality and sustainability in cities

Table 4. Trusted Service Criteria

<table>
<thead>
<tr>
<th>Standard role</th>
<th>Typical criteria row</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driving on the schedule **</td>
<td>At least 80% arrive in time (delay 0-5 minutes) at the peak time, usually 90% accuracy</td>
<td>Short intervals</td>
</tr>
<tr>
<td>Boarding and disembarking time</td>
<td>Max 3 - 8 minutes stay at the station</td>
<td>Used for small transport enterprises</td>
</tr>
<tr>
<td>Immersed journeys **</td>
<td>A minimum of 90% - 95% on schedule</td>
<td>Immersed journeys is at risk of reliable service criteria</td>
</tr>
<tr>
<td>Passenger safety **</td>
<td>Maximum of 6-10 passengers to 106 passengers in an emergency. Max 4-8 crash to 1.6 * 105 vehicle-km</td>
<td>Dependent on updated data about security</td>
</tr>
<tr>
<td>Passenger complaints</td>
<td>There is no restriction, on the complaints driver / time</td>
<td>Passenger complaints always be received</td>
</tr>
</tbody>
</table>

* Displays the main data from the U.S.
** Typically used standards

approach is that it has the potential to perpetuate the status quo by only focusing on a change within the transport sector to the exclusion of change across sectors. Transport is only one sector and it must work in conjunction with other sectors or areas – such as energy, manufacturing, and housing / land use – if system transformations are to be made towards sustainable development [15]. In other words, a sector such as transport or agriculture cannot be characterised as sustainable or unsustainable, because they are not independent of the other sectors. However, transport can be characterised either to contribute or not to contribute to the sustainability of society, all other things being equal. Biofuels are a good illustration of this. From a transport point of view, biofuels are or could be sustainable (considering only transport energy), because they could be a renewable source of energy. But if the production of biofuels is made to the detriment of the diet of a large part of the world population, biofuels cannot be described as sustainable [4].

Currently, the air quality in the city of Riga is poor, so it is the time to seriously think about reducing the number of vehicles in the city centre. Currently, the company “Rīgas Satiksme” opens up a number of new paid car parks in the city. The aim is to optimize the traffic in the city, especially on streets with heavy traffic of public transport. It is important to streamline the flow of cars and to arrange the parking so that motorists can drive up close to objects of interest to them.

Reliable service attributes that apply to passengers:
- Waiting time;
- Boarding time;
- The opportunity to sit in the vehicle;
- Travel time;
- Disembarking;
- The total running time (including embarkation and disembarkation);
- Data transmission time;
- Advance information on driving times.

Reliable service attributes relating to the administration:
- Departure according to a list;
- Route keeping the schedule;
- Space allocation;
- Individual vehicle space;
- Departure time;
- Missed routes;
- Technical emergency;
- Message on retention time;
- Driver’s driving experience.

Externally, reliable service attributes:
- Road congestion;
- Accidents on the streets;
- Incidents;
- Weather.

11. Conclusion

The task of development of electric power application, an effective improvement in the public transport system is formed as a formal task of model investigation that can provide the affectivity of the exiting transport system investigation that is significant for economy especially under the conditions of hard city traffic. The task of the power consumption optimization is connected with technologies and methodology that can provide passenger’s transportations with more effective application of the available resources and avoiding duplicated routes to provide effective use of electric energy. The graph theory is applied to develop power consumption affectivity improvement.

The existence of difficult dynamic topologies; the priority of the customers and its changing with time; not enough statistical data for the modelling were taking in to account.

The procedure of improvement to the quality of service, time, costs, electric energy effective use. The concept of hyper graph is used with a combination of aid – a base graph approach in numerical calculations was used. The role of aid – base graph approach is numerically examined. The suggested theory is assessed with the use of a homomorphic model.
Bibliography


Integrated problem of ship route planning

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ABSTRACT
Planning and realization of ship route is a complex problem, which consists of elements from different disciplines. It is necessary to take into account: the formal requirements, the organization of traffic in restricted areas, exploitation limitations of the ship; economic issues relating to the costs of fuel and the costs associated with the possible unscheduled reaching the ship at the port of destination and waiting for unloading. It is important to maintain safety conditions related to extreme weather conditions. As the sailing is done on the changing weather conditions, considerable issue is the problem associated with the acquisition, processing and integration of weather data.

Issues connected directly with the procedures of route computation are also important - the choice of optimization algorithm, matching the speed characteristics, the state of load.

Increasingly being taken into account as restriction of navigation has to be the threat of piracy and terrorism. In the planning and realization of a ship voyage important issue is so called human factor and thus the experience of the master, which will include a decision as to the extent of detail of route planning, taking into account the restrictions importance and eventual adoption or not the proposed route

KEYWORDS: ship route planning, limitations, procedures

1. Introduction

Ships route planning is still an actual problem of maritime navigation. Ship as the object is still under the influence of changing environmental conditions and environment (weather) and the effect of travel depends on the changing economic aspects.

Route selection is based on criteria describing the safety of the ship and cargo, the minimum travel time, lowest fuel consumption for a given travel time, a certain degree of travel comfort (e.g., for passenger ships or specific cargo), the criterion of profit.

These criteria are often contradictory, so the aim is to set the level of compromise and Pareto-optimal solutions. The route is Pareto-optimal when there is no worse route in every respect, and is better in one respect. Each route better due to some criterion, must be worse because of the other. This is a problem of multi-criteria optimization, which should contains all the appropriate constraints.

The whole process of ocean route programming can be divided into two stages: finding a set of routes for a given optimization problem, and the second stage, arrangement of a set of designated routes taking into account their ranking and compromise between the accepted criteria. In the first stage can be used calculations based on the isochrones method, defined by a grid of roads and directed graphs, or most convenient route for the most effective method of evolutionary algorithms [8, 9].

Taking into account the constraints of the environment (weather, prohibited areas) and control (dangerous slamming, flooding the deck, dangerous resonant states) usually
2. Criterions and relationships

Among the many criteria for optimizing the most important role is attributed to the criterion of minimizing travel time. This minimum time substantially affect the final selection and approval of the route.

In a second stage the decision maker's preferences on the criteria for optimization are complied, which can be described by linguistic values with weights assigned to them, for example, in certain conditions, the captain acknowledges that he has a reserve of time for the service ordered by the agent at the port of destination and decides to designate route with minimum fuel consumption for a given predicted travel time. Statistical methods and tools of artificial intelligence, such as multi-criteria ranking method [3] can be applied here.

Undoubtedly, from the economic point of view the time criterion is not sufficient. The owners are interested in multi-criteria optimization and searching for the ultimate economic effect of profit maximization, so the equation can be written as [7]:

\[ Z = F - Kz - Ko(t) - Kp(t, Vs) \]  \hspace{1cm} (4)

where:
\( Z \) - profit, \( F \) - Freight, \( Kz \) - the cost of loading, \( Ko \) - prime cost, \( t \) - time travel, \( Kp \) - fuel costs, \( Vs \) - velocity of the ship.

Given that the most favorable time of arrival of the vessel to the point of destination may not always be a minimum time (pier reservation time for unloading/loading), function of time will take the form:

\[ f_{passage\_time}(t_n) = t_n \rightarrow t_{expected\_time} \]  \hspace{1cm} (5)

Equation 4 can be considered only if the process is deterministic. On the other hand it is known that the ship speed (Vs) is a function of many variables, even if the weather conditions and characteristics of the ship power. Similarly, travel time (t) is a function of weather conditions and control parameters.

It follows that, weather conditions always affect in the variable way on the changeable costs (Ko + Kp) and the various factors that impact on it (the main engine speed, fuel consumption, course, speed). For this reason, minimizing travel time, which takes into account the weather conditions is a fundamental task in optimizing the entire project.

In some cases, it is reasonable to seek such a route that would include the minimization of fuel consumption, which ultimately boil down the problem to finding the optimum of these two criteria [7]. This problem will be important for ships, which are imposed deadline for entry to a port when it precedes a specific trip planned times or is likely to complete an earlier voyage. This applies to both linear and tramp shipping.

In each situation should be considered the criterion of safety of navigation [11, 13]. It is of course dependent on the the condition that the ship safely reaches the destination. It is important so that ship or cargo is not to undergo the negative effects of excessive slamming, flooding and generally understood storm damage, and the crew was not subjected to a critical stress. A particular example which so directly translates to the level of safety and economic effects is the threat of piracy and terrorism.

External factors affecting the planning and implementation of the journey are the weather conditions, exploitation constraints, and external threats and constraints.
2.1 Weather data

In the case of weather data the most important issues are:

- The time interval of available forecasts,
- Reliability of forecasts,
- The extent of the data received,
- The frequency and regularity of the data received.

The scope and frequency of the hydro-meteorological data depends on the method and sources of their acquisition. The most comfortable situation we have in case of a regular, usually every 12 or 24 hours, obtaining information from land weather routeing centers. In the case of acquiring information in a traditional format such as Facsimile charts, NAVTEX, it requires a greater investment of time and the interpretation of information is more difficult. Either way, we get the problem of decreasing forecasts reliability with increasing time interval.

One possibility to reduce the negative impact of expected inappropriateness of data, especially concerning the height and wave direction and wind speed is to apply fuzzy sets to describe the meteorological situation [10].

An example of fuzzy set can be set of high waves FW. Waves with a height of 6 - 9 meters, we can clearly classify as high, which is entirely belonging to the set of tall waves, 1-meter waves as certainly not high (not belonging to the set of high waves), while intermediate values: 2, 3, 4 and 5 meters belong to a set of high waves only to a certain extent.

The operation to assign individual wave heights given degree of belonging in this case is subjective and dependent on situational context. Wave height can be defined here as a linguistic variable, which can assign linguistic values - such as high waves (6 meters and higher), rather high (4.5 meters), average (3 meters), rather mild (2 meters).

Let's suppose that we are dealing with information that at a given point of the ocean, after 48 hours (48-hour forecast), there is a wave height of 4 meters. According to the assumptions forecast of given hydro-meteorological parameter for a given time interval (the range of forecasts) will be treated as a fuzzy number that is “about 4 feet.” To determine the function of belonging of fuzzy number “about 4 feet,” we use the method of determining the degree of belonging based on measurement data.

In other works [10, 12] the waves in the North Atlantic were analyzed, including 48-hour forecasts of wind wave height issued by the U.S. NCEP (National Centers for Environmental Prediction) and compared with the analysis (from the same source), which was taken as completely verifiable.

For the selected period of years 2000-2003 for the North Atlantic, for example, 49 289 forecasts wave height of 4 meters (as a wave height of 4-meter adopted range between 3.51 - 4.50, similarly other ranges in height were digitized) were issued. On this basis the degree of belonging (m4(hf)) for each wave height to the set “wave height of about 4 meters” attributed in the following way: the largest number of events (23 224 cases) the actual wave heights of 4 meters is assigned degree of belonging m4(4) = 1, the remaining wave heights belonging degree were assigned proportionally, such as the 3-meter wave m4(3) = 14 899/23 224 ≈ 0.64 (normalization of fuzzy set). Course of membership function m4(hf) were approximated by asymmetrical Gaussian function [4], where the degree of belonging m4(hf) is determined by the relation:

$$
\mu_4(h_f) = w \cdot e^{-\left(\frac{h_f - m}{a_1}\right)^2} + (1 - w) \cdot e^{-\left(\frac{h_f - m}{a_2}\right)^2}
$$

where:

- m - modal value (center of function);
- w - logical variable informing about the level of variable: w = 1, when 0 < h_f < m; w = 0, when h_f > m;
- a1, a2 - width of the left (a1) and right (a2) side of the fuzzy set for the level m4(hf) = e⁻¹.

2.2 Operating limitations

Operating limitations are partly derived from the
weather conditions encountered. Ability to achieve preset waypoints in appropriate time results mainly due to the ship speed characteristic and in part may be conditioned by the nature of the cargo and the need to provide adequate levels of comfort and convenience of carriage of passengers and the crew. Maintained engine rotations and the ship speed obtained in the given meteorological conditions affect the size of the fuel consumption, so in some situations, the ability to lower rotations and reduce the speed of the vessel brings the effect of economic benefits.

The accuracy of ship speed characteristic, its adaptation to the type of vessel, loading condition, the actual seaworthiness, is a key element in the process of computing the route of the vessel [2, 6].

Speed characteristic in addition to losses resulting from natural motion resistance also includes reductions in speed performed by masters in order to eliminate the adverse effects resulting from the impact of waves [10].

The difficulty of accurate determining the ship speed characteristic, therefore, results from the fact that the assessment of safety of navigation is a subjective assessment of the ship’s captain. So, to record changes in vessel speed as a function of the impact of wind and waves, notation in a fuzzy form can be offered.

Imprecision (fuzziness) of environment in which there is a decision-making process is represented by introducing so-called fuzzy environment, which consists of the fuzzy objectives, fuzzy constraints and fuzzy decisions [2, 12].

In order to formally define the fuzzy environment elements a set of so-called options (variants) is introduced, denoted as:

\[ X = \{x\} \]  

- set X contains all possible values (procedures, variants) in the concerned situation.

It is assumed that the optimal route choice is a problem of choosing among a finite, predetermined number of variants. Let's confine the number of variants to 9 roads, which the ship can realize (Fig. 4.).

Fuzzy goal is defined as a fuzzy set \( G \) specified on the set of options \( X \), described by the belonging function:

\[ \mu_G : X \rightarrow [0, 1] \]  

such that \( G(x) [0,1] \) determines the degree of belonging for each option \( x \) to fuzzy goal \( G \).

Another possibility to improve the ship speed characteristic could be its constant current correction based on the comparison of planned and achieved positions in the \( i \)th time interval against the weather conditions encountered. This issue can be achieved through using self-learning neural networks.

### 2.3 External threats and limitations

For several years for the safety of navigation next to the weather and navigational conditions the pirates began to threaten. They became the main navigation hazard early twenty-first century. Just because of them, the existing routes of ships depart from the seasonal, and the threat they bring is taking into account in the decision making process to choose the sea route of the vessel [1].

The amount of pirate attacks and their regional assignment vary in different years and weather seasons. It is important to continuously analyze these changes to consider the “best” alternative routes for the safe planning of the ship route.

Pirates attack on the ship in monsoon season is doubtful. Such a weather determines the number of pirate attacks, therefore, it may be reasonable to dispense with additional protection or additional insurance of the ship.

Passage through the areas at risk of piracy limits the ship route choices. For example, in planning the ship’s voyage through the Gulf of Aden it is recommended that masters go through established International Transit Corridor, which is indicated route by this waters with length of 492Nm. It consists of two separate tracks 5Nm wide, dissociated by the separation zone with a width of 2Nm (Fig. 5.).

An example shows the calculation of two routes - a shorter and more dangerous by the Gulf of Aden and a longer around Africa.

Both routes have been calculated based on the programs Navi Sailor 3000 and SPOS 7.0 with consideration of navigational criteria with the current and forecasted weather conditions.

On the basis of the adopted data an average exploitation costs for the route from Kuwait to Rotterdam around Africa with the calculated 33 days of travel are about 480
000. USD. For a route through the Suez Canal at 18 days of travel it's estimated to be around 510 000 USD, so the cost of both voyages can be comparable. For such calculated route through the Suez Canal channel costs are nearly 33% and the cost of protecting the ship about 18% of the total travel expenses without an extra insurance and additional equipment.

In the process of optimizing the route of ships the ship owner should consider the criterion of safety, because events related with the loss of cargo, the ship, and especially the people in the Indian Ocean are very significant. In this case saving 15 days of voyage through the Suez Canal does not compensate for losses.

According to different criteria ships routes should be optimized paying attention to the impact of exploitation parameters. For each vessel route optimization must be made separately by the ship owner, which has much greater access to confidential information, the amount of insurance premiums, fuel costs, etc. For the ships with high broadside and reaching higher speeds, it may be appropriate to dispense with the protection of the vessel, or dispense with taking out additional insurance.

**2.4 Optimization procedures**

To select the optimal route for a ship on the ocean, we can use different algorithms and different methods such as isochrones method, directed graphs, or genetic algorithms and plotting for evaluation of hazardous sectors of ship courses.

**2.5 Logistics and economics of the transport**

All the above mentioned conditions and restrictions will affect the economic aspect of a journey. In addition to the navigation costs, there are also additional expenses related to insurance, fuel, and other expenses. Therefore, the optimization of the route is crucial to minimize these costs.
to the timely arrival of the vessel to the port of destination while maintaining the safety of the crew, ship and cargo, fuel economy is an important factor. Minimum-time route may also be often minimum-fuel route, but may also significantly differ.

Sample calculation of ship Powstaniec Śląski routes due to the fuel consumption for weather from 24.04.2001 present Fig.7. and Table 2 [9].

2.6 Weather advisory

Weather routeing center meets consultative role for vessels and relieves the captain from some considerations related to the weather conditions in the process of route optimization. The final result of cooperation depends largely on the quality of communication between the ship and the center, as well as the procedures implemented by the same center.

Route optimization results obtained using different tools used by the centers shows Fig.7. and as you can see they are not identical.

2.7 Decisions resulting from experience of the captain

The final implementation or rejection of the assumptions about the planned and realized route belongs to the ship’s captain. His decision will be conditioned by the guidelines of the ship owner or charterer, weather information available, possible indications of land weather routeing center and knowledge about the behavior of ship in the present weather conditions.

An important role of the master is the current verification of previously planned route of the vessel at the time of a journey and an eventual correction.

3. Conclusion

Running route optimization taking into account the many factors we obtain the resulting set of routes consisting of routes with assigned the appropriate balance of individual wages of preferences resulting from optimization criteria (time of passage, risk factor, fuel consumption, ...).

The final sorting of a set of routes can be achieved by statistical methods or the application of fuzzy set theory.

The effectiveness of the practical use of the integrated calculation program depends on the proper selection of weights assigned to certain limits.

Seems to be a deliberate departure from the pure minimum-time optimization of ocean routes towards the optimization of other factors, while maintaining the assumed time to reach the destination point.

Bibliography

INTEGRATED PROBLEM OF SHIP ROUTE PLANNING


