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Using GIS tools to assist the management of the area of limited use around the airport and the direction of development of the system

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ABSTRACT
The study contains a description of the use of GIS tools in compensation proceedings using the example of the area of limited use set up for the Katowice International Airport in Pyrzowice. Additionally, the study describes the development history of the system so far and presents future trends allowing integration of the existing system with projects fulfilling requirements of particular airport departments. Consistently taken development steps will ultimately allow reducing the expenses incurred in relation to compensation proceedings on account of noise emissions and allow significantly better management of the infrastructure of Katowice International Airport in Pyrzowice.

KEYWORDS: GIS, airport

1. Introduction

The documentation of the Area of Limited Use was prepared by INVEST-EKO of Katowice in the 2nd half of 2007 on the basis of a mathematical model, which was corrected on the basis of noise measurements taken in 20 points.

The legal basis for establishing the area was:
• Act of 27 April 2001. Environmental Protection Law. And in particular:
  Art. 135. 1. If proceedings concerning environmental impact, post-implementation analysis and ecological review show that despite the application of available technical, technological and organisational solutions, environment quality standards cannot be met outside the area of an industrial plant or other facility, then for a sewage treatment plant, landfill, composting plant, communication route, airport, power line or substation and radiocommunication, radionavigation and radiolocation installation, a limited use area is created.

Whereas the legal basis for establishing ALU zones was:
Regulation of the Minister of Environment of 14 June 2007 on acceptable levels of noise in the environment (Journal of Laws No. 120, item 826). The Geographic Information System built within the framework of establishing the Area of Limited Use constitutes an integrated database on the terrain, containing a division on the basis of land ownership, and the facilities located in areas defined as acoustically protected in the surroundings of an airport and located within range of excessive effects of airline operation.
Due to the extensiveness of approx. 16 km of the designed Area of Limited Use, Invest-Eko of Katowice prepared documentation using specialised GIS tools. The specialised software for the system was supplied by WINUEL – SYGNITY.

2. Elaboration

The System introduced by the author of the study on the Area of Limited Use enabled the correct processing of data and results of acoustic analyses and appropriate preparation of an application constituting a formal basis for the regulation enacting the area of limited use for the Katowice International Airport in Pyrzowice by the Silesian Local Government Assembly.

In the case of Katowice International Airport, the Area of Limited Use was created by the **provincial local government assembly by way of resolution No. III/27/3/2008 of 27.08.2008**.

The resolution specified:
- boundaries of the area,
- restrictions concerning intended use of the area,
- technical requirements for buildings,
- methods of using the areas.

In the period of two years from the moment the resolution came into force, the GIS system functioned as a tool for managing the area of limited use by the airport service staff. It allowed systemic servicing of the Area of Limited Use within the scope of possible claims of parties acting as owners of land located within the boundaries of the Area of Limited Use. The employees of the Investment and Real Estate Department, after receiving a claim, checked whether the claimant’s plot was located within the Area of Limited Use and added information about the claim to the GIS database along with the parties’ contact details.

The area of limited use covered **15,89 km²** of land.

The system included the following backgrounds:
- vector – plot areas and buildings;
- raster – orthoimage maps, topographic map, master map, zone boundaries of the area of limited use and equations of the reach of equal-loudness contours, locations of the noise measurement points.

The supplied system included:
- SONET application – open architecture (supports all databases compatible with the Open GIS (OGC) standard, such as ESRI ArcSDE, Oracle Spatial and many more. Presentation of data is based also on such standards as WMS and WFS and is possible in various environments, (including) ESRI (ArcGIS Server, ArcIMS), Oracle MapViewer, Google Maps, GeoServer. The system supports most standard CAD and raster formats without the need for additional components.
- system requirements – works under Windows XP Professional SP2.
- server part – the minimum configuration is: processor at least 2GHz, 1 GB RAM, 2xHDD 80GB SATA2, Windows XP Pro SP2.
- client part – processor at least 2GHz, 1 GB Ram, 1xHDD 80GB SATA2, Monitor 19”, graphics card compatible with DirectX9C 256 MB RAM, Windows XP Pro SP2.
- the system includes a server part, i.e. Oracle Standard Edition One – licence for 5 users and a client’s application Sonet EE1 licence.

The database created under the project included:
- a list of plots existing in the area of limited use;
- a list of land plot owners;
- the size of each plot located within the zone;
- percentage share of a plot within the area of limited use;
- information on buildings located on plots, i.e. no., number of storeys, number of windows;
- information on submitted compensation claims;
- intended use of plot or building;
- which administrative division a plot belongs to.

Additionally, the system contained the following backgrounds:
- vector – plot areas and buildings;
- raster – orthoimage maps, topographic map, master map, zone boundaries of the area of limited use and equations of the reach of equal-loudness contours, locations of the noise measurement points.

The software allows inventorying of real property, airport infrastructure and Areas of Limited Use (ALU). The data is gathered in one spatial-descriptive database, which allows easy access and preparation of spatial-descriptive reports and analyses. The data presented in the system has the form of maps which may be presented in any manner, printed and shared on the Internet (intranet).

In relation to a verdict of the Supreme Administrative Court II OSK 2032/09 of 23.03.2010, Resolution No. III/27/3/2008 of 27.08.2008 of the Silesian Local...
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Górnośląskie Towarzystwo Lotnicze SA may develop the database assets by assigning its updating to third parties or perform the updates in-house.

Both these options entail specific expenses, such as:

- in the case of the former, expenses related to hiring an external company
- and in the case of the latter, expenses related to purchasing a software license for multiple workstations, purchasing a system server, field equipment and data analysis software.

It was decided that work shall be implemented in stages, mostly using external company services and developing a technical and specialised knowledge base in the company.

In subsequent years until 2011, this resulted in data expansion in the GIS system including:

- the update of information about land plots within the Area of Limited Use in 2009;
- preparing a map overlay for the website of the Katowice International Airport allowing anyone to quickly check if their property is located within an Area of Limited Use zone;
- the database was extended to include an inventory of protected species present in the area of the Katowice International Airport, surveyed in 2009; the data collected in this respect constitutes one of the backgrounds for the existing GIS database, which allowed, after overlaying the background maps prepared under the General Plan, to determine clashes between implemented facilities and identified protected areas;
- within key investment projects, since the database appeared, detailed designs have been prepared in the form of backgrounds allowing implementation in GIS software;
- in 2010 a background containing the inventory of underground installations within the airport area was created;
- also in 2010, a project of inventorying instances of runway damage was prepared by Grzegorz Myrda (project co-financed by the European Union with TEN-T); Supplementing the terrain data for the area within the Katowice International Airport allows:

- introduction of data concerning the course, inspection and repair of all kinds of installations and buildings,
- creation of layers by services operating within the airport infrastructure and introducing via these layers terrain data which is important for them, such as: identification of vehicles and persons present in the vicinity of the runway, recognition of areas and completion dates of implemented infrastructure elements, identification of terrain obstacles, adding building maintenance and inspection data, specifying places of priority action in emergencies.

Such actions permit more complete control over the area surrounding the airport.

Particular departments of Górnośląskie Towarzystwo Lotnicze SA have been equipped with the following sets of tools assisting the process of inputting changes into the database:

- DGPS field receiver.
- Field receiver software, controlling its operation.
- One-workstation software for terrain data processing and incorporation into the currently possessed GIS system.
- Underground installation detector with a generator.
- Laser rangefinder for entering distances and checking building heights.
- Database server.
- Employee training courses.

Next, system development was provided for through:

- Purchasing GIS field equipment for services operating in the airside zone, i.e. min 1 for the Energy Department, Airport Operation Department, SOL, and training these employees in updating the GIS database.
- Purchasing GIS network software along with servers and making this data available for the above mentioned departments and allowing them to update the system.
- Training the employees of other GIS departments.
- Updating the airport background for imaging in the visible band and with a layer in near infrared and LI-DAR scanning.
- Updating the data entered into the system to encompass the data on the new area of limited use, for the creation of which GTL SA will apply to the relevant administrative organ in the 4th quarter of 2011.
- Introduction of a continuous noise monitoring system managed by GIS tools.

After the system data is extended, the system may play a significant role in the management of the airport area, emergency management, business, environment protection and improve air obstacle spatial data analysis.
2.1 Airside

Air corridors, navigation – possibility of planning time intervals for landing approaches and take-offs and tracking moving objects in real-time. This application improves the efficiency of airspace management, improves the level of safety and may be used to relay public information such as information of noise monitoring and may automatically transmit information on flying aircraft in real-time. Inclusion of information on critical situations which occurred in the past or may occur in the database. The ease of adding critical events and the simple process of transmitting such information to interested parties is an additional asset.

Analyses in 3D – in this respect, the system has the capability of creating a 3D model of the geographical data of the terrain surrounding the airport. The data concerns the land use type, building heights and changes in the terrain surrounding the airport. This application allows better graphical imaging of the operational zone of the airport and finding security weak spots, airspace obstacles and monitoring the land use of the surrounding areas.

2.2 Landside

Illustration of the consequences connected to the introduction of subsequent changes in the infrastructure around the airport.

Owing to the possibility of entering and illustrating in the form of a model on any backgrounds of unique data.

Planning and designing – using the backgrounds from design and conceptual documentation prepared by design offices and industry experts for analyses. Placing background maps concerning local infrastructure and community, such as land usage types, neighbourhood-related restrictions and environmental sensitivity (for example protests and disputes initiated by local residents) in the system. It allows setting and minimising the timeframe for performing field analyses and land development and specifying the best locations for planned facilities even in very densely populated and urbanised areas, where public sensitivity is very high. This material formed the knowledge base used by GTL SA and external companies implementing works for benefit of the Company.

Operations – the projected increase in air traffic may cause many opportunities associated with better usage of the airport operational zone to slip away. We must carefully balance between security issues and the necessity to increase the operations generated in the airport area. The analyses which can be performed in the system allow specifying the barriers limiting traffic capacity of a facility such as an airport. The system will soon be a principal tool for performing analyses of noise propagation around the airport. Ultimately, in the near future it will work with data from continuous aircraft noise monitoring devices and analyse their results in conjunction with data from aircraft.

Efficiency – the target system will integrate real property data and managerial tools so that it can be used to specify fully the needs associated with profit-yielding and loss-making elements for the company, thus allowing reducing losses to the necessary minimum by precisely defining the boundary needs.

Maintenance – the system is able to modernise the management of airport maintenance, within the scope of controlling, for example, the condition of the pavement (inventory of repairs, damage, checks), runway lighting system, terminal infrastructure, airport drainage system and accounting handling. It also allows managing the most vital elements of airport infrastructure with a graphic interface. Ultimately, it may be included in the system connected to automatic on-line relaying of data from measuring instruments.

Security – it allows integration of separate security data into one management and decision-making environment (crisis centre). Owning to the standardisation of data flowing into the GIS system, there is a possibility of creating an integral security system inside the airport, including airport border protection, protection of the terminal zone, code access of entry and exit, and monitoring.

3. Conclusion

Summing up the above-mentioned considerations, the GIS system built in Katowice International Airport could become a turning point for the strategy of managing the airport infrastructure and neighbouring areas. Abandoning further development of the system will result in the loss of value of the already developed material, which will not undergo further updates and development. Developing the system at the time of the planned extension of airport infrastructure, which is planned within the next few years, will allow reducing costs associated with subsequent updates of the system. Purchasing equipment and training GTL SA employees in supplementing the database will reduce the costs of maintaining and expanding the system. Otherwise, each update will require the services of third parties. It is also important that all data introduced to the system be coordinated by one department, so that the system maintains appropriate quality. All new works implemented in the airport area should take into account the possibility of updating under an agreement concerning the project and implementation, and the possibility of entering new infrastructure into the GIS system. This concerns such issues as preparing design documentation.
in an electronic form, which may be easily introduced in GIS in the form of a background map, applying an appropriate system which remotely transmits the information on utilities usage and, for example, sewage disposal to GIS. This allows continuous monitoring of the airport infrastructure.

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Utilisation of the light polarisation to increase the working range of the video vehicle tracking systems

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ABSTRACT

Most of the vehicles, which can be observed by the cameras used in the Intelligent Transport Systems, are coated with reflective layers which, like car windows, are characterized by the effect of light polarisation. Utilising this effect by using a camera designed for the Intelligent Transportation System along with the linear polarizer it is possible to improve the extraction of the vehicles from the surrounding. The article presents the methods of using the polarised light for increasing the operating range of the video systems along with an illustration of the possibilities and limitations of this technique. Some experimental results obtained by the fusion of data recorded for the standard video sequences and the use of linear polarisers are also presented.

KEYWORDS: light polarisation, vehicle tracking, Intelligent Transportation Systems

1. Introduction

Video Image Processors (VIPs) used in Intelligent Transportation Systems (ITS) support both infrared and visible light cameras [1]. The most important advantage of such camera based tracking systems is their ability to track vehicles at different distances. Moreover, some parameters of vehicles cannot be recognised without cameras (e.g. colour, detailed profile or exact size) [1,2].

Nevertheless, tracking of distant objects is limited by several physical factors e.g. road lighting (natural or artificial), dust, fog, snow. The extension of the maximum working distance of such methods is one of the most important elements allowing further improvement of the performance of the ITS. Increase of the maximum tracking distance is possible using for example some alternative wavelengths. The Far Infrared (FIR – typical wavelengths can be e.g. 100-300 mm) and Middle Infrared (MIR) wavelengths (about 10-30 mm) are valuable for the ITS applications, because vehicles are usually well visible due to the heat emission [1]. Moreover, both wavelength ranges are less influenced by the fog and dust in comparison to the visible light. The cost of cameras and lenses for such wavelengths with appropriate quality (resolution, number of frames per seconds) is rather too high for contemporary systems so they are used for special purposes only. It is also worth to notice that the Near Infrared (NIR) wavelengths can be valuable only due to superior sensitivity of the silicon sensors in this wavelength range. From the image processing and analysis point of view images acquired by infrared cameras are similar to the greyscale ones obtained from the typical visible light range camera.

Another interesting technique is using a number of cameras with different lenses. In such systems some fixed focal length lenses are necessary because of their significantly
better quality in comparison to the variable focal length lenses. Unfortunately the acquisition system is much more complicated in this case. In the most universal systems the VIP should support multiple cameras and multiple images instead of processing the image taken from a single camera.

An interesting alternative for increasing the working range of the tracking systems are super-resolution techniques [3-10], but their application requires some sophisticated image processing algorithms. The acquisition of multiple images from a number of cameras can lead to significant increase of the resolution of the resulting image but a good data-fusion algorithm is necessary. A better choice is usually previously mentioned variant of multiple cameras with different focal length lenses.

In this paper another approach that could be used instead of the techniques discussed above or together with them is considered. In typical video tracking system only a light level or light levels at different wavelengths (colour) are considered without the utilisation of the light polarisation effect. However, the light polarisation could be very useful for image acquisition, since its application is inspired by the nature and many animals use this property of the light in their own vision systems.

### 2. Light polarisation

The shapes and colours of the vehicles observed by the cameras are usually different. Their surfaces reflect light and most vehicles are very shining due to multiple layers of the vehicle’s body (typical masks etc.). The glass or plastic car windows are also influenced by the light polarisation. The effect of light polarisation is well known in vehicle photography, since the application of the linear polarising filter allows obtaining some interesting photographic effects. The same polarisation effect [11-14] can be relevant for vehicles tracking in the ITS applications. This effect is illustrated in Fig.1 (dots indicate polarisation perpendicular to the image).

This effect for the glass has been described firstly by Brewster [11]. The direct sunlight is not polarised but after it is reflected by the glass or similar material, the reflected beam and the beam refracted into the material (e.g. glass) can form the right angle, what leads to the polarisation of the reflected light. Nevertheless, if the incident beam is polarised in the plane of incidence, it will not be reflected.

The skylight is also polarised and its polarisation depends on the place on the sky hemisphere (angle) as well as the position of the sun. The level of polarisation is up to 80% in very specific situations and is much lower in typical cases [14].

The application of the polarisation for optical vehicle tracking purposes is possible using two cameras. They should be located close to each other due to some distortions related to the perspective view causing the necessity of alignment such acquired images, preferably with subpixel accuracy. If the distance between tow cameras is larger or the tracked objects are close, the 3D alignment is necessary instead of the 2D, e.g. for the distances to objects about 100 meters and the distance between cameras about 20 cm as in our experimental setup.

The necessary alignment can be performed using calibration techniques for the stereovision systems [15,16]. If there are some other static and characteristic objects (e.g. trees, buildings) in the scene the external camera parameters should be estimated without any additional calibration markers. The internal parameters of cameras (optical distortions of the lenses, focal length) should be estimated before the acquisition of the video frames.

Image processing part of the calibration is mostly related to the 3D reprojection of the images (from both cameras or from a single one as in our experiments). The absolute difference for greyscale images can be used as the difference metric as well as the simple average RGB difference:

\[
P(x,y) = \frac{1}{3} \left( |R_h(x,y) - R_v(x,y)| + |G_h(x,y) - G_v(x,y)| + |B_h(x,y) - B_v(x,y)| \right),
\]

where the indices \(h\) and \(v\) denote the RGB channels obtained from two cameras with different polarisation filters.

It is also possible to utilise some more sophisticated colour related polarisation differences but is has not been considered in this paper.

The position of the sun is also important because there are two light sources in the scene. The first one is the sun that is the main non-polarised light source but the second source...
is the sky, which disperses the light and adds the polarisation.

The vehicles have different sizes and shapes but the flat reflective areas are unusual and the most of the cars have rounded aerodynamic smoothed shapes. This is the main reason why the whole area of the car is not significantly reflective in the polarisation domain. The maximum values of polarised light reflections can be observed only for some parts of the vehicles and this can be considered as the disadvantage related to the loss of potential information. On the other hand it can be an advantage for the tracking system because the size of the car is less important for them and then some point objects are tracked instead of some larger ones.

The calculation of the difference between images needs not only a geometrical alignment. Two images must be synchronously acquired by two cameras and the same light characteristics are necessary including iris size of the lenses, shutter speed or gain. The additional colour corrections are also important and in this paper some areas located aside the road are used for testing purposes. The observed differences without any corrections are less than 2 values of 256 levels for each colour channel (about 1% of the maximum signal level).

During the tests various sets of video images have been acquired and only the one with a minimal polarisation (the worst case) is further considered.

3. Experimental tests

The results obtained in our experiments have been obtained for the sunny day monitoring the traffic on an asphalted road. The cameras have used zoom lenses with a maximal focal length. The reference image has been cropped due to the presence of some other unimportant objects in the cameras’ field of view. The example video frames acquired from both cameras and their differenced are illustrated in Fig. 4. Such image set has been used mainly for testing the performance of the vehicle’s detection. Two new sets have been created by image rescaling for the simulation of the larger distance or smaller physical resolution of cameras. The images having 4 times smaller horizontal and vertical resolution (simulation of the 16 times smaller resolution of the cameras) are shown in Fig. 5, while Fig. 6 illustrates the 8 times smaller resolution (horizontally and vertically) images (simulation of the 64 times smaller resolution of the cameras). Those images are typical for the tracking systems, especially Track-Before-Detect ones [17], which operate usually on small resolution images.

The polarisation effect is related to the small part of each vehicle. The observed difference between both polarised images is high for high resolution images but the details are less visible due to the low-pass filtering if the resolution is reduced. Nevertheless, some small objects (around pixel size or smaller) may give large signals related to the polarised images.

The stereoscopic system presented in the paper allows for some interesting observations. First, a very interesting phenomenon is the fact that the polarised light observed by the camera is related not only to the glass or metal parts of the vehicles. The road itself (asphalt) reflects part of the light with a polarisation effect as well. It is well visible on the acquired images and related especially for the wheels’ tracks on the road.
Another advantage of such configuration of two cameras is also interesting for the 3D tracking systems. Two cameras with wide field-of-view (wide angle) could be used for stereovision image processing in near and medium distances. Properly aligned cameras can also support detection and tracking of the vehicles with a small parallax as in the case considered in the paper. Nevertheless, for the near distances such system is not adequate as is shown in Fig. 7. Analysing this image it can be easily noticed that the top of the truck is moved in horizontal direction depending on the position of the camera. In such situation the proposed technique should not be used.

In order to reduce such parallax effect the camera with the embedded different polarisation filters integrated with the sensors should be used. Another possibility is the use of the optical separating system, similarly as in 3CCD technology.

An interesting observation is the proper detection both moving and non-moving vehicles, what can be useful for the application of background estimation techniques, estimation of vehicles’ position and speed as well as techniques of fitting a model to the image (classification, correlation) for static vehicles.

4. Conclusion

One of the main advantages of the proposed approach can be observed analysing the images presented in Fig. 5, where the vehicle moving towards the camera after the truck can be efficiently tracked utilising the differential image. The effect of light polarisation allows a good detection of this vehicle based on its windscreen reflecting polarised light. Similar effect can also be observed for some other vehicles where the glass or metallic surfaces can be utilised in the proposed technique.
The approach presented in the paper can be used as a part of the video based vehicle tracking system created using the super-resolution imaging combined with the Track-Before-Detect approach as a part of further research.

The polarisation approach gives also some new possibilities for the classification of vehicles, since some matt and glossy vehicles could be additionally distinguished.

Multiple wavelengths (more than 3 colour channels) are also important for the separation of objects on images. The multispectral imaging is used for remote sensing (usually in satellite observations of the Earth surface). It is also possible to use this technique for the ITS but this approach is rather expensive. Nevertheless, the multispectral sensors may improve the tracking accuracy in the future systems, similarly as the use of polarisation.

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Bibliography

Influence of satellite equipment control systems on economics of working machines operation using the example of excavators

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ABSTRACT
The paper describes the principle and operating range of currently used satellite monitoring devices of working machines. The paper presents some possibilities of satellite control systems of working machines. We analyzed the impact of satellite monitoring equipment work on the fuel consumption during the operation of excavators.

KEYWORDS: GPS controls, excavator, consumption of fuel

1. Introduction

One of the basic conditions for the selection of working equipment to various types of work is to make full use of ground and technology conditions. Moreover, the economics, reliability, availability, service and spare parts are very important.

In recent years diagnostic systems of working vehicles significantly expanded – caused a substantial increase in reliability. Elements of diagnostic systems are often installed on vehicles. These systems are designed to collect the information on performance of the basic equipment of excavators.

The scope of the built-in diagnostic systems for excavators has been considerably extended. In the equipment manufactured in the 90’s the systems control parameters like the temperature of engine coolant, the engine oil temperature and pressure, the fuel level, the level of hydraulic oil dirt and indicators of various kinds of filters. The diagnosis takes now into account a much larger number of measurements [1].

Control parameters of the equipment produced in the 90’s allowed only to protect the machine and the basic level was associated with a great machine operator’s responsibility, which was somewhat parallel to the job of sensors analyzing. Measurements were not archived and reported hence a coming hardware failure could not be foreseen. In many cases such a situation resulted in the occurrence of major accidents and therefore in restraining it frequently for many days.

Current approaches to the excavator diagnosis are based on measurements of many more indicators such as the fuel consumption, engine load level, as well as the burden of work such as hydraulic excavators. Moreover, in modern devices, all operating parameters are archived and a periodic summary and analysis is possible. The spread of satellite navigation systems also allowed for an almost continuous transmission of data collected in an excavator to service centres. This resulted in the current situation of serious accidents of the equipment equipped with a satellite tracking system, leaving the mechanics of failure to know what to expect and have the information, what kind of spare parts may be needed during the repair.
A schematic representation of the principles of current monitoring systems of the work of diggers is shown in Figure 1.

In addition, current systems used and their combination with wireless data transmission allows identifying quickly important parameters and transferring them to the dispatcher in real time.

KOMATSU excavators used in KOMTRAX allow tracking the following information [3]:
- Map of the location of the fleet
- Location of the machinery
- Driving condition
- Run time
- Remote engine start interlock
- Remote start the engine block at any given time
- A view on the monitor in the cabin
- Use of working equipment
- Hydraulic oil pressure. (excavator)
- Motive force (bulldozer)
- Maintenance intervals
- The maximum cooling liquid temperature
- Operating time of the machine
- The level of fuel in the tank
- Fuel consumption

Current systems beyond the control of satellite monitoring of the operation of the equipment itself also allow their remote immobilisation, which causes that the equipment is better protected against an unauthorized use.

2. Analysis of the benefits of the monitoring system of excavator work

The introduction of a range of devices monitoring the excavators working conditions and transmitting these conditions in real time to the dispatcher makes that the operator of such a machine is equipped with a nearly permanent scrutiny of compliance with established standards for loading wheeled, fuel consumption, the work on site, and compliance with working time.

The analyzed example of Company “X” involved in the implementation of water supply shows economic benefits of the introduction of excavators monitoring systems.

We analyzed two structurally similar – an excavator equipped with a GPS monitoring system and the other without such a system. Both excavators have engines of similar power. Both excavators worked very close – under field conditions within a construction site, and performed there very similar in terms of the load task. Analyzed excavator specifications are summarized in Table 1.

The weekly fuel consumption was analyzed for an
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Influence of Satellite Equipment Control Systems on Economics of Working Machines Operation Using the Example of Excavators

The study was conducted from 1 to 5 March 2011. The information on fuel consumption of the excavator equipped with a monitoring system (Hitachi ZX250LC-3) and without such a system (Komatsu 240-8).

Operators of both analyzed diggers were not aware about the analysis. Operators knew, in which excavator the monitoring system was installed.

In order to compare the fuel consumption of two excavators manufactured by different producers on the basis of data collected during research as well as the information from the literature, the fuel consumption was calculated as deviation from the nominal values defined by the user as the norm1. Normative fuel consumptions of two analyzed excavators established by the user are shown in Table 2.

The study was conducted from 1 to 5 March 2011. The information on fuel consumption of the excavator equipped with satellite control system was read from the web site e-Service Owner’s Site1. Charts showing the fuel consumption in the month of March for the excavator examined are shown in Fig. 3.

The Hitachi e-Service Owner’s Site information website could also give the information about the time of engine working, while driving excavator, working time, etc. This information is presented in Table 3.

The satellite control system also allowed reading the location of analyzed excavator. Locations of the excavator during tests are shown in Figure 4.

Table 3 shows that in the analysed period of time (1÷5 March 2011) the Hitachi excavator consumed 307 dm3 of diesel fuel. During this period of time the excavator worked less than 31 hours (including travel time, time of preparatory operations.) This gave an average fuel consumption of 9.9 dm3 / h.

The second of the analyzed excavators (Komatsu PC 240-8) was not equipped with a satellite control system. For that excavator the average fuel consumption was calculated based on the fuel supplied to the excavator and the number of hours worked. This information is presented in Table 4.

Table 4 shows that in the analysed period of time (1÷5 March 2011) the Komatsu excavator consumed 459.8 dm3 of diesel fuel. During the analyzed period the excavator worked more than 35 hours (including travel time, time of preparatory operations.) This gave an average fuel consumption of 13.1 dm3 / h.

3. Conclusion

The work of excavator equipped with a satellite control system was more economical in terms of fuel consumption than of the machine not controlled by satellite. The fuel consumption of the first machine differed from the normative consumption set by the user by + 10%, whereas in the latter case – by + 25%.

---

**Table 2. Normative fuel consumptions established by the user**

<table>
<thead>
<tr>
<th></th>
<th>HITACHI ZX 250 LC-3</th>
<th>KOMATSU PC 240-8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel consumption, dm³/h</td>
<td>9</td>
<td>11</td>
</tr>
</tbody>
</table>

**Table 3. Works parameter of Hitachi excavator in the analysed period of time**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>date</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine ON, h</td>
<td>March 2011</td>
<td>6.00</td>
<td>9.50</td>
<td>2.30</td>
<td>2.70</td>
<td></td>
</tr>
<tr>
<td>Travelling time/Engine-ON Time, %</td>
<td>March 2011</td>
<td>11.50</td>
<td>13.50</td>
<td>15.40</td>
<td>10.40</td>
<td></td>
</tr>
<tr>
<td>Travelling time, h</td>
<td>March 2011</td>
<td>0.70</td>
<td>1.20</td>
<td>1.20</td>
<td>0.50</td>
<td>0.20</td>
</tr>
<tr>
<td>Non-operation hours during engine-ON, h</td>
<td>March 2011</td>
<td>3.40</td>
<td>4.40</td>
<td>5.40</td>
<td>4.40</td>
<td>1.20</td>
</tr>
<tr>
<td>Fuel consumed, dm³</td>
<td>March 2011</td>
<td>53.00</td>
<td>120.00</td>
<td>85.00</td>
<td>21.00</td>
<td>28.00</td>
</tr>
<tr>
<td>Fuel consumption, dm³/h</td>
<td>March 2011</td>
<td>0.70</td>
<td>11.20</td>
<td>9.10</td>
<td>8.60</td>
<td>10.30</td>
</tr>
</tbody>
</table>

**Table 4. Parameters of Komatsu excavator work in the analysed period of time**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>date</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine ON, h</td>
<td>March 2011</td>
<td>7.00</td>
<td>9.30</td>
<td>2.50</td>
<td>4.70</td>
<td></td>
</tr>
<tr>
<td>Fuel consumed, dm³</td>
<td>March 2011</td>
<td>106</td>
<td>163.6</td>
<td>99.9</td>
<td>32</td>
<td>58.41</td>
</tr>
<tr>
<td>Fuel consumption, dm³/h</td>
<td>March 2011</td>
<td>15.10</td>
<td>14.10</td>
<td>10.70</td>
<td>12.80</td>
<td>12.40</td>
</tr>
</tbody>
</table>
The system of satellite equipment monitoring mobilizes operators to use rationally the power of targeted machines. The satellite monitoring system contributes to increasing so-called culture of equipment service, which translates into its greater reliability and safety.

Bibliography

[3] Catalogue KOMATSU, KOMATSU 240”.
Cost model of the urban toll system in Žilina

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ABSTRACT
Trend related to the city mobility is now focused on limiting access of cars in city centres. One possible solution is traffic calming with urban toll system. In our paper we would like to focus on only one of the most important steps of introduction of the urban toll system - cost model and specifically to determine model process for optimisation of toll price for the limitation of transport intensity and maximize revenue from toll.

KEYWORDS: amount of toll, cost model, transport intensity, incomes, revenues

1. Introduction

Urban toll system can be defined as a special fee that is paid by vehicle for its entrance into the specific area of city.

The amount of toll is usually dependent on number of entrances into the area or time spent there or according to vehicle mode.

There are general reasons to support positive state decision in the question of city fee application:

- it is another financial resource for traffic improvement by improvement of either transport infrastructure or public mass transport,
- it can decrease congestion in certain area, certain communications or in certain hours, and thus increase traffic system accessibility,
- it can improve city living conditions by decrease of noise, emission, accident rate and air pollution,
- it can advance public mass transport demand that means also its better financial sustainability.[7]

2. Characteristics of city Žilina

Žilina is a regional centre of NW Slovakia and the biggest town on the Váh river. Number of the population was 84 546 (31. 05. 2011) and area of city is 80,03 km². Number of registered cars in Žilina county: 60 217 vehicles (43 571 passenger cars). Level of automobilization: 510 vehicles/1 000 citizens. [8]

CMZ is a small containment area (2,7 km²), where can be input cordon defined by 10 entrances (Fig. 1.).

As in many of European cities, as well in Žilina, the traffic situation in the past few years is getting steadily worse. Therefore we tried to suggest a system of town toll, which would partially eliminate load in the Central Town Zone (CTZ).

This problem is too large and complicated. So we focused on only one of the most important steps of introducing the urban toll system – and that is cost model.
3. Cost model

It is desirable to make economic and financial evaluation of assets and costs. It is important to find out whether the tool system is a contribution for the town. In few years time, assets summary should be higher than the cost system. The main outputs of financial analysis are the test results of costs and assets of the proposal. Moreover it is necessary to pay attention not only to technical costs and supplier’s costs, but also to the costs for the information campaign, running costs etc.

It is vital to evaluate or rate the socio-economic assets for the following:

- Users of individual automobile transport (IAT) – for example decrease of congestion.
- Users of public transport – increasing transport reliability public mass transport (PMT), increasing quality of PMT, etc.
- The city – toll revenue, more attractive and more accessible the city centre, etc.
- Operator of PMT - higher number of passengers, increase of transport reliability.
- Increase of residents, visitors, employees who are not using means of transport in charged areas, also increase of air – pollution, noise, decrease of accident rate, etc.

Economic costs consist of following:

- Financial cost for the city – for example investment costs, operating costs, etc.
- Socio-economic costs for IAT users – toll, increase of time loss, accident rate, asset costs of vehicles, etc.
- Socio-economic costs for PMT users – reduction of waiting time at the station, less transport reliability of PMT on the border zone and outside the traffic peak.
- Socio-economic costs for residents, visitors, employees – increase of emissions, noise, accident rate on the border zone, etc.
- Socio-economic costs for businessmen in the charged area – higher costs for purveyance, decrease of amount of customers in the shops, etc. [1, 3]

Output should be the approach between the economic assets and economic costs of the proposal.

In this step we did not consider all the social and economical costs and profits for introduction of urban toll system in Žilina. We focused mainly on important financial costs, e. i. operations and investments. After their consideration, the following model technique for determination of optimal amount of toll and the supposed urban toll revenues are also accounted.

3.1. Investments and operational costs

In frame of the whole effectiveness of imposing fees on urban roads in CMZ (Central Town Zone), it is necessary to follow systematically not only the limits imposed on automobile traffic, but also the fiscal profit of the mentioned rule. If we want to estimate the precise profit that the Urban Toll will bring, it is necessary to analyse the investment, operational costs and revenues. Finally, the technology is proceeding and getting better. So the things hardly imaginable a few years ago (cameras system was too expensive) is not actual any more.

We can put investment costs into several basic groups. Those are costs put on:

- Enforcement:
  › costs on road side equipment (RSE), e. g. cameras, equipment to recognise the registration number and local computers, plus their connection to data network,
  › costs for providing the connection,
  › working place for controlling operator with necessary technical equipment,
  › service centre – main role is the maintenance of technical road equipment,
  › service vehicles – are available for the service centre.
- Working place of financial operator – financial operator checks the financial transactions as well as unpaid balances and fees exacting for not keeping the prescribed dates of payments. He also communicates with financial institutions, mobile operators and other subjects that provide the possibility of payment for the final users. The costs involve the working place equipment and the training of working stuff.
Cost model of the urban toll system in Žilina

Working place of customer centre – communicates through telephone lines, emails and other communication channels with system users and solves their complaints. The costs involve the working place equipment and the training of working stuff.

Working place for manual recognising of registration number – this place is responsible for the right identification of registration number of motor vehicles that was not possible to recognise automatically. The costs involve the working place equipment and the training of working stuff.

Payment automatic machines – serve to pay the urban toll and they are located in the centre of the town at chosen places. Automatic machines make the cash payments and payments by credit cards possible and inform the user about the number of subscribed drivers. The prices of automatic machines include the installation and connection to data network.

Costs on software development – include the development of complex communication environment including database operating invoices, etc.

Communication and information campaign for a system operating without problems, it is necessary to realise a campaign that will inform about the prepared rules and will also explain the profits that the charging will bring. \[4, 5\]

Total investments costs for this system were estimated at 4 185 858 euros.

Operational costs

Investments costs include the financial means that are necessary for the first investment. Except for these costs, it is needed to analyse carefully the operational costs from the point of view of profitability. We can put the mentioned costs into these basic groups:

- Wage costs – represent one of the highest items of operational costs. These costs involve also the costs on social and health insurance for management workers at individual working places.
- Operational costs – include for example costs for renting the offices and other technological equipment or costs on consumption of energy. For simplification it is accounted as a certain part of wage costs.
- Data transmissions – costs on necessary data transmissions between individual physical components of the system.
- Administration and maintenance of enforcement and payment system – includes especially the costs on parts for equipment by rods and payment automatic machines. For simplification it is accounted as a certain part of investments costs on enforcement.
- Administration and maintenance of software – costs are determined as a percentage of investment costs on software.
- Taxes depreciation – expresses the system amortisation at time and after finishing the period of lifetime, they can be used to its reconstruction and modernisation. The supposed lifetime of Urban Toll system is 10 years. \[2, 3\]

Total operational costs for this system were estimated at 1 172 737,8 euros.

3.2. Determination of amount of urban toll

It is important to determine the incomes from fee very carefully, so that it is possible to consider the profitability of the system. We also have to consider that the main goal of introduction the urban toll system is to reduce the intensity of automotive traffic in CTZ and not to maximise the incomes from fee.

The height of incomes depends on two basic quantities that are closely connected. It is the amount of toll for the entry and the number of vehicles that enter to the zone and pay the toll.

Basic starting points

Urban toll systems that mean paying the entrance toll for entering the city centres are often discussed lately, especially the way of regulation of individual automotive transport mainly from the point of view of congestion regulations and the reduction of the amount of emissions produced by automotive transport. It also concerns the augmentation of so called walking transport. Even in this case it is valid that determination of the level of urban toll based on quantification of external costs from congestion and emissions is very difficult, more or less impossible. That is why an approach of so called environmental standards was chosen, considering as well the amount of toll determined on the basis of functional relationship:

\[ V_M = f(\Delta I, T) \]

where:
- \( V_M \) - amount of toll,
- \( \Delta I \) - decrease of individual automobile transport intensity,
- \( T \) - pure incomes of public budget from urban toll (difference of total incomes and costs on building and operation of system).

The basic starting point is supposing that determination of the amount of toll is a political (social) choice and...
it is supposed that with increasing amount of toll, the intensity of transport in city centre will fall, which will influence the urban toll.

In general we can determine the role of amount of toll by following way. Individual transport flows I₁, I₂… in enter to chosen area, where the basic role is to find out how these transport flows will react on imposing the entrance fee. Let’s suppose for the moment that the decrease will depend on exponential function, so:

\[ I'_i = I_i e^{-cVM} \]  

where:
- \( I'_i \) - intensity for the i-entry after the introduction of toll,
- \( I_i \) - intensity for the i-entry before the introduction of toll,
- \( VM \) - amount of toll,
- \( c \) - coefficient, negative number sign indicates the assumption of decrease of transport intensity after the introduction of toll.

Another question is the amount of toll, which will depend on requirements of this system and will be a function of two variables – decrease of transport intensity in CTZ and pure incomes from payments. The already mentioned research of acceptance was made with this aim. One of the main questions was where the respondents were to express their will to enter to CTZ with certain toll. This research found out the results mentioned in following table 1.

The chart evidently shows that the amount of entrances will fall according to augmented payments. It is very difficult to pronounce any prognosis concerning this fact. Finally the transport intensity would probably slightly raise with time, as in case of increase in fuel prices, where after a certain time the passengers will get used to new prices and will use the car anyway, almost as before the price increased. The individual automotive transport demand is not elastic, which is mainly caused by the fact that a comparable substitute does not exist, providing the passengers transport at the same level of quality as a car.

Table 1. The survey of willingness to enter to CTZ with certain toll

<table>
<thead>
<tr>
<th>Amount of toll</th>
<th>Percentage representation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 €</td>
<td>95 % 5 %</td>
</tr>
<tr>
<td>1,33 €</td>
<td>88 % 12 %</td>
</tr>
<tr>
<td>1,66 €</td>
<td>76 % 24 %</td>
</tr>
<tr>
<td>1,99 €</td>
<td>63 % 37 %</td>
</tr>
<tr>
<td>2,32 €</td>
<td>38 % 62 %</td>
</tr>
<tr>
<td>2,66 €</td>
<td>21 % 79 %</td>
</tr>
<tr>
<td>2,99 €</td>
<td>11 % 89 %</td>
</tr>
<tr>
<td>3,32 €</td>
<td>4 % 96 %</td>
</tr>
</tbody>
</table>

1 Euro (€) = 3,9302 PLN
Source: [4]

Regression of polynomial function
While taking in consideration the table 1 values, we definitely have to state that the amount of entrances to CTZ will fall with raising the amount of toll, which can be characterised by following diagram. Now the question is if by higher values this way reflects the reality where it is evident that by higher values of urban toll (for example 3.3 euros), the intensity of transport will be at a zero level (Fig. 3.).

Intensity fall in area charging is the only criterion that determines the amount of toll. Naturally with the raise of urban toll, the number of entrances into the centre will fall, which will influence the second criterion – the pure incomes from urban toll. We will divide the incomes to fixed ones (from the one-time fee of residents) and variables (from the numbers of one-time entrances into the centre, which will depend on the amount of toll. We will consider the costs as constant (operational and investment costs, which are present in operational costs as depreciations), we get those pure incomes from urban toll and they can be expressed as follows:

\[ T = (P_r \cdot V_f + I_S \cdot \frac{7.45 \cdot (V'_m)^{4/3} \cdot 7.10 \cdot V'_m + 104.81 \cdot V'_m \cdot d}{100} - N) \]

where:
- \( T \) - pure incomes per year of public budget from urban toll (difference of total incomes and costs on building and operation of system),
- \( P_r \) - number of residents who pay one-time fee,
- \( V_f \) - amount of one-time fee for residents,
- \( I_S \) - current number of entrances for one day into consideration area at zero fee,
- \( V_M \) - amount of toll,
- \( D \) - number of days in operation in calendar year (\( d = 250 \)),
- \( N \) - annual costs including taxes depreciation.
For any other accounting analysis, it is necessary to find out the supposed number of vehicles which enter presently to the area charging and determine the amount of vehicles which would be obliged to pay as a one-time fee or an annual fee. After that we have to know the supposed operational and investment costs (chapter 3.1.).

If we consider the one-time fee for residents as a 25-times of urban toll (residents having 90% discount of daily entrance, number of days - 250), then the pure annual incomes from urban toll will be:

\[ T = \left( P_c \times 25 \times V_M \right) - \begin{array}{c} 7,474 V_M^2 - 7,407 V_M + 10,481 \\ 100 \end{array} \]

and after modification

\[ T = \left( P_c \times 25 \times \frac{V_M^2}{100} - \begin{array}{c} 7,407 V_M + 10,481 \\ 100 \end{array} \right) - N \]

Function which is gained by approximate values from the research, it is only for the orientation. It is necessary to realize that we are coming from a limited number of respondents and that is why it is necessary to consider this proceeding only as a model instruction to gain the optimal toll price. As except for the price all the other values are constant we can rewrite this equation generally as a relationship:

\[ T = V_M \left( a + b \times V_M + c \times V_M^2 + d \right) - N \]

where: 
\( a, b, c, d, n \) are constants and \( V_M \) is the toll price.

By derivation of this function according to \( V_M \) and keeping this derivation equal to zero, we will gain the optimal amount of urban toll price.

\[ \frac{dT}{dV_M} = 0 \Rightarrow V_M^{opt} \]

### 3.3 Supposed revenues from urban toll system

Expressing the revenues in numbers comes from values and dates which were counted in previous chapters and from the equation 4. Following table 2 documents the trend of pure revenues from urban toll by polynomial regression of intensity development depending on the urban toll price. The result is that the highest pure revenues are by toll 1,99 euros. But we have to remember that the main motivation of urban toll is limiting the automobile transport and not to maximise the incomes from financial means.

<table>
<thead>
<tr>
<th>Amount of toll (€)</th>
<th>Incomes from residents (€)</th>
<th>Current incomes (€)</th>
<th>Costs (€)</th>
<th>Pure revenues (mil. €)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0,33</td>
<td>16 500</td>
<td>1 836 043</td>
<td>1 172 738</td>
<td>0,68</td>
</tr>
<tr>
<td>0,66</td>
<td>33 000</td>
<td>3 495 408</td>
<td>1 172 738</td>
<td>2,36</td>
</tr>
<tr>
<td>1</td>
<td>50 000</td>
<td>4 926 985</td>
<td>1 172 738</td>
<td>3,80</td>
</tr>
<tr>
<td>1,33</td>
<td>66 500</td>
<td>5 956 028</td>
<td>1 172 738</td>
<td>4,85</td>
</tr>
<tr>
<td>1,66</td>
<td>83 000</td>
<td>6 540 838</td>
<td>1 172 738</td>
<td>5,45</td>
</tr>
<tr>
<td>1,99</td>
<td>99 500</td>
<td>6 939 119</td>
<td>1 172 738</td>
<td>5,52</td>
</tr>
<tr>
<td>2,32</td>
<td>116 000</td>
<td>6 024 580</td>
<td>1 172 738</td>
<td>4,97</td>
</tr>
<tr>
<td>2,66</td>
<td>133 000</td>
<td>4 696 207</td>
<td>1 172 738</td>
<td>3,66</td>
</tr>
<tr>
<td>2,99</td>
<td>149 500</td>
<td>2 595 604</td>
<td>1 172 738</td>
<td>1,57</td>
</tr>
<tr>
<td>3,32</td>
<td>166 000</td>
<td>0</td>
<td>1 172 738</td>
<td>-1,00</td>
</tr>
</tbody>
</table>

1 Euro (€) = 3,9302 PLN

Source: [4]
4. Conclusion

The estimate of cost model and amount toll is the main point of this introduction. Also in our paper we focused on model process for optimization of toll price for the limitation of transport intensity and maximize revenue from toll. Here it is necessary to point out that the toll is not only an economic issue but also the public, especially political and legislative and politicians will decide on individual items, including the introduction of such a system.

Finally, we want to remind, that this procedure is taken as model instruction how to proceed further with introduction of urban toll system and price determination.

Acknowledgements

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Bibliography

Intelligent electronic embedded systems for the protection of railway transport from accidents

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ABSTRACT
The paper considers an intelligent electronic embedded system for the protection of railway transport from accidents, its compatibility with the existing railway control system, principles of its components interoperation and control algorithms.
The paper gives the definitions of the functions performed by the system considered and its mathematical description applied to the realization of the control algorithm.
The process of the device prototype testing is described with the obtained results, advantages and further prospects

KEYWORDS: embedded systems; intelligent control, railway transport

1. Introduction

The railway transport experiences the tendency towards increasing the routing speed and movement intensity of this type of transport. At the same time this fact encounters a lot of problems the reason of which is a high motion speed. One of these problems is the level of safety that should be sustained at the same or even higher level than it was so far [1].

Therefore, keeping it in mind, intelligent embedded systems are developed being aimed at the protection of trains from accidents and able to solve at least a part of the problems in the industry of railway transport.

The implementation of a new system into operation each time requires a preliminary development of a mathematical model and prototype, a detailed analysis and testing that recognizes drawbacks of the equipment and ways of their overcoming. The testing process often discovers the problems that are difficult or impossible to find during a theoretical analysis.

Thus the paper analyses the devices that are applied in a general safety control system of a locomotive and in a system using the global positioning system and a wireless communication system providing the basic functions of the device operation: the defining of the moving object location in time and the data exchange between objects.

The application of programming logic controllers in turn solves the complex tasks of the railway transport control.

2. Purpose and tasks

The main aim of the authors is to analyze the operation algorithm of an intelligent embedded system control and to realize the testing of the of the system equipment under the conditions of real work.
The main objectives are:

- To describe the main operation principles of an intelligent embedded system where new devices protecting from accidents are applied [3].
- To define the functions realized by the protecting devices.
- To develop a mathematic model and algorithm for the equipment control.
- To carry out laboratory tests of the main functions performed by the equipment.
- To test the prototype under real operation conditions and to analyze the obtained results.

2.1 Operation principles of the control system

As it was mentioned above the main task of an intelligent embedded protective device is to improve the safety of the railway transport routing without changing the present control system of trains. Therefore one of the most important objectives is to integrate this device with the general control system without decreasing the functionality of the present control system and safety level that is of top importance.

Two types of the device are proposed – a locomotive device [4] and a track-section device [5]. The locomotive device is installed in the locomotive and connected to its emergency braking system to stop the train when necessary.

The track-section device is installed in the outside traffic light control enclosure and is connected to the supply and relays of traffic light signals control and railway point control. It controls the light and railway point conditions.

Fig. 1. General structure of the system

The scheme of interoperation of the embedded safety system elements is given in Fig. 1.

The existing railway system contains the following elements [6]:
- rolling stock – RS1, RS2; locomotives – L1, L2, wagons V1, V2; railway points CP; signalling, centralization and interlocking system SCB; dispatching centre DC; traffic lights TL; shunts P and rails – S.

The new embedded safety devices include: locomotive equipment – IL1, IL2; equipment of railway points ICP containing receivers of satellite positioning system SPS, wireless communication devices at locomotives IL1 and IL2 and railway point CP; information output displays – TDL1, TDL2 at the locomotives and railway point TDCP.

GSM-R network serves to provide a wireless communication channel. As it is seen from Fig.1, both embedded control devices are equipped with the aerial of satellite positioning system, that allows defining the coordinates, the height above the sea level for the locomotive at any moment.

2.2 The realised functions of the system

The following functions are defined for the train safety protective device:

- Establishment of connection between two devices (traffic lights and train);
- Greenwich Mean Time for the IL;
- Train location latitude, longitude, altitude for the IL;
- Traffic lights location latitude, longitude, altitude for the ICP;
- Obtaining the signal from a traffic light from its control device;
- Obtaining the signal from a railway point from its control device;
- Sending the traffic light signal to the locomotive device IL;
- Sending the railway point signal to the locomotive device IL;
- Warning the train driver on the necessity of emergency braking start if the risk of accident exists;
- Start of train emergency braking.

A great attention is paid to the control of locomotive and visual representation of different variable parameters using light indicators or messages that are displayed at the train driver place. That provides the driver with the information on the device operation stability, the accuracy of the obtained information and the obtaining of warning signals.

The main task of the device is to warn the driver on the necessary routine or emergency braking and to complete the necessary operations for protection of the train from accident decreasing the speed.
In the case when the locomotive driver does not complete the necessary operations at a particular moment the emergency braking system is operated stopping the train in front of the place of traffic lights with a stop signal.

3. The formulas applied in the calculation algorithm

The following functional relations define the mathematical model of the device operation:

The total braking way (m):

\[ S_{Sr} = S_{zalg} + S_{regi} \]  \hspace{1cm} (1)

where \( S_{zalg} \) is a preparation braking way (m):

\[ S_{zalg} = \frac{v_0 \cdot t_{zalg}}{3.6} \]  \hspace{1cm} (2)

where \( t_{zalg} \) - the preparation time, assuming that the train contains less than 200 axes (s):

\[ t_{zalg} = 7 \cdot \frac{10 \cdot t_{z}}{b_f} \]  \hspace{1cm} (3)

\( S_{real} \) - the real braking way (m):

\[ S_{real} = \sum \frac{500 \cdot (1 + z - \frac{1}{b_f})}{b_f} \]  \hspace{1cm} (4)

where \( v_0 \) - initial speed of braking, (km/h);
\( v_f \) - finishing speed of braking, (km/h);
\( \zeta \) - braking of the train while rolling in the opposite force operation (for cargo wagons \( \zeta = 1.1 \));
\( b_f \) - the specific braking way of the train;
\( \omega_{zalg} \) - the specific basic opposite force to the train movement;
\( \omega_{regi} \) - the specific opposite force according to the profile of the way.

The specific braking force of the train \( b_f \) is defined from the formula:

\[ b_f = 1000 \cdot v_f \cdot \varphi_{Sr} \]  \hspace{1cm} (5)

The braking factor \( v_f \) is defined from formula (1), but the braking shoe factor \( \varphi_{Sr} \) is as follows:

\[ \varphi_{Sr} = 0.27 \cdot \frac{v_f + 100}{5 \cdot v_f + 100} \]  \hspace{1cm} (6)

The specific basic braking force opposite to the train movement \( \omega_{zalg} \) is defined from the formula:

\[ \omega_{zalg} = \omega_{zalg} + \omega_{regi} \]  \hspace{1cm} (7)

The basic braking force opposite to the locomotive movement is defined from the formula:

\[ \omega_{regi} = 2.4 + 0.01 \cdot v_f + 0.00035 \cdot v_f^2 \]  \hspace{1cm} (8)

The basic braking force opposite to the wagon movement is defined from the formula (cargo wagons):

\[ \omega_{zalg} = 0.7 + 0.1 \cdot v_f + 0.0025 \cdot v_f^2 \]  \hspace{1cm} (9)

Where \( q \) - the pressure on one axis of wagon, (t).

The basic braking force opposite to the wagon movement is defined from the formula (passenger wagons):

\[ \omega_{zalg} = 1.2 + 0.012 \cdot v_f + 0.0002 \cdot v_f^2 \]  \hspace{1cm} (10)

Using the described basic formulas the logic controller program used in the locomotive device includes the corresponding program implemented for the calculation of braking distance.

The following algorithm is used to define the distance between the objects. At the beginning the distance \( SABO \) in degrees between station A (locomotive) and station B (traffic light or locomotive) without accounting the height above the sea level (Fig. 2). The calculation applies the Pythagorean Theorem assuming that the difference of width and longitude is a cathetus but the distance between the stations is the hypotenuse.

Then the distance between stations A and B in meters is obtained from the distance in degrees using the obtained results of the previous step. We assumed that one degree is 111,120 (m), 1 minute is 1,852 (m), 1 second is 30.87 (m).

Knowing the height of the station above the sea level \( H \), applying the Pythagorean Theorem it is possible again to define the distance between the objects including this value \( S_{AB} \), that results in more precise calculation of the given value (Fig. 3).

Wherewith the distance in meters between stations A and B is obtained including the height above the sea level. In the same way the distance between the objects is obtained applying the geographic locations of these objects.

Fig. 2. Defining of the distance between the objects in degrees
4. The algorithm of the device control and its implementation

This section defines the new control algorithm for the embedded accident protective device and its implementation with a programmable controller.

The block-scheme of the algorithm is given in Fig. 4. List 1 presents a fragment of the program that notes the processing from GSM-R aerial obtained information and data sending to the locomotive device.

List 1. Obtaining the data from a GSM-R aerial.

// Block 1.
LD SM0.0 // always complete the following operations,
CALL WDC_INIT: SBR6, INIT_own
stationmb: VW1982, // station number is initialized,
&INIT_IP_Address: &VB1800, &INIT_Dest_Prot: &VB1820, // server IP address is initialized,
&INIT_Modem_Name: &VB1826, // title of the modem is initialized,
&INIT_Modem_PW: &VB1834, &INIT_SIM_PIN: &VB1844, &INIT_APN: &VB1852,
&INIT_APN_User: &VB1880, &INIT_APN_User_PW: &VB1890,
&INIT_DNS: &VB1900, &INIT_Clip_Numbers: &VB1940, INIT_BUSY
// Block 2.
LD SM0.0 // always complete the following operations,
CALL WDC_RECEIVE: SBR8, 0, // data sending block is called,
RECV_AreasStart: VW1984, RECV_AreaLength: VW1986, // data sending volume is defined,
RECV_Received_From: VW1792, // initial defining of the data sending range,
RECV_Rcvd_DataStart: VW1794, RECV_Rcvd_DataLength: VW1981,
RECV_NewTime_Rcvd: V1780.7
// Block 3.
LD SM0.0 // always complete the following operations,

Fig. 3. Defining of the distance between the objects in meters

Fig. 4. The block-scheme of the control algorithm
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The stability of the program operation is checked in different ways:

• Initiating the devices with active sending regime and fixing its sending stability (the data accuracy and its transfer rate);
• Fixing the received coordinates realizing the bulk of the data and analyzing stability;
• Carrying out the switching of different regimes of the locomotive devices and railway points and analyzing the operation stability.

5. Stability testing of the proposed electronic embedded system operation

The testing of the device is required to evaluate the functional stability of train safety protective system under real operation conditions and the interoperation of its elements when the devices are the elements of a general control system with a wireless communication channel.

The track section device was tested at a real railway station, being connected to the relay circuit of the control cabinet of the station entry traffic light. Thus the device obtains the signal of the light on supplying control pulses to the input of the programming logic controller applied in the device.

For a person on duty at the station, who completes combining different routes, different station entry traffic light signals are switched that are instantly doubled by „SAFE-R 4” device displaying the light on at the front panel installed indicator lamps as well as with the help of information window.

This information is sent to the locomotive device that gives the information to the locomotive driver to know the light on signal of the entry traffic light although physically the light is out of the field of vision. This function is provided also at the coded railway sections that for sure is an advantage of the device.

The testing of the locomotive device is made at a workbench, fully imitating the emergency braking starting system, available at a railway station.

After a successful testing at the workbench the experiment was continued at a real station with a real locomotive. The locomotive device is connected to the locomotive M-62 control circuit of electric pneumatic valve (EPV) (Fig. 5). This connection allows controlling the main EPV control coil, i.e. opening its supply circuit initiating this way the process of emergency braking.

The control output of the device is connected to the emergency braking circuit of the workbench. The train motion according to traffic lights is imitated manually,
entering the location points of the locomotive, which provides the testing process with the necessary distance. Therefore, moving along the planned route, the locomotive is directed to the traffic light that in turn displays the stop signal. At the moment, when the distance between the objects is equal to that necessary for train stopping and preparing the emergency braking system (with warning time delay of 10 sec), the emergency warning signal informs on the forthcoming emergency braking process.

Then, when 10 seconds are counted (the preset time interval), the control relay opens the control relay coil supply circuit connected to the emergency braking EPV activating this way the emergency braking system. Now 7-second time delay starts during which there still is an opportunity to switch the emergency braking off (the present locomotive control system), but the locomotive device blocks this as in this case the braking takes place only according to the absolute necessity when this switching off is not already possible.

6. Testing of the system device prototype under real operation conditions

The testing of the device took place at a station of Latvian railway in Riga Bolderaja.

The testing of the prototype consisted of two parts. The first aspect to be tested was whether the device disturbs the work of the driver and warns the driver on the emergency situation. Driving the train to the traffic light with different speeds the driver obtains the information about the red signal of the traffic light but performs the braking manually. During the second testing the ability of the device to stop the train automatically was examined.

The display of locomotive device during the test displayed different types of information on the speed of the locomotive, the distance to the traffic light and the type of its light and other info (Fig. 6.).

For example, when the locomotive starts its motion from a distance of 998m (according to the data from the device) to the station entry light with a red stop signal it is accelerated up to 35 km/h. The locomotive device displays a warning and the locomotive driver starts the routine braking. As a result the locomotive stops at a distance of 344 m ahead of the traffic light with a stop signal.

During the second stage of the testing the driver „does not mention” the warning of the device. Therefore after some interval the device automatically operates the emergency braking and the locomotive is stopped in all cases ahead of the traffic light with a stop signal.

For example, when the locomotive starts its motion from a distance of 1,503 m (according to the data from the device) to the station entry light with a red stop signal it is accelerated up to 60 km/h [8]. During the warning the routine braking does not take place. As a result the locomotive device automatically starts braking and stops the locomotive at a distance of 432 m from the entry light.

A large distance which can occur between the traffic light and the locomotive after its stop may be explained by the fact that the algorithm calculating the braking distance assumes the corresponding factors defining that the braking system of the locomotive (braking shoes etc) is in a poor condition. As the locomotive braking system under testing was fully in a good condition it allowed stopping the locomotive faster.

7. Conclusion

The results obtained during the test prove that the proposed prototypes of the system are able to provide the braking of the train ahead of traffic lights or any other object including level crossings or ahead of another train at a distance large enough from it, improving the safety of the proposed system operation. This function is successfully tested at different motion speeds of locomotives.

The device is able to react timely to an unexpected switching of the traffic light that proves the performance and mobility of the device.

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Fig. 6. The information display of the locomotive protective device
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Analysis of elements of telematic systems interaction and rules of their mutual communication

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ABSTRACT
The paper presents an analysis of the basic principles of telematic systems in which the timely execution of tasks and the interaction of those systems distributed modules is the critical element. The first part lists the most important ideas and concepts of real-time systems. The second part refers to the communication principles of elements of a distributed telematic system-level exchange of messages of the third layer of the OSI model. The last part presents an example of a telematic system in terms of reported issues.

KEYWORDS: telematic systems, real-time systems, communication

1. Introduction
The information society development and constantly increasing volume of road transport resulted in a significant increase in the number of services offered by ITS systems. A general division of these services has been described by several standards organizations of which TC 204 is the most important. The ISO 14813 has characterized eleven areas of ITS services which include: Traveler Information, Traffic Management, Services, Vehicles, Freight Transportation, Public Transportation, Emergency, Transportation-Related Electronic Payment, Road Transport-Related Personal Safety, Weather and Environmental Conditions Monitoring, Disaster Response Management and Coordination, National Security. Each of these areas requires the use of specific services or of prepared telematic devices, where the interaction within the system will ensure achievement of objectives.

Most telematic systems should be classified as real-time systems, which operate on the principle of severe time limitations. Another feature of these systems is their distributed structure, whose elements (sensors/actuators) are located at various places such as vehicles, road shoulders and the public transport. Examples of such systems were presented by the RITA (Research and Technology Innovate Administration) and are available on the website (http://www.itsoverview.its.dot.gov/). About fifty different systems of supporting the implementation of ITS services are mentioned there. Each of these systems, based on a network of sensors collecting and disseminating a variety of information processed by a dedicated driver or the Traffic Management Centers, is designed to improve the road transport.

That character of telematic systems leads to fundamental questions about the methods of communication between devices within the system and the rules of the information exchange at the level of systems management. The mentioned source (RITA) considers in general terms both methods of communication between the systems and the scope of messages.
2. Character of Telematic Devices Operation

Telematic systems are a group of systems responding to events (Event-Driven System), that is their behavior depends on external events occurring in their environment. For such systems there is a direct action (Straight Forward), which describes the immediate reaction or a reaction in a determined the time (Due-Time). That time is strictly defined due to the continuity of transport processes and to response capacities of the recipients of information from telematic devices over time. If a message is delivered over a period longer than expected (Deadline), such message is defined as expired and preventive measures undertaken. It is possible to talk about systems in which the timeout can be treated as a system failure (Hard Deadline) or a distortion of its operation (Soft Deadline). Examples of the first category of systems include vehicle operation support systems, electronic toll collection systems, and systems of national security. Telematic systems, which exceeded response time does not lead to safety risks, may include travel information systems, management systems of public transport and systems of data archiving.

The presented time conditions are characteristic of real-time systems, which are widely described in handbooks on the theory of industrial automation and computer techniques. The use of these sources may be helpful to solve many problems related with the operation of telematic systems. One of them is scalability, which means that the size of the system, expressed by the number of attached thereto components (devices), can be customized to the customer requirements, but also to further development. Scalable real-time systems lead to a number of issues related to the concurrence of their activities and mutual synchronization of tasks and processes, also to access to limited resources and communication among devices.

The concurrence is defined as a process based on the coexistence of multiple processes carried out simultaneously and assuming data sharing. While in the case of a system in which each of components has an internal processor and memory it is possible to talk about the system hardware concurrency, whereas in the case of systems with a central management unit it is possible to talk about pseudo-concurrence performed actions. In practice, the number of tasks to be performed always exceeds the number of processors in the module, so a full concurrence of hardware may be referred to only for structures of FPGA (Field Programmable Gate Array). The concept of concurrence in telematic systems is bound by a common struggle of resources in the system. This problem is very important, because large distributed telematic systems usually refer to the global database by reading the current states for example of the traffic, busy parking area, pavement condition in different parts of the road, etc. Simultaneous access to records of the database by a number of control modules is just an example of such sharing of a limited resource. The lack of access control mechanisms leads to overwriting the data of the processes carried out at the same time based on past data sets. To this end telematic systems should take into account the problem of mutual exclusion tasks, which brings the need to guarantee the execution of disjoint fragments of tasks in which a reference is made to the common system resources. These fragments are called critical regions or short regions.

The experience of telecommunications engineers and computer scientists, the execution of two or more tasks at the same time requires the introduction of mechanisms for their synchronization. The task synchronization occurs during the execution of a greater number of concurrent tasks, each of which is carried out independently, but with the moments at which each will have to replace the information, or to communicate. It should be noted that in the discussed systems, the sequence of operations depends largely on the sequence and timing of external events initiating the processes in the system, so it is not possible to predict. This lack of determinism in the process of calculation cannot mean a lack of control and security of processes. The achieving of tasks synchronization is possible through appropriate control processes and mechanisms of resting the responsibility on both the programmer’s choice of programming language and operating system. The most popular mechanisms used include the application of a buffer and instructions suspend “Suspend” and resume “Resume”. A more advanced technique consists in using a structure known as the semaphore. It is a system variable whose value can be checked and changed by all the tasks using manual Wait (S) and Signal (S). A major problem related to the synchronization of tasks is the possibility of deadlock group of tasks, namely a situation where the suspended task is waiting for the resumption of the task, which in turn is suspended pending the resumption of the former. The deadlock may result from the existence of the state that has no output transition or an output transition is based on the event which will never happen. The mechanism of critical decision is a method of defending against deadlock. It is based on the attribution of priorities or tasks using the meeting time (Timed Rendezvous). But the easiest way is to block all other tasks before the task releases the occupied resources.

Issues described above are not new but authors noted that they are not known or trivialized by developers of the road transport telematic systems.
3. Analysis of Communication Messages in Telematic Systems

Modern communications provide several means of information transmission both inside the telematic systems, as well as outside. They are divided into wired and radio, the first of which contrary to popular belief are a major percentage of all solutions. The popularity of wired communications results from a higher reliability of links, and a high resistance to interference and much higher level of security of the information transmitted. However, the use of wireless communication is needed in cases of transmitting messages, such as warning messages, from and to vehicles during their trips. That is when cars are approaching a traffic signal, the wireless communication allows cars to be aware of all other vehicles on the road, even if the drivers are not. The wireless connectivity allows cars to be continuously aware of each other, where they are, so if a car suddenly brakes the cars several yards behind the vehicle get a safety warning before they get too close. Another typical case is a contactless identification of vehicles at characteristic points, e.g. at places charging fees for entering the highway. In wireless communication telematic devices an increasing attention is paid to the wireless vehicle to vehicle communication (V2V communication). Examples of V2V communication on freeways will help to prevent crashes, Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) communication showing types of messages V2I that can be delivered to the vehicle.

The variety of available means and methods of communication leads to fundamental problems, related to adjusting the message form and content to the possibility of teletransmission through wired and wireless networks. The basic reference is the model of layered networks OSI (Open System Interconnection), developed by ISO (ISO standard 7498-1). The model is a reference for most of today telecommunication standards. It defines seven layers organized in such a way that each of them provides services to the adjacent layers. Among the layers, the three upper layers (L7 – Application Layer, L6 – Presentation Layer and L5 – Session Layer) are directly implemented in the software controlling the system modules while the lower layers take an active part in preparation of data for transmission. The Transport Layer (L4) segments are long or consist of sets of data. The Network Layer (L3) is responsible for switching the data streams. The Data Link Layer (L2) is responsible for ensuring a transparent channel (error-free) communication and describes the characteristics of the Physical Layer (L1) interfaces and contacts between devices and systems.

The analysis of the principles of communication at the first and second layers is different for each of the adopted transmission media and technology of communication. Similar situation is in layers from the fifth to the seventh, where the information is processed to the specific needs of IO interfaces. As a result the analysis and any action to integrate devices and telematic systems need to focus on OSI layer three and four.

The adaptation of telematic devices at the transport layer involves the establishment of common rules to control the reliability of a given link through flow control, segmentation/desegmentation of large data portions and to allow the error control. The network layer is responsible for the process of establishing, maintaining and terminating the exchange of messages. In connectionless networks it is responsible for the proper routing of data packets. The network layer during the process of compiling a call negotiates the terms of communicating parties.


An example of analysis of information sharing in telematic systems can be an IP communications network project for the management and control of traffic on a highway, where the main aim is to provide the network communication capabilities of various systems that make up the whole system, while maintaining adequate security. Main communication network nodes (switches and routers) are placed in functional buildings (SPO, PPO, OUA)
in all locations on the motorway junctions. The analyzed network consists of two functional parts: backbone, providing connectivity between locations (SPO, PPO, OUA) and the local area in a single location.

The backbone network is built based on the Ethernet switches which, in each location, operate modular hardware redundancy. Ethernet switches are connected in a ring topology using optical ports. In order to increase the bandwidth between locations for redundancy and devices used in the modular version aggregation on the physical level. The backbone network packets are routed between locations, using the functionality of Ethernet routing switches. The transfer of traffic organization on the third layer of the OSI model (network) provides a separation between the locations of the second layer of the OSI model, for protocols such as ARP (Address Resolution Protocol), which improves the network performance and prevents the transmission of traffic generated by the disturbance of applications in one subnet to the other virtual network.

Figure 2 shows a diagram of the backbone network at the physical layer. Two 1GB links working in LAG (Link Aggregation Group) will be used for communication between different locations, increasing the available bandwidth, double the rate 2GB. These links belong to different VLANs as shown in Figure 2.

A local loop provides a transport-access layer, the second model in OSI implemented for all systems on the network backbone. The loop is constructed in a ring topology with Turbo Ring protection, as shown in Figure 3.

Local loop-access is connected with two calls from two different devices. The Turbo Ring protocol used in the network topology protects against the loss of resources of the ring in case of damage to the network. This protocol, when connection is broken in the ring, reconfigures the network and communication switches to a redundant path in time, which is always less than 300ms. Switches connected in this architecture, blocking one of the calls, thus prevent the occurrence of loops in an Ethernet network. In the event of any interruption of the connection, the switches will automatically detect this event and reconfigure the network to a redundant (backup) path. The restoration of communications networks for 10/100 connection is always in less than 300ms. Ports, which are connected to the local loop-access to the core network, are configured as transit packets moving between different systems to ensure separation between the VLANs.

In the backbone network used in the field of network management and divided in such a way that the addressing plan concerns the connections between locations in the aggregation network. The VLANs in a network backbone running OSPF dynamic routing protocol is responsible for filling the dynamic routing tables of switches. Telematic devices, such as highway motorway meteorological stations, controllers and variable message signs, are
connected to the local access network using switches and through the virtual network VLAN created for the needs of remote management and monitoring to assure the safety switches and control over network traffic.

5. Conclusion

The paper presents an analysis of the basic principles of telematic systems operation, particularly systems in which the timely execution of tasks and the interaction of distributed modules of these systems is the critical element. The presented concepts and issues of real-time systems are not new, but the authors noted that they are not known or underestimated by the people developing road transport telematic systems. An example of network design for IP management and control of traffic on the highway shows the character of telematic systems and related temporary conditions.

Bibliography

Basics of transport information management

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ABSTRACT
A paper concerns the problems of information ordering in intelligent transport systems accordingly their role and meaning for various transport processes. There is given an attempt to rules of classification of information, their standardisation questions, reduction of redundancy and false specimens necessary for proper information management. All these questions are of great importance from the information accessibility, usefulness and reliability point of view. Also are discussed problems of the information selection, its protection, and its evaluation as a factors influencing possible improvement of the transport decisions making. Finally, some outline of standardisation rules are presented

KEYWORDS: information management

1. Introduction
Dynamic development of the modern information technologies applied to all the activities in transport, generally called as intelligent transport systems (ITS) becomes possible thanks for growing accessibility to ICT solutions. But really just the broadened accessibility to information becomes crucial for great progress in the discussed area. Information, being beside energy and technical means an indispensable factor for realization of the all transport tasks, may have a decisive meaning for high effectiveness achievement. It is easy to observe, that in the last tens of years, thanks to new technological possibilities appeared not noticed former access to huge amount of ready or possible to obtain information. At the same time, in provided information emerge also considerable content or volume redundant, and even false or erroneous specimens, what obviously reduce effectiveness of the transport activities based on such information and certainly – even all the information processing tasks.

Generally observed growth of information meaning, resulted from progress of ability and possibility of its intensified usage allowing all human activities improvement, caused even development of the research over this peculiar good, headed toward further improvement of it's usage. Among others there are conducted research on information evaluation, reduction of the redundancy and incidentality, extraction of the valuable parts, mainly these indispensable. It combines with the necessity of developing proper rules for broadly understood information management, what particularly concerns transport branch. Just there exists a need to work out standards (in meaning of mediocre type, pattern, model) and norms, which could be applied in particular areas of information applications in transport. It should improve the effectiveness of operations of various transport systems, level of the cohesion of transport activities and – may be first of all – it's security.

With reference to existing state of ITS resulted by spontaneous and incidental development (Wydro 2006), it should mean ordering of information management and processing according to its content, what should give possibility to remove its redundant part and processing of this part, but mainly considerable gains coming from more effective systems operations, (as at actual state systems are weakly co-ordinated or not co-ordinated at all as a result of compatibility lack). Actually even information
exchange between systems and equipment made by various producers and providers – often necessary – leads to additional costs and lower reliability of ITS as a whole. It became also a big obstacle for introduction to systems the new functionalities; it’s extension or improvement. In particular, emerging in last time tendencies for creation of multi-modal transport structures, rising the security level, providing better transport conditions with information services to millions of individual recipients with very diversified needs profiles, requires efficient systems co-operation an – in some extent – it’s mutual replacements or functional substitutions (Harems & Obcowski 2008, NTCIP 2009). That’s just what a need of information operations ordering and rational management on the basis of exchanged information systematising and content selection, becomes an urgent and important task.

In many cases such procedures already are executed, nevertheless in numerous ITS applications areas lack of the proper information management and regulations can be observed. It is a result of various reasons, among which lack of necessary or desirable cohesion of the ITS as a whole is one of most important. Elimination of this and other shortcomings requires firstly to identify and systematize information users types (as well human as machines ones) and their needs, then making classification of the types of information, their features, considering even their dimensions and utilitarian meanings. Even defining of the features of technical means necessary or useful for information processing, exchange and presentation is needed. IT is to point that in the last mentioned area, one of main elements influencing system’s cohesion and compatibility becomes protocols for inner- and inter-systems communications and interfaces to systems users and surroundings. Such a need can be superbly illustrated by the shortcomings resulted by traffic management systems incompatibility or variety of electronic fee collections along the international routes, from one side, and idea of internationally unified safety supporting eCall system – in other.

2. Transport branch information

Intensifying and improving quality of the transport related information requires – from technical side – creation and installation of various more advanced devices and programs for information gathering, distribution, processing and usage for inner systems needs and proper improving interoperability between particular systems. Interoperability – first of all – means inclusion by common communication rules the information provision for all of users and operators of all transport systems, enabling distribution of actual, useful and reliable information which can be collected from all possible sources and provided for usage by all interested users, possibly suitably to theirs expectations. It causes a need to pay special attention to information content flowing in telematic systems and between them, especially ensuring optimal solutions applied for execution of these flowing.

It is to be underlined, that optimisation problems are always mostly related to quality of information content, i.e. it’s adequacy to time and place of origin, validity and importance, but not as much to technical features of processing and distribution of information.

From the ITS needs point of view, the systems inner information decides about the state and activity of given kind of transport, but important role plays even outside generated information, describing circumstances and conditions influencing actions of this kind of transport. Of course, for assuring a proper and effective realisation of the transport tasks, there is also need to reach sets of information describing relatively constant (quasi-static) states and circumstances as well as dynamics of occurring processes (Wydro 2009).

It is obvious, that the total amount of information appearing in the system depends on system’s dimension, i.e. on numbers of it’s elements and processes in it occurring, theirs distraction and geographic locations, on dynamics of these processes and changes in surrounding, but also on types and tasks of the information systems utilizing this information. Also it is reasonable to take for analysis as an area of reference a road transport, which due to its specificity characterized by complexity of roads network with diversity of classes and conditions, states but even managing entities, bearing intensive traffic with high randomness and dependence on environmental conditions, even an area with richest range and diversity of implemented telematic applications, ensures possibly comprehensive analyse of information management problem.

Also, it have to be remembered, that as a result still emerging new technological possibilities, beside new user needs stimulating constructors invention, variety of new telematic applications still is rising, and existing ones use to be essentially upgraded – what together strongly increases demand for information amount and it’s improved quality (Report 2009, Wydro 2003). Obviously it broadens also areas of above-mentioned analysis.

With information management questions are also related problems of information transmission (understandable as carrying in space and/or time). What’s important, in more and more transport cases, the information have to be delivered to moving objects. Besides, for the sake of required level of the reliability and resistance to possible interferences, some protections means are to be applied, what naturally expands the volume of transmitted information. Such a circumstances
brings some difficulties for creation of the information systems, but have to be considered at information categorisation (i.e. problem of confidentiality).

In fact, for various modes of transport can – or may – be applied specialised teleinformatic systems, but, as a rule it's basic structures remains similar, what have some reflection in ITS architectures. Also particular basic applications for information exchange and processing may be equal, what in turn arise legitimacy and need of technical standardisation activity in transport telematics domain. But these last said so far concerns the forms of information, not interfering their contents\(^1\). If yet the devices should be active with reference to information's content or essence, functioning of such a devices should even be embraced by some defined rules and principles. Also, from infologic point of view, in electronic communications area the kind of transmission technical means is not important, although choice among accessible kinds may have some meaning for reliability, transmission capabilities and costs. Important is however so that information was transmitted in agreed formats (patterns) ensuring mutual understandable communication of system's elements. Having in mind that in telematic solutions becomes needs of communication among:

- Vehicles and infrastructure's teleinformatic equipment,
- Various vehicles,
- Vehicles and informatic and service points or centres,
- Infrastructure's teleinformatic equipment and service points or centres,
- Drivers and related informatic surrounding,
- Informatically co-operating parts of particular vehicles,

may be expected, that will be continued works on integration not only means of information exchange, but even on the manners of these exchange in ITS as a whole and firstly – on information transmission content-oriented protocols and selection and distribution of information methods with striving to more and more necessary automatic languages translations, as well as building personally tailored and dedicated information packages (Gut & Wydro 2010).

\section*{2.1 Information sources}

In each of information-operated system can be distinguished two main areas of information origin. These are the observed objects and processes delivering basic information and sources of various supporting, already processed information. In transport system as such can be pointed the informational equipment of the transport infrastructure, transport means and entities (persons and institutions) participating in these processes. As examples of infrastructure's equipment delivering primary basic information may be mentioned vehicles detectors or other measuring devices (as photo-radars or weights), weather stations and other environmental sensors, observation systems (cameras), pedestrians detectors, security systems elements and alike. In turn, vehicle's information generating equipment embraces elements of such systems as warning, positioning, emergency (i.e. eCall), movement registration or even specialised measuring equipment (Floating Car Data). It is worth to underline that contemporary cars use to be equipped with various driver-supporting solutions, as ABS (Anti-lock Braking System), ACC (Adaptive Cruise Control), EBS (Electronic Brake Assist System), ESC, LDWS (Lane Departure Warning Systems), WLDW (Wireless Local Danger Warning) and others (2). These systems actually undergoes to operational integration and delivers information partially used at the time internally in the vehicle, partially transmitted for the outside use, both, in extend appropriate to needs, registered for future use.

Next, information delivered by entities participating in transport processes are these generated by persons – individual, corporative or institutional – moving or causing movements of some transport objects.

As mentioned, centres for gathering and processing of raw temporary information, which later is supporting various users of information, form another important group of information sources. By the information processed here is understood operational information used in currently realised transport processes, as well as analytic or reporting ones as for example results of short-, middle- or long-time analysis. These can be i.e. data from control centres, databases, or managing entities. A good example are sets of information passed to infrastructure's roadside equipment i.e. concerning or applied to traffic control elements as traffic lights or variable message signs, radio announcements and other actual communiques. Similarly is with information for travellers.

Next, information creating strategies of traffic control in various areas (town, village, roads between inhabited areas) and current circumstances, methods of reaction to particular types of incidents, fleet management and alike, may be numbered among information coming from middle-time analysis. To this class can be included also information collected from observations and registrations of the vehicle's pictures with register plates recognition or points of truck weighing. Hoverer for example prognosis of the traffic flows spread stands for long-time analysis. Distinction between duration of the validity of forecasts

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1 Regulations related to the form of information concerning technical parameters have been known long ago as a "standards" and are properly advanced.
important for determination of the sampling frequency of observed processes and observation of it’s information content irregularity, seems to be important for information classification patterns.

2.2 Information users

Essentially, set of types of information recipients and users is the most meaningful classification criterion for transport information ordering purpose, as types of recipients determines what kind (in meaning of content) and of which quality information is to him needed and when and where have to be delivered. Among information users can be distinguished following main categories (Wydro 2009):

- Rescue services and systems,
- Information and communication systems,
- Administrative institutions,
- Drivers and travellers,
- Corporate operators,
- Research and educational institutions,
- Financial institutions,
- Legal institutions.

Their needs decides about basic content structures of used information and schedules as well as conditions of information delivering.

3. Information ordering and standardization

In the last years in ITS development frames emerged few projects comprising some elements of information content ordering and standardisation. As examples can be mentioned:

- Conception of the Minimal Set of Data (MSD) in eCall system,
- National Transportation Communications for ITS Protocol (NTCIP) project,
- Transport Protocol Expert Group (TPEG) project,
- Open Communication Interface for Road Traffic Control Systems (OCIT) project.

Minimal Set of Data (MSD) brings information necessary to inform rescue services about place, time, circumstances and nature of occurred incident or accident. This information is passed automatically or manually through emergency number 112 to nearest so called Public Safety Access Point (Gut, Wydro 2010) initiating rescue action.

The NTCIP (NTCIP 2009) is a name of American group of standards for communications in transport, specifying open, based on the project participants' agreement, suitable for this communications profiles and protocols as well as common data definitions. These standards allow fulfil all the conditions resulting from needs of communications in the areas of traffic control and transport managements centres.

However TPEG Forum (TPEG), is an European organisation of the group of experts in information technologies, aiming elaboration of the methods and techniques of the collection and delivering for various users – by the broadcasting means (radio, Internet) – information for traffic control and travellers. Here is assumed forming of hierarchically structured information, which recipient will get and will be able to use in various technical means of information processing and also – language independently – by humans. It has to be also information useful for multi-modal transport systems.

Other important accepted assumption is that in information systems structures are not foreseen necessity of building big auxiliary databases, especially in users receiving devices. Forum tends to develop modular set of tools in prospect standardised by ISO and CEN, taking into consideration possibility of contemporary or future use for various informatic applications.

In traffic management systems particularly important for data exchange organisation are communications protocols. This exchange, usually essential for co-operation of devices and systems provided by various producers, often needs extra investments for building appropriate interfaces and software, what brings significant complications for co-ordination of the systems operations, but even for new functionalities and applications implementation in traffic management structures. In such a cases, as generally in various others information systems, applies a rule of application of "open" protocols. It means application of the protocols worked out and standardised so, that system could work with any device independently of it producer and possess feature of "scalability".

Such a solution presents OCIT protocol (Haremza & Obcowski 2008) being a German standard, but in last years applied in other European countries as an open interface for communication between traffic control systems. OCIT standards are defined for two applications groups. First one, called OCIT-Outstation, pertain communication between local equipment (i.e. traffic lights controllers, measuring stations, VMS) and managing centres. Second one, OCIT-Instation, concerns exchange of information between various applications and systems on the central level of control or management.

Of course an important role in ordering of information areas plays standardisation institutions, mainly international ones like CEN and ISO (ISO).

In both of them activities in ITS (telematic systems) areas are performed by special Technical Committees (TC), each of which is divided between Working
Groups (WG), in both cases thematically almost similarly structured. On the basis of commonly accessible information structures of the can be supposed, that in each of Group can be found some elements connected with transport information treatment rules.

4. Basic classification rules

It is obvious that basic group of features characterising information used in each well working system are these which can be recognized as determining their utility. Usually assumes (Wydro 2008) that each information in the system have to be:
- Essentially and operationally adjusted to recipient's needs,
- Possibly exhaustive as it concern meaning, completeness and conciseness,
- Ascribed to the time and place,
- Articulated, and in case of transport – easy to language translation,
- Possibly most up-to-dated,
- Verifiable.

As it mentioned earlier, ordering in information management area have first of all to be captured in some classifications frames, what make possible better identification and more convenient operations with their elements. Below are presented fundamental premises for the formation of the frames for content standardisation and information ordering for their more efficient management and usage.

Generally can be accepted, that division of the information features into groups mostly distinctive from the infologic point of view is a proper approach (Wydro 2008). These are features:
- Phenomenological, i.e. universal in relation to any area of application or analysis,
- Social and economic, related to utility in economic or social activity,
- Operational, significant from the point of view of information managing operator or information user.

A an example of phenomenological classification may be quoted a division of information according the following criteria:
- Type of source: inner – external, primary – derivative, public – private
- Kind: quantitative – qualitative, formal – not formal,
- Time: former – actual – future,
- Frequency of occurring: continuous – periodical – incidental,
- Usage: planning – control – decision-making – concluding,
- Level of usage: strategic – tactical – operational,
- Detail level: detailed – summarized – general,
- Presentation form: written – oral – visual.

As economic and social features may be mentioned: a direct market value of information, utilitarian value for economy, accessibility, utility for social activities in various dimensions – cultural, military etc.

From our research matter point of view, the most important is the set of operational features, however others can be also discussed. Analysis of the research matter shows, that legitimated is proposal of classification in two dimensions:
- Areas of applications (utilising),
- Conditions of usage.

Acceptance of the area of applications as the basic classification criterion results from the primacy of meaning and role of information in transport (similarly in any case as in each other branch). For ITS such areas are to be determined by the character of services provided by given system for which given information is necessary. Groups of systems with similar service tasks makes up separated areas of applications. It is to point, that on systems qualifications in some extend influences also technical solutions applied in particular cases, which are often unique from the construction point of view, but shows some universality as can be used in various systems for various goals (i.e. vision systems use to be applied for security levering, traffic control or vehicle recognition). As the systems usually are not mono-functional, ascription them to areas of applications are even not unambiguous. Similarly not unambiguous are qualifications of the areas of applications. These are also qualifications and ascriptions of arbitrary types, even changing with the time. Nevertheless currently these qualifications are quit stable, what seems to be i.e. reflected in the names of Working Groups in relevant Committees of standardisation institutions or research works and papers concerning ITS, as well as in used commonly terminology in professional communication.

What concerns of the formal usage conditions, it easy to state that can be distinguished three categories of obtained or distributed information:
- Obligatory,
- Contacted,
- Free.

It combines with legal rights to information and it's availability, but also with formal conditions related to technical means for information collection, distribution and presentation (Gut, & Wydro 2010).
Undoubtedly it is a factor essential for information operation and requires to be considered in assumption of rules and standards of information operation processes. For completeness of standardisations needs, it is also necessary to give for information (communiques) some ordered structural form.

4.1 Main areas of ordered information usage

Among already numerous telematic systems may be distinguished (Report 2009) basic ones, designed for the provision of single service or fulfilling some particular function (when it work in broader system) and complex ones (integrated) for servicing more complex transport processes on i.e. separated geographical area, mode of transport or tasks group.

Systems of the basic type are numerous and supported on various technical solutions. A good illustration to variety of such a systems, classified on the basis of users needs and contemporary technological possibilities gives list of real service systems presented – among others – in (Wydro 2006), where additionally the systems were grouped with respect to applications areas, though it have to be pointed that the list is not closed as with the time emerges new solutions resulted by new technological possibilities, constructor’s invention and users expectations.

Next, as the examples of complex systems can be pointed sets or sub-sets of the basic systems, completed for realization of the complementary functions for fulfillment of the tasks for which they was build. Such a systems are usually ascribed to some given functionality (servicing) areas (IST-FRAME 2004).

According to said above, in particular complex system with well-defined tasks may be distinguished specialised parts, being components of the system as a whole. It is to underline, that specialised systems can in many cases fulfill some additional functions, for example deliver information to other systems.

In proposed standardisation concept assumes that formal classification of the information should be related to concrete telematic systems, with strong consideration of their role in the system and co-operation in functionality area frames, but also with consideration of it’s capability to co-operation with other systems, with simultaneous preservation of the development openness and scalability.

Obviously, real classification of the systems from the point of view of information standardisation needs much more deeper analysis.

4.2 Structural requirements

As it was mentioned earlier, there is a need to give to information communiques defined structural form. It is particularly important when are exchanged information between technical devices and even – in some cases – in transmission of the communiques which have to be of high completeness and precision, as for example it is in the eCall system. Structurally ordered information makes all the operations concerned with information storage in databases, processing, surveying and analysing. Even transmission of information in agreed formats inside each of systems ensures unambiguous mutual articulation between its elements as well as is necessary for compatibility of different systems. It’s the reason for tendency to operations on the ordered sets of dialogues and communiques and ordered sets and allowed ranges of data, thanks for what not only information users but even telematic system’s constructors could communicate in mutually comprehensible and unambiguous manner. It is also obvious need to complete communiques and other information mails with data pointing place and time of the incident described in this information, and – if it concerns some process - also defining a proper frequency of taking of samples describing a following states of this process (Wydro 2008).

Foregoing remarks allows to state, that in fact the description of the structural form of information means creation of the corresponding meta-information i.e. information about information, which supports, among others, convenience of the identification, absorption and usage of information (Wydro 2008). It suggests elaboration of the system of markers, each of which could be ascribed to particular category of information and which interpretation would be stored in some database. It could create a convenient in operations, shortened form of above-mentioned description.

4.3 Accessibility conditions

The second classification dimension having valid operational meaning is the accessibility status. As mentioned earlier, may be distinguished information, which has to be provided obligatory and cost of which bears operators or administrators of the infrastructure, who bears also responsibility, concerned with regularity of these information and correct delivering. Such obligatory information is for example road signs content, among them – these modern like VMS – or broadcasted by radio or Internet official information. Such ones have to be properly formatted and pass a proper verification procedure, as usage of it may result in material or legal consequences of high significance.

Another category makes information exchanged between partners contracting services containing information as content of the service itself or as a factor influencing essence of the service. Exchange is fulfilled on the basis of the contract (agreement) between provider and
recipient. As an example may be pointed delivering of roads condition pictures or parking accessibility, performed on the aid of infrastructure administration by some external professional entities. Here also the ranges and formats of information are established, and some legal aspects concerns nor the contents of delivery, but rather assurance of keeping on agreed frequency and continuity of delivery.

At last, there exists also a huge area of free information exchange and provision. As example can be mentioned positioning data (non-professional) delivered by the satellite systems or information broadcasted by CB-radio (even other radios or Internet). In such a cases there is in fact no any formal constrains, and if a recipient undertakes some decisions or actions based on those information, does it on the own responsibility.

5. Conclusion

Elaboration of the rules (standards) allowing to order activities in area of obtaining, exchange and usage of the context valuable information should create an important circumstance facilitating functioning, but even construction of the ITS solutions. Such a conclusion comes from survey of contemporary implemented telematic systems as well as from direct discussions in involved professional environment – technicians, researchers as constructors. In many areas of information users such a ordering are in scope of interest of administrations in sense of development and modernizing activities in transport. Therefore elaboration and putting to practice broadly accepted methods of coherent manners of information exchange in transport branch as whole and in ITS particularly, is an urgent question. It should lead to formation of the rational system of operation on content-selected ordered information in transport area.

An important part of above defined task requiring to be researched broadly is a problem of transport meta-information creation and manners of information verification, especially these of high importance for the systems. Other important tasks are reduction of redundancy existing in information by the nature and also caused by information replication, and elimination of unimportant information. Possible solution in these last tasks needs of advanced research with methods of semantic selection (Wydro 2008).

Fulfilling of the pointed expectations may be done by adequate research and development entities working in proper interdisciplinary structures and co-operating with international ones. Achieved results in a broader depiction could also make a contribution to methodology of electronic communications systematising and rationalising in other branches of economy, what can be exploited at construction of various development plans in broadly understood electronic communication in information society.

Bibliography

Safety related control systems for railway signalling applications with a safety PLC

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ABSTRACT
Nowadays, there are available on the market not only standard PLCs (Programmable Logic Controller) but also safety PLC’s. These are primarily designed for industrial applications. Their guaranteed safety properties, however, enable to be used in applications, in which the usage of PLC has not been common until now. The aim of this article is to focus on problems related to the usage of safety PLC in railway signalling systems.

KEYWORDS: PLC - Programmable Logic Controller, safety PLC, SIL – Safety Integrity Level

1. Introduction

One of the appropriate devices for an automatic control realisation are programmable logic controllers (PLC - Programmable Logic Controller), to which also their circuit and technological solution responds. Because of its parameters, they are becoming favourite means for solution of different control tasks (e.g. [1]). Nowadays, there is available the large-scaled PLC’s assortment from different producers on the market. Their application possibilities and comfort by their programming and debugging make them tools which cannot be compared with those at the beginning of the PLC development. Producers attempt to constantly innovate the possibilities of the PLC. Main trends in the PLC development can be summed up into the following areas:
- comfort increase by programming and debugging of the PLC – first of all, it concerns automation of some actions by programming and possibilities expansion of their programming by various programmable languages (so the PLC are becoming more available to different user groups); nowadays, almost all programmable environments meet the needs defined in the standard [2];
- increase of the application possibilities of the PLC – it concerns development of new modules which belong to the modular structure of the PLC; as a typical example can be mentioned modules for servo – unit, intelligent sensors, high – speed counters etc.; modules of analogue inputs and outputs are self-evident; this reality relates to the fact that some producers leave the traditional name Programmable Logic Controller and use the name Programmable Controller; also this indicates that traditional, mainly logic character of the PLC, is becoming the past;
- increase of communication possibilities of the PLC – PLC fulfils only some of control functions of the entire control system in modern distributed control systems (generally the PLC are used on the process level) and
must be able to collaborate with parts of the system on other control levels or other control systems (e.g. [3], [4] deals with communication possibilities of modern PLC);

- increase of reliability and safety parameters of the PLC – increase of these parameters relates indirectly to increase of application possibilities of the PLC even in areas where it has not been possible until now (for example control of the safety-critical process).

The main difference in producers approaches to increase of reliability and safety parameters of the PLC is the fact that some producers follow these parameters separately (they offer the PLC with increased reliability or the PLC with increased safety) and some of them offer the PLC with modular structure which enables to follow increase of reliability and safety parameters at the same time.

For PLC, having the property that after occurrence of failure, they will remain in the original condition (if it is not critical in view of control process) or will go to a pre-defined safe state (usually a setting of outputs to the state log. 0; this feature is necessary to take into consideration by usage of PLC), the name safety PLC is being used. For PLC, having the property to be able to perform its function even in the presence of hardware failures or errors in program, the name fault-tolerant PLC is being used.

Commercially available safety PLCs are principally intended for industrial applications up to the required level of safety integrity SIL3. Dangers that may occur in railway transport are associated with serious human consequences (transport of people) and therefore, the systems for control of train drives have to be usually realized with SIL4.

Usage of commercial safety PLC for such applications is not possible because the increase of SIL to SIL4 would signify intervention to the technical solution of PLC and this is practically impossible for user. Companies solve this problem by developing of special safety PLC, which are certified for SIL4 (for example, system NEXUS from Prvni Signalni, a.s.).

In railway transport, however, there also exist applications in which for the reduction of risk (arising from the control process) to the tolerable level, it is sufficient to apply technical measures with lower SIL than SIL4. It regards mostly the traffic control on the hump yards, on factory railways and in recent years there are discussions about level crossing systems devices on secondary lines where little ground speed and low traffic intensity are.

So that the safety PLC could be certified for the required safety integrity level, it has to meet the requirements for SIL against systematic failures (especially application software errors) and also against random failures (mostly the failures of hardware components). Meeting these requirements is characterized by certain specifications in application, to which this contribution is dedicated to.

2. Ensuring the safety integrity level against systematic failures

Systematic failures neither occur as a result of system aging nor have a random character, but their presence is linked to a particular situation and state of the system. In case of PLC, systematic failures are associated with software errors caused by system proposal.

When creating a control system based on PLC, hardware part of the control system is built-up on the basis of modules offered by the selected manufacturer (s) of PLC, whereby the interfaces are clearly given and it is not necessary to deal with their definition. After determining the architecture of the control system, the centre of its creation will be resting in creating of application program because this one implements the required safety and control functions of the system.

One of the most important activities in developing of safety critical control system is to define functional requirements. If the specification of functional requirements is made only by an informal specification, it will be a high probability (especially if it is a more complex system) of failures occurrence in software due to its incompleteness and often little lucidity. Specification of functional requirements must be done so as to be clear, understandable, complete, consistent and controllable. Therefore it is recommended that the specification of functional requirements would be carried out on the basis of semi-formal and formal methods. These methods are oriented to minimize systematic errors in software and greatly help to enhance the functional safety of the system.

If the PLC is used to control the discrete-event systems, it can be regarded as a sequential system. The mathematical model of such system is a finite automaton.

The finite automaton M is arranged by:

\[ M = \langle A, S, U, p, v \rangle \]  

where A is a set of input vectors, S is a set of states and U is a set of output vectors; p and v are transforms:

\[ p: S \times A \rightarrow S \]  

\[ v: S \times A \rightarrow U \text{ (eventually } v: S \rightarrow U) \]  

where the transform p is called transfer function and transform v is output function [5].

The finite automaton, whose output function v has the domain range S \times A, i.e. it assigns certain output symbol to each pair (state, input), is called Mealy’s automaton. If the transform v has its domain range S, i.e. it assigns the
output symbol to each state, then it is Moor’s automaton. Both of these types of automata can be implemented as synchronous or asynchronous sequential circuit.

Finite automaton can be described as following:

• Mathematical expression – sequential circuit’s behavior in discrete time area can be described by expressions:

\[ s(t+1) = s(t) + P_a(s(t),u(t)) \]
\[ u(t) = Y(s(t),a(t)) \]

where the symbols \( a(t) \) and \( u(t) \) symbolize particular input and output vectors of the system in time \( t \); symbols \( s(t) \) and \( s(t+1) \) symbolize the particular states in time \( t \) and \( t+1 \). In fact, the main task is the compilation of the Boolean functions, of which the elements of state vector \( s(t+1) \) and output vector \( u(t) \) can be calculated on the basis of input vector elements \( a(t) \) and the state vector in the previous time \( s(t) \).

• Table representation – it defines the input words which may cause state transition.

• Graphically – by the state diagram. State diagram is a directed graph whose nodes represent the finite automaton states and directed edges correspond to the transitions between states. The edges are rated by inputs vectors \( a_j \in A \), which activate transition of finite automaton from one state to any other. If each state of automaton is assigned the output vector, then it is a Moor’s automaton. If the output vector is assigned to transition, then it is a Mealy’s automaton. In practice, we can see a combined state diagram (the output vectors are assigned to states and transitions, too).

From the mentioned ways of finite automaton notations, the state diagram can be considered as the most suitable from the view of its usage for program creation. This is because the fact that it is easily understood by the people involved in system specification and can be used for direct creation/generating of software for control system.

The basic idea of the state diagram using for the program creation consists of assigning a code to diagram states \( (s_1,s_2,\ldots,s_j) \). So as the control system could fulfil its function according to state diagram, the code of actual state must be kept in its mind constantly and the conditions for transition from this state to another state must be evaluated. The transition can be initialized by input word / words from the set \( A \). In case of fulfillment of the conditions, the place of the actual state is replaced with a code of a new state in program memory and the actions connected with the new state, eventually with the transition, are executed (the setting of output word / words from the set \( U \)). In the Fig. 1 the structure of ladder of the program is shown, created according to state diagram in principle.

Program shown in the Fig. 1 uses ladder logic. It is a graphic method of programming, based on techniques used for relay circuits. Considering its lucidity it can be used advantageously for programming of the safety critical control systems. Such a built-up program can be directly implemented into the safety PLC. For example, programming language F-LAD (Fail-safe ladder logic) can be used. This language differs from standard language LAD mostly by limited instruction file and accurate defining of individual subprograms callings.

In the Fig. 1 there is applied a binary code for coding of states. Using the binary code is not a condition. However, it seems to be advantageous in regard to its simplicity, lucidity and instructions applicable in F-LAD language. In case of usage this methodology for programming of standard PLC e.g. decadic code can be used, eventually code consisting of alphanumerical symbols.

From the perspective of the PLC functionality it does not matter which way of states coding is being used. The coding of states, however, will have an impact especially on the speed of program running. The influence of coding on the program speed will be more noticeable with increasing complexity of the program. This is because of the fact that by evaluating the program created according to Fig. 1, the number of comparison actions (the evaluation, in which state the currently control system is) is adequate to the number of automaton states.

Fig. 2. Comparison of execution times of the programs created by various coding of states
The influence of the selected code to the execution speed of the program is shown in the Fig. 2. The Fig. 2 compares the execution time of one cycle of the program for standard and safety PLC. For standard PLC, various codes of states are being used. The measurements were done for control system SIMATIC S7-300 in standard and safety version. A very simple program was implemented. This example assesses pushing the button. After its pushing and releasing, the output is activated. After repeated pushing the button it comes to deactivation of output.

The first and the fourth column show the program execution time under the same conditions for standard and safety PLC. Significantly longer program execution time of safety PLC is caused by a producer defined functions. These functions relate to the required level of safety and the user cannot influence them in any way.

3. Ensuring the safety integrity level against random failures

The system safety integrity level against random failures is mostly influenced by:

- Structure of the system;
- Intensity of system elements failures;
- Diagnostic features of the system
- Mutual independence of the system channels, eventually common cause failures (CCFs), in case of multi-channel system.

In railway applications, safety-relevant control systems with safety PLC are being used mainly on process level and therefore the part of the control system are, apart from safety PLC, sensors and actuators, too (Fig. 3; SRCS-R is Safety Related Control System for Railway).

The final level of the system safety integrity SRCS-R is dependent not only on safety features of safety PLC, but also on reliable and safety features of sensors and actuators and the way of their connection to the safety PLC and their reliability and safety parameters. Therefore it is necessary to pay attention to sensors and actuators selection, the way of their connection and setting of input/output circuits of the PLC (to which the sensors and actuators are connected).

According to producers data (for example, in the document [6]) 90% of dangerous failures is caused by sensors and actuators failures and only 10% of dangerous failures is caused by the safety PLC failures. Setting of appropriate parameters of input/output circuits needs to be done not only with respect to the required level of safety integrity, but it is also necessary to take into consideration the parameters of the connected sensors, respectively actuators (for example, by some actuators there is not acceptable pulse testing).

The basic building elements of safety PLC are modules (processor module, input / output module, ...). Each module is defined by the intensity of dangerous failures. Knowledge of the intensity of dangerous failures is a necessary prerequisite for quantitative assessment of the assembled SRCS-R. The most commonly used model to evaluate the safety SRCS-R with safety PLC is a serial model. Such a model is recommended by the PLC producers themselves. The reason for using the serial model is its simplicity. In the view of safety, such a model is acceptable because it comes from assumption that a dangerous failure of any module causes a dangerous failure of the whole control system.

Fig. 3. Block scheme SRCS-R with safety PLC

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For example, for the assembly of the safety PLC is valid:

$$\lambda_{PLC}^{S} = \sum_{i=1}^{n} \lambda_{M}^{i} \leq \sum_{i=1}^{n} \lambda_{M}^{i} \quad (4)$$

where $\lambda_{PLC}^{S}$ is intensity of dangerous failures of the PLC, $\lambda_{M}^{i}$ is the intensity of dangerous failures of i-th module of the PLC and $\lambda_{M}^{i}$ is intensity of failures of i-th module of the PLC and n is the number of PLC modules.

Likewise, we can determine SIL for SRCS-R. This means that:

$$\lambda_{SRCS-R}^{S} = \sum_{i=1}^{n} \lambda_{SRCS-R}^{i} + \sum_{i=1}^{n} \lambda_{S}^{i} + \lambda_{PLC}^{S} \quad (5)$$

where $\lambda_{SRCS-R}^{S}$ is intensity of dangerous failures SRCS-R, $\lambda_{SRCS-R}^{i}$ is intensity of dangerous failures of i-th sensor, $\lambda_{S}^{i}$ is intensity of dangerous failures of i-th actuator, n is number of sensors, m is number of actuators and $\lambda_{PLC}^{S}$ is intensity of dangerous failures of PLC.

The standard [7] does not define SIL for the system, but for the safety function of the system. It means that for
the calculation of intensity of dangerous failures of a given safety function are relevant those system elements, which are involved in its implementation.

Let us define two safety functions \( F_1, F_2 \).

If the function \( F_1 \) is realised by sensor \( S_1 \), safety PLC and actuator \( A_1 \) (Fig. 4), then

\[
\lambda_N^{F_1} = \lambda_N^{S_1} + \lambda_N^{PLC} + \lambda_N^{A_1} \tag{6}
\]

where \( \lambda_N^{S_1} \) is intensity of dangerous failures of function \( F_1 \), \( \lambda_N^{PLC} \) is intensity of dangerous failures of sensor \( S_1 \), \( \lambda_N^{PLC} \) is intensity of dangerous failures of PLC and \( \lambda_N^{A_1} \) is intensity of dangerous failures of actuator \( A_1 \).

If the function \( F_2 \) is realised by sensor \( S_2 \), safety PLC and actuator \( A_2 \) (Fig. 4), then

\[
\lambda_N^{F_2} = \lambda_N^{S_2} + \lambda_N^{PLC} + \lambda_N^{A_2} \tag{7}
\]

where \( \lambda_N^{S_2} \) is intensity of dangerous failures of function \( F_2 \), \( \lambda_N^{S_2} \) is intensity of dangerous failures of sensor \( S_2 \), \( \lambda_N^{PLC} \) is intensity of dangerous failures of PLC and \( \lambda_N^{A_2} \) is intensity of dangerous failures of actuator \( A_2 \).

For the intensity of dangerous failures \( \lambda_N^{SRCS-R} \) according to Fig. 4 is valid that

\[
\lambda_N^{SRCS-R} = \lambda_N^{S_1} + \lambda_N^{S_2} + \lambda_N^{PLC} + \lambda_N^{A_1} + \lambda_N^{A_2} \tag{8}
\]

From expressions (6), (7) and (8) it is evident that

\[
\lambda_N^{SRCS-R} = \lambda_N^{F_1} + \lambda_N^{F_2} \tag{9}
\]

The way of sensors connecting depends on sensors features and requirements for safety of SRCS-R. For example, in railway applications, there is very often required the evaluation of the state of the contact button while by pushing the button it is necessary to execute the required safety function. And there are several options of button connecting to safety PLC. In Fig. 5 two of these options are shown.

The connection according to Fig. 5 a) can be used when the contact button is closed in a basic state and there is excluded contact failure - short circuit - with such a probability which corresponds to the required SIL of the given safety function. The connection according to Fig. 5 b) does not impose any special requirements for safety features of the button. The intensity of dangerous failures, with which the button circuit contributes to the overall intensity of dangerous failures of the required safety function, can be calculated from the expression:

\[
\lambda_N^{F_2} \approx 2 \cdot \lambda_{K1} \cdot \lambda_{K2} \cdot t_{CH} \tag{10}
\]

where \( \lambda_{K1} \) is intensity of contact failures \( K_1 \), \( \lambda_{K2} \) is intensity of contact failures \( K_2 \) and \( t_{CH} \) is the maximum value of time between two pushing of button. Contacts \( K_1 \) and \( K_2 \) are controlled by one button.

Analogic approach can be used for connection of actuators on the output of safety PLC. Output modules of safety PLC, like the input modules, enable single-channel or dual-channel connection of actuators.

Failure detection (detection of fault) and the subsequent negation of failure (negation of fault) are crucial for ensuring the required level of system safety. SIL of the system is influenced by two features of diagnostic:

- Fault detection time;
- Diagnostic coverage.

Measures for the negation of fault can only be effective if the fault is identified. Therefore SCRS-R contains, apart from functional diagnostic, test diagnostic, too. Diagnostic system implements specific (testing) signals to the object of diagnosis and analyses the responses. In case that such a diagnostic system is also being used when the object is in use (operating diagnostic), test signals may not interfere with normal operation of the object. Diagnostic test is being used in operation to detect faults which do not appear immediately in the object operation, but by the change in the system or in combination with other fault they can lead to a critical state. In this case, test procedures must be analysed for safety, because they can be a source of faults themselves.
Fig. 6. The probability of dangerous failure occurrence SRCS-R with safety PLC

The influence of failure detection time on probability of dangerous failure occurrence SRCS-R with the safety PLC is shown in Fig. 6 (Note: it would also be right to consider the time needed for fault negation; this time is usually not considered because it is usually negligible in comparison with the time of failure detection).

The graph (Fig. 6.) shows that with increasing time of detection, the probability of dangerous failure occurrence of the system is increasing, too. The required level of safety SRCS-R can be achieved either by continuous diagnostics (on-line tests), or by regular controls (off-line). The graph shows the maximum time allowed for the detection and negation of failure for the required SIL ($t_{DmaxSIL2}$, $t_{DmaxSIL3}$). In order to control the interface between the safety PLC and controlled objects (COs), feedback must be used. A typical example of connection of safety PLC outputs with feedback, that allows early detection of failure, is illustrated in Figure 7 b). In this case, the application program must include testing procedures to control the functionality of switches S11, S21 and also the mechanism of failure negation.

SCRS-R with a safety PLC does not have to include feedback with aim to detect a failure of output switches (Fig. 7 a)) if:

- The time required to detect failure is greater than or equal to the required time of system life, i.e. SIL achieved without feedback is sufficient for the given application;
- Possible failures are detected during regular inspections; the time between these checks must conform to the required SIL.

If a continuous diagnostic (on-line testing) is not able to detect all potentially dangerous failures (diagnostic coverage $c < 1$), then it is necessary to combine the continuous diagnostic with regular checks.

Safety of multichannel systems can be even threatened by a common cause failure. If we consider two-channel system, then the impact of common cause failures to safety SCRS-R can be illustrated by a simple tree in Fig. 8.

It should be noted that the mutual independence of the channels is not only related to the technical solution, but also to the independence of persons (organizational measure) involved in the developing of the system.
4. Conclusion

The usage of safety PLC in safety systems restricts the maximum attainable safety integrity level SIL3 (without additional hardware and software components). For applications, in which the safety integrity level is sufficient, safety PLC can considerably simplify the proposal and implementation of safety system. Then the greatest emphasis should be given on connecting of sensors and actuators and the parameters influencing the way of their assessment.

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Bibliography


Computer simulation of traffic as a tool to facilitate decisions on the organization of traffic

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ABSTRACT
Paper presents an experiment using a specialized tool - traffic simulator. The results of computer analysis of traffic have been presented as a very quick, easy and cheap method as base of making complex decisions in the process of organizing traffic. For example, motion simulation for the planned reduction in traffic, resolved the dilemma at the local level, the theoretical analysis at this level is difficult for obvious reasons.

KEYWORDS: Traffic simulator, simulation systems and processes, transportation, transport policy

1. Introduction

In the process of decision making related to the organization of traffic is required math (scientific) justification of the solution. Most theoretical calculation in terms of bandwidth. While known for simple and repeatedly proven formulas for calculating the bandwidth traffic light at the intersection operation is the calculation of bandwidth for non-standard situations, or when there is free movement of vehicles, it is often impossible task. Local decision makers need to have simple and effective tools that give reliable results. Such a tool may be road traffic simulator.

Traffic simulator that is used to illustrate the results of the experiment described in the article was made by the author of the article and has been repeatedly used successfully as a tool for illustrating the operation of complex signaling street and as a tool to simulate traffic at intersections.

2. The boundary conditions adopted

2.1 Boundary values for the experiment:
- [E] contractual vehicles (passenger vehicle idealized)
- in the amount of 1,400 vehicles per hour [E / h] to ensure supersaturation of road traffic on one lane.
- buses in an amount of 5 (measurement 1) or 15 (measurement 2) buses per hour.
- road section with a length of 1200 m bus stop starting and ending at the intersection of entering graniczonej example, by signaling street (roundabout - traffic roundabout) bandwidth to 886 [E / h].
- bus stop in two variants, with the need to enter the bus bay, and without entering the bus bay.
- Number of measurement series - after 30 for each test case.
Fig. 1. Simulation / base model

Fig. 2. Simulation - adopted the path of the bus
Fig. 3. Phase 1 / bus on the bus bay.

Fig. 4. Phase 2 / bus start up from the bus bay.
Fig. 5. Phase 3 / bus wait for stop of the traffic chain.

Fig. 6. Phase 4 / bus in the traffic chain
Fig. 4. Simulation - adopted the path of the bus

Fig. 4. Phase 1 / bus on the bus stop with out bus bay.
One is a motion simulation to estimate the buses off the benefits of moving from the bay tour bus, loaded with traffic on the road beyond the limits of theoretical and practical capacity.

The results of computer analysis of traffic can be very fast, easy and cheap method when making complex decisions in the process of organizing traffic. For example, motion simulation for the planned reduction in traffic, resolved the dilemma at the local level, the theoretical analysis at this level is difficult for obvious reasons.

In several cases the results obtained from the traffic simulator was applied to the adoption of specific design solutions for complex atypical cases.

2.2 Description of the experiment and simulation

2.2.1 Tool

For the analysis the author used motor traffic simulator TrafficLS. This program has a built-traffic model based on stochastic theory. In this case it is important that traffic model used and whether other models of motion are “better” or “worse” because for all conducted experiments in the article uses one and the same traffic model and the experiment was comparative in nature. So important was the quality of the experiment that every attempt was performed with identical initial data.

3. Description of result

3.1 Experiment results – interpretation

The experimental results clearly show a faster bus ride through the analyzed section of the road where buses do not leave the lane. Tests on the simulator in an unambiguous way to indicate this fact. Theoretical description of the results of the experiment beyond the scope of the article.

3.2 The legal aspect of the problem analyzed. Law, the Law on Road Traffic

Article 18

• 1. Driver, when approaching the bus stop marked (trolley) on the built-up area, is required to reduce speed, and if necessary stop to allow the driver bus (trolley bus), join the traffic, if the head of such a ve-
Computer simulation of traffic as a tool to facilitate decisions on the organization of traffic archives of transport system telematics

Vehicle direction indicator signals the intention to change lanes or to enter this in the bay on the road.

- 2. Control bus (trolley bus), referred to in paragraph 1, may enter the adjacent lane or on the road only after having ascertained that it will not cause danger to road safety. ITS.

4. Conclusion

The article showed that decision-making process concerning the selection of solutions for traffic engineering tools can be used to simulate motion. Simulator as a result of comparative experiment clearly suggests that the proposed solutions should be used. Theoretical justification for this choice is no longer needed. Of course you can based on experiments carried out for synthetic theoretical models, but these proposals go beyond the subject of the article. To demonstrate the attractiveness of the method should be noted that the preparation and interpretation of the results of the experiment does not require a profound theoretical knowledge as the article confirms that the visualization experiment, the simulator can be made for decision or review of that decision by people who do not have expertise in calculating the bandwidth traffic.

<table>
<thead>
<tr>
<th>n</th>
<th>Experiment name</th>
<th>travel time 1200 m [s]</th>
<th>difference ti-t1 [s] i=1..5</th>
<th>bus stop time tz [s]</th>
<th>facilitating the transit bus tp= - (ti - t1 - tz) [s]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Control sample without stopping the buses t1=</td>
<td>483,1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>the buses not use the bay (5 buses per hour) t2=</td>
<td>488,5</td>
<td>5,4</td>
<td>25</td>
<td>19,6</td>
</tr>
<tr>
<td>3</td>
<td>the buses not use the bay (15 buses per hour) t3=</td>
<td>489,8</td>
<td>6,7</td>
<td>25</td>
<td>18,3</td>
</tr>
<tr>
<td>4</td>
<td>the buses use the bay (15 buses per hour) t4=</td>
<td>522,3</td>
<td>39,2</td>
<td>25</td>
<td>-14,2</td>
</tr>
<tr>
<td>5</td>
<td>the buses use the bay (5 buses per hour) t5=</td>
<td>528,1</td>
<td>45</td>
<td>25</td>
<td>-20</td>
</tr>
</tbody>
</table>

Table 1. Results of the experiment