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SWOT analysis of the road cargo transport companies in Poland

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ABSTRACT
This paper gives an overview of some chosen aspects of the market recognition of road cargo transport services in Poland, assumed that there is a possibility of a change in the functioning of small and medium companies. The opportunities, threats, strengths and weaknesses of companies in the sector of hire or reward road cargo transport in Poland and in the EU-15 member states have been compared and the results of this comparison are shown in the SWOT analysis format.

KEYWORDS: hire or reward road cargo transport, SWOT analysis

1. Conditions of Polish hire or reward road cargo transport competitiveness

The opening of Polish economy and the increasing penetration of Polish market by foreign companies are responsible for the fact that Polish transport companies, if they are to survive and develop, have to undertake activities that will improve their competitiveness. The functioning of a transport company under the situation of constant changes of economic conditions which, due to a variety of reasons, take place in the market of transport services, means that the company is either capable of retaining its competitive advantage, or developing a new competitive advantage [4].

According to i.a. J. Burnewicz [2], K. Bentkowska-Senator and Z. Kordel [1], B. Kos [7], the competitiveness of a transport company depends on the following crucial factors:
- modernity of fleet vehicles,
- utilized infrastructure – its availability and quality,
- IT systems,
- qualifications of employees,
- organizational efficiency,
- marketing strategies.

The above conditions are shaped by the knowledge, skills, objectives specified by the company management, and financial capacity of a company. The mechanism of developing competitiveness by a transport company begins with an estimation of users of the offered transport services and the company image in the market. Potential customers compare the prices of services, their widely understood quality, and pay attention also to the company image and reputation.

The ability of a transport company to effectively function and extend its potential customers market for its services is restrained by many factors, which can be classified into internal ones, i.e. depending on the transport company itself, and external ones, which do not depend on the decisions made in the company.

Domestic competition of small and medium carriers who prevail in the Polish market mostly takes place in the sphere of prices for the services they provide, which is the most obvious factor of market competitiveness in this sector. A number of other factors, which are decisive for the selection of a particular provider of hire or reward cargo transport services by a customer, include the
quality of customer service, fleet and company credibility, and remain beyond the sphere of capabilities of small carriers. Undoubtedly, competing by means of prices is not and cannot be a long term market strategy of a company, especially if the business entity in question does not have enough financial resources even for its current activities.

A frequently utilized method of competing consists in offering customers a complex range of services, and constantly extending and perfecting this range. As a rule, small and medium companies do not have a range of services wide enough to compete with large companies. Usually, only companies with an established position can be afford providing professional transport services [10]. It demands a strong capital condition, modern management and compliance with quality standards, which makes it possible to compete in the European Union market in the future. A majority of carriers active in the Polish market are not able to face such challenges single-handedly. The presence of many small and medium carriers in the Polish market results in a situation when the offer of most entities is limited to providing customers with the simplest forms of services. The provided services can be classified as traditional and uncomplicated ones, mainly such as the transport and forwarding, while the storage or distribution is less frequent. In connection with Poland’s accession to the EU a gradual replacement of the services of road cargo transport by delivery chain management, common in the economically developed EU-15 countries is expected. This replacement can already be observed, although its degree is still rather limited. At present the competition between international carriers from the EU and from Poland is taking place in different markets, however, the strengthening of carriers who are active in Poland can be observed simultaneously with a dynamic expansion of Polish carriers into the European Union markets [8].

Changes in the economy reflected in transportation and services changes have a decisive impact on the evolution of focus in operations of companies active in that economy sector. Depending on the company organization and legal form, size, and operations extent, one can see the following new directions that occur in the services of road cargo transportation in Poland [14]:

- diversification of transportation companies’ operations – extension of the basic activity profile by all types of additional services, i.e. shipping, storage, customs, IT, and financial, up to, and inclusive of, comprehensive packages of logistic services offered to customers;
- introduction of state-of-the-art transportation technologies (innovation) or new types of transportation services using the existing infrastructure of transportation companies raising their effectiveness through the adaptation of services already offered to market requirements;
- focus only on the chosen basic services (which is the case of small companies).

The absence of steady contracts and looking for market niches are responsible for the fact that the carriers who belong to the sector of small and medium companies in the long run are unstable. Thus, in a natural way these entities which are weak with respect to their financial and organizational structure are eliminated from the market, and replaced by new, equally weak entities [1]. The functioning under uncertain market conditions and a still fiercer competition forces companies to look for strategies that would assure their survival in the market. An efficient way of facing the difficulties by companies, which assures their collaboration, seems to lie in their integration [9]. The path leading to a consolidation of Polish companies certainly ought to take into account the establishment of strategic alliances, agreements, and consortia. The establishment of a group of companies being mutually complementary with reference to the offered services would increase the chances for their development by improving the factors connected with organizational matters, capital, contracts, and leading to a decrease of incurred costs [10].

2. SWOT analysis of companies in the hire or reward sector of road cargo transport in the EU-15 member states and Poland

At present and in the nearest future small and medium transport companies in Poland have to search for their own way of surviving in the competitive and saturated market of transport services. However, taking into account the still more limited opportunities of carriers in this group, also with reference to a widely understood innovativeness of their offer and a lack of willingness in the business environment to undertake any consolidating activities, the future of the companies in question in most cases will be reduced either to being subcontractors or to functioning in market niches [16]. The absence of a protective umbrella of the state over these companies and their lack of skills in acquiring financial resources from the EU are undoubtedly among the factors which make the functioning of transport companies more difficult. Various aspects of their functioning, including those that have already been hinted at and some more, as well as potential opportunities and threats to their development, are shown in Table 1 in the SWOT analysis format.
Table 1. SWOT analysis of Polish hire or reward road cargo transport companies

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Weaknesses</th>
</tr>
</thead>
<tbody>
<tr>
<td>- The carriers are getting prepared for the growing competition with EU countries by gradual replacement of fleet vehicles by ecologically-friendly and more modern ones;</td>
<td>- Large dispersion of carriers, evidenced by the fact that the prevailing number of carriers are small companies (owning a single vehicle);</td>
</tr>
<tr>
<td>- Small transport companies are acquainted with manufacturing companies in the local market;</td>
<td>- A considerable majority of companies is managed by natural persons;</td>
</tr>
<tr>
<td>- The specialization of transport is growing due to investing in vehicles adjusted to specific types of cargo;</td>
<td>- No long-term transport contracts in small companies;</td>
</tr>
<tr>
<td>- The number of attestations required for specific types of cargo transport is growing, e.g. for transport of hazardous goods (ADR) or animals;</td>
<td>- Poor financial standing and low earning capacity of companies which makes it difficult to acquire capital;</td>
</tr>
<tr>
<td>- The system of financial services is growing rapidly; improving the access of companies to capital.</td>
<td>- Low level of education, inadequate level and inappropriate structure of vocational qualifications;</td>
</tr>
</tbody>
</table>

Opportunities

- Stimulation of trade with the EU countries; reduction of internal customs tariffs and trade barriers, as well as the tightening of economic associations;  
- An expected growth of demand for consumer goods from other countries will enliven the transport market;  
- Building modern warehouses, custom bonds and logistics warehouses in order to facilitate goods distribution;  
- Forwarders will look for carriers willing to deal with the transportation of LCL goods;  
- A consolidation of small companies will allow for their more effective and profitable negotiation of transport agreements with large companies;  
- A development of industry branches with higher processing levels (as one of the ways to enliven regions) will result in the increase in specialised transport services, mainly provided by small companies;  
- Improvement in the access of small and medium companies to external sources of financing (i.e. acquiring funds from the common capital market of Europe).  

Threats

- Lack of a decision center indispensable in a situation of a high demand for transport services provided by small companies;  
- Poor access of small transport companies to information and new technologies;  
- Forced cooperation of small transport companies (acting as subcontractors) with large logistic companies that have their headquarters in distant regions;  
- An considerable price increase of vehicles and transport equipment (including specialised equipment and vehicles) and price increase of fuels (due to the increase in the excise duty) would increase the costs incurred by Polish carriers and diminish their competitiveness;  
- When Polish carriers have to pay taxes at the same level as the carriers in other EU countries the cost of transport will rise considerably;  
- Polish carriers might be eliminated from some segments of the transport market by carriers from Eastern and Central Europe who can assure slightly lower costs of transport;  
- The expected concentration of logistic services will transfer the assumed lowering of costs to carriers dealing with a clean transport, i.e. small companies;  
- The risk of inadequate level of absorption of the EU aid.

Source: own work on the basis of [1]

On the basis of the market recognition of road cargo transport services, it is assumed that there is a possibility of a change in the functioning of small and medium companies, the major premises of such changes being the following:

- a growing inter-branch competition, which may cause:  
  - intensification of the consolidating tendencies which would make it possible to concentrate capital, expand the range of activities, and change forms of organization; this might be possible if we assume that the awareness of potential profits of the consolidation will grow; however, a change in the traditional way of conducting business activities will be a process gradually taking place over a number of years;  
  - improvement in service qualities as a basic condition for retaining competitiveness of Polish carriers; this necessity is conditioned by the level of transport services offered in other countries of the European Community and the current requirements of customers interested in such services;  
  - increasing the number of specialised vehicles (together with semi-trailers) as a response to the increasing share of highly processed goods in the total volume of production;  
  - a growing demand for attest enabling the transport of hazardous goods, perishable goods and animals;  
  - a change of the fleet structure: increasing the share of truck tractors with semi-trailers and reducing the share of universal trucks;  
  - an opportunity to acquire funds from the European Union.

The premises for the development of Polish market of transport services have a macroeconomic character: an increasing economic growth causes an increasing dynamics of growth of the road cargo transport sector, which is larger in Poland than in other countries of the EU-15 member states. The increase in turnover calculated in Polish zloty is achieved while at the same time the total quantity of transport services drops. It is expected that due to the systematic drop in transport demand of Polish economy after Poland’s accession to the EU the quantity of transport calculated in tonnes and tonne-kilometres will not grow; in the case of high dynamics of GDP it may be retained at the present level. Basic consequences of the EU extension for the Polish sector of road cargo transport boil down to tidying the market and accelerating its evolution. The conditions of competition are going to change gradually due to the transition periods that have been negotiated in the field of transport. The assumption is becoming confirmed that the EU extension would cause an increase in the trade turnover between the EU-15 member states and the new members; regardless of the falling transport demand of Polish economy an increase in the road transport was to be expected. Poland’s integration with the EU increased the competition in international transport and accelerated the process of
3. Problems of road transport policy in Poland

On the one hand, the joining of the EU structures by Poland increased the opportunities of Polish entities for functioning in the Union market, but on the other hand it made the national transport companies to face the challenge of meeting higher requirements and expectations, including the improvement in price and quality competitiveness [15].

From the point of view of transport policy it is important to create conditions for development of companies and their functioning according to the principles which are complied with everywhere in Europe, which entails the improvement in the quality of Polish transport and adjusting it to the standards and requirements obligatory in other countries which belong to the Community.

The basic objectives of Polish transport policy are in accord with the objectives of the European Union specified in numerous primary and secondary pieces of legislation and in the form of White Papers, of which the latest was published by the European Commission in 2001 under the title “Time to Decide” [19]. The fulfilment of several dozen postulates which it contains i.a. it is supposed to change the proportion of the share of road transport with reference to other branches of transport. This means that until 2010 the competition among particular branches has to be regulated and the branches have to be integrated, resulting in an effective intermodality.

A government document implementing the transport policy in accord with the EU recommendations in the field of assuring proper conditions for a lasting, sustainable development is the document specifying a long-term state policy on the subject, entitled “National Transport Policy for 2006-2025” (abbreviated as “PTP”). The directions of road transport development specified in this document refer especially to the vehicles infrastructure, investment planning, organizational modernization and traffic management. It also assumes that due to the differences in conditions of competition between road and rail transport, the development of intermodal transport will be financially supported by the state [1].

Simultaneously with the PTP, the Ministry of Infrastructure developed another document, entitled “National Strategy for Transport Development 2007-2013”. The road transport and problems associated with it were discussed under strategic objective no. 4: improvement in safety, and strategic objective no. 5: ecological sustainability.

Another project that was developed was entitled “National Development Policy 2007-2013,” and included five horizontal programs. One of these was entitled “Transport infrastructure” and encompassed two operational programs, such as “Road infrastructure” and “Transport Competitiveness”...

Table 2. A comparative SWOT analysis of companies in the sector of hire or reward road cargo transport in the EU - 15 member states and in Poland

<table>
<thead>
<tr>
<th>SWOT</th>
<th>EU</th>
<th>Poland</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strengths</td>
<td>- Higher efficiency due to: know-how in the field of transport, flow of information; - Utilizing the concept of intermodal transport.</td>
<td>- Low remuneration; - Determination and work commitment of drivers; - Acquaintance with local conditions; - Better communication skills in the countries of Central and Eastern Europe.</td>
</tr>
<tr>
<td>Weaknesses</td>
<td>- High working costs; - Language and cultural barriers encountered by drivers in Poland and other countries that freshly joined the EU structures.</td>
<td>- Older, less reliable fleets (mainly domestic ones); - Scarcity of financial resources; - Limited knowledge in the field of transport and logistics, as well as information and communications systems.</td>
</tr>
<tr>
<td>Opportunities</td>
<td>- Growing demand for transport services; - Further development of intermodal transport; Collaboration with Polish carriers; - Demand for ecologically-friendly fleet vehicles.</td>
<td>- Expansion of the market of transport and logistics services; - Collaboration with carriers from the EU-15 member states; - Intermodal transport; - Initiating relationships with the countries of Eastern Europe and Asia.</td>
</tr>
<tr>
<td>Threats</td>
<td>- Shortage of long distance drivers; - Growing remunerations, taxes and fees; - Permits.</td>
<td>- Competing with carriers from the EU-15 member states; - Growing tolls, taxes and fees; - Permits.</td>
</tr>
</tbody>
</table>

Source: own work on the basis of: [5]

systematization of the whole branch. The abolition of the prohibition of cross-border transport among the EU members and of the necessity of border checks lead to a growth in efficiency of international transport services provided by Polish carriers. At the same time their profitability was decreasing due to the rising prices of fuels and the introduction of road user fees [3]. Frequent provision of services at lowered prices results in a scarcity of resources for investments and development, and even for the replacement of the means of transport. Meanwhile, the carriers from Western Europe are perceived as entities implementing state-of-the-art technologies, being better organized and providing higher standards of services [6].

The opportunities indicated and not indicated above, strengths and weaknesses of companies in the sector of hire or reward road cargo transport in Poland and in the EU-15 member states have been compared and the results of this comparison are shown in the SWOT analysis format in Table 2.
These programs addressed particular development opportunities of the sector in question with regard to the relatively low degree of association with long-term processes of capital accumulation and pointed out the objectives to be achieved: extension and modernization of transport network.

As a result of alterations in the organizational structure of government institutions the distribution of tasks referring to the development of projects specifying the objectives and priorities of the economic policy also changed. The basic strategic document entitled "National Development Strategy 2007-2015" addresses the issues of transport in one of its five operational programs: "Infrastructure and Environment". Furthermore, another document entitled “National Strategic Reference Framework 2007-2013" (abbreviated as "NSRO") was developed and approved, supporting the economic growth and employment. The concepts of economic development taken into account in this document and resulting from the renewed Lisbon Strategy, as well as the relationships among the priorities determined by the Community Strategic Guidelines, are reflected in the strategic objective no. 3 of NSRO: "Building and Modernization of Technical and Social Infrastructure Crucial for Better Competitiveness of Poland".

It is rather disquieting that the references to road transport in the above mentioned documents focus mainly on the state of road infrastructure, its modernization and development. Meanwhile, the activity potential of the sector in question is limited by many other barriers, for instance a difficult access to the profession of a carrier and the particular market segments, the problem of extending the scope of services provided, restricted freedom of technological and organizational innovations, low dynamics of creating new places to work, limited improvement in the effectiveness of transport processes and a limited productivity growth of transport companies. Therefore, the new version of "National Strategy for Transport Development 2007-2013" ought to take into account a much wider scope of problems connected with the road transport policy, and also encompass some chosen aspects of the sphere of hire or reward road cargo transport.

**Bibliography**

Lighting device parameters influence on signal circuit safety in interlocking systems

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ABSTRACT  
Signal circuits are an important part of the interlocking system. The main role of the signalling circuit is to switch the required signal aspects and signal checking. A signal is an interface between the interlocking system and a driver of the railway vehicle. Light bulbs are mostly used as a light source in most types of interlocking systems. It is possible to think about alternative light sources within the context of modernisation of the interlocking systems. The use of alternative light sources using must not cause signal circuit safety degradation. The article deals with problems of light bulbs replacement for another light source in AŽD 71 type relay interlocking in the Railways of Slovak Republic.

KEYWORDS: signal circuit safety, interlocking system, colour light signal, alternative light sources

1. Introduction  
Relay interlocking systems were built for train control at railway stations in Czech and Slovak railway circumstances between 70-ties and 90-ties of the last century. AŽD 71 type relay interlocking systems were mainly used at railway stations on main lines. This type of interlocking equipment was produced and installed by the Czechoslovak company Automatizácia železničnej dopravy (Automation of Railway Transport), now called AŽD Prague. Many railway stations are now controlled by this system in Slovak railways.

AŽD 71 type relay interlocking system is based on the technique of own safety on failure – fail safe. NMŠ type relays are used as a basic construction component in this system. This type of relay belongs to the safety relays group. All safety relevant functions of this signal box are realised and checked by a part called an executive group based on this type of relays.

Signal circuits are very important part of the executive group. The main function of these circuits is to switch on individual signal lamps to create necessary signal aspects and to check lighting of them. In the case of any malfunction the signal has to light on a less allowing signal.

Management of Railways of the Slovak Republic considers an idea to replace signal bulbs used as a light source in colour light signals by other energy-saving light sources. Parameters of new signal lamps must not make the safety of signal circuits worse.

2. Signal circuit of AŽD 71  
A schematic representation of the signal circuit used in AŽD 71 system is shown in Figure 1. The signal circuit consists of OM-2-60 type supervisory light relay ($xS$), fuse ($F$), ST-3/R type signal transformer ($Tr$), signal bulb 12 Volt / 20 watt, limiting resistor 100 Ω ($R$), wires and a connecting cable between the signal box and light signal.
The circuit is powered by AC voltage 230 V/50 Hz in a daytime lightning routine or 160 V / 50 Hz in a night lightning routine.

The scheme shown in Figure 1 is identical for all signal lights on a signal device. The dashed line block represents control circuits for individual lights.

Signal aspects shown on a signal device are defined by signal rules of ŽSR [1]. In general a signal aspect can consist of one or more colour continuously or intermittently lighting lights. In the case of intermittent light the system can use slow flashing with a blink frequency of 0.9 Hz (54 cycles per minute) or quick flashing with a blink frequency of 1.8 Hz (108 cycles per minute) [2].

2.1. Signal circuit states

The following situation is considered to be the basic operating state: a signal lamp is without failure, the circuit is powered by nominal power voltage specified for the daytime or night light mode of signal lights. The work current flows in the circuit, the signal bulb is on and the circuit current controls the light relay attraction. The relay operation indicates lighting of the signal light. The following situations are considered failure states:

a) the signal light does not light, but the supervisory light relay operates (relay armature up) and indicates lighting of the light;

b) the signal light is flashing without command to flash and the supervisory light relay indicates a steady light;

c) the signal light is flashing or lights steadily, but the supervisory relay is released and so indicates a lightless state of signal.

The failure state according to point a) is potentially unsafe state. It is a possible situation in which a more allowing aspect is on the signal than informed by the feedback circuit. A similar situation is in the failure state according to point b) – flashing lights can be interpreted as a more allowing aspect.

The design of signal circuits in AZD 71 type relay interlocking gives a possibility to react to the state according to point c). This state is not unsafe then.

The origination of a failure state is influenced by several factors – an important factor is the length of supply cable wire. A cross capacitance and longitudinal impedance are characteristic parameters of the cable. In the case of cables used in signal circuits we can transform the longitudinal impedance to longitudinal resistance. The cross capacitance and longitudinal resistance of the supply cable vary with increasing length of the cable. It is necessary to evaluate the maximum possible length of the supply cable. Standard [3] evaluates this length as 4 km. If the length of cables exceeds this value, the following failure states can occur:

- A signal bulb filament will burn, but the length of supply cable is too long, so the parasitic capacitance of the cable has a value sufficient for the circuit current to hold on the light relay armature up. So the signal bulb does not light, but the light relay signals that it does.

- At the end of signal circuit (e.g. primary or secondary winding of signal transformer, lamp-socket …) a short circuit will occur. In normal circumstances the fuse (F) at the power end of the circuit should be broken. But if the supply cable is too long, the longitudinal resistance of cable reduces the current value and the fuse will remain without any reaction. And again – the signal bulb does not light, but the light relay signals a correct state.

3. Bulbs replacement

There are more practical reasons to replace the older construction of signal lamps which uses bulbs as a light source:

- interlocking system modernisation,
- energy consumption decreasing,
- signal lamps life extension,
- signal lamps optical parameters improvement,
- maintenance reduction.

Modern interlocking systems often use the light emitting diodes (LED) as a light source in signal lamps. The main advantage of LEDs compared to bulbs is the energy saving and a longer life. The volt-ampere characteristic of LEDs is different from the V-A characteristic of a signal bulb. It is possible to design a circuit using LEDs which will simulate the V-A characteristic of a signal bulb. The advantage of this solution is a simple replacement of a bulb by an LED lamp. In this case no modifications to the signal circuit are necessary. The main disadvantage of this solution is the elimination of one of two LEDs advantages – energy saving.

Another possibility is to use a lamp with a different characteristic; this solution requires the signal circuit modification. One of many reasons for this modification can
be a different method of LEDs lamp lighting checking. These modifications of signal circuits are more expensive than the way mentioned above.

The basic difference of lamp using LEDs is the fact, that an LED lamp needs an additional electronic circuit, which will simulate bulb properties. This circuit has to be powered. Because individual powering is impossible, additional circuits will use the energy dedicated to bulb powering.

The safety of signal circuit is based on reliable detection of non-luminous state of the signal lamp. In the case of any failure in an LED lamp the energy consumption of electronic circuits in the lamp must be low enough. The current via this circuit must not lead to the signal light relay operation – this is the condition for a safe reaction of relay to non-luminance state of the lamp. The electronic control circuit in an LED lamp has to be able to fully turn off all LEDs in the case of a defined number of LEDs failure or of the LED control circuit failure. An acceptable number of non-luminous diodes has to be defined in accordance with the signal lamp optical properties. Otherwise it is possible to have an ambiguous identification of signal aspect by the driver.

4. Analysis of lamp replacement effect on signal circuit

In the case of implementing functions described above with a defined safety level, it is necessary to define the maximal acceptable current level flowing in the circuit in the non-luminous state of lamp. In ideal circumstances the current should be 0 A. In reality, the current must cover the energy consumption of electronic control circuits of the signal lamp. The analysis should show, if the LED lamp has the same influence on the signal circuit as the original bulb.

Verification of the influence on circuit properties of safe reaction of signal light relay to expected lamp failures can be realised using a computer simulation or practical measurement.

4.1. Circuit simulation

For simulation of the light relay response to the current flowing in the circuit we can use a model based on cascade matrices. The cascade matrices model the transmission properties of particular components of the circuit. We can substitute each component of the circuit by an equivalent circuit which represents the electrical properties of the component.

Supervisory light relay can be substituted by a coil representing serial connected winding inductance \( L_R \), winding resistance \( R_R \) and limiting resistor \( R \).

Supply conductors can be substituted by equivalent T-network which represents the primary parameters of line wiring \( R_K \) – longitudinal resistance of cable, \( C_K \) – leakage capacitance of cable. The signal transformer can be substituted by equivalent T-network with different coefficient meaning – T-network of the transformer represents primary winding impedance \( Z_1 \), secondary winding impedance \( Z_2 \), leakage reactance and iron loss \( Y_3 \).

The signal bulb or LED lamp can be substituted by a resistor which represents their input impedance \( Z_Z \). Fig. 2 shows the equivalent scheme of the signal circuit.

It is possible to compute values of cascade matrix for each component of the equivalent scheme. The computed values can be used then in the simulation of circuit. The values of current flowing through the winding of signal light relay are key values for the assessment of failures influences on the signal circuit safety. From this point of view

\[ U \quad A_R \quad R \quad R \quad \frac{R}{2} \quad \frac{R}{2} \quad C_K \quad A_C \quad A_T \quad Y_3 \quad Z_1 \quad Z_2 \quad Z_Z \]

Fig. 2. Equivalent scheme of the signal circuit

Source: [own work]

\( U \) – power voltage
\( A_R \) – cascade matrix of relay
\( A_C \) – cascade matrix of cable
\( A_T \) – cascade matrix of signal transformer
it is possible to transform the equivalent scheme shown in Fig. 2 to the common cascade matrix (AC). For this matrix we can compute the input impedance ($Z_{in}$). When we connect power voltage $U_n$ to this impedance the current flowing through this impedance is the same as the current through the relay winding. [4]

The progress of cascade matrixes transformation is shown by Figure 3.

The software suitable for simulation of services and failure conditions is MATLAB (MATrix LABoratory). MATLAB is a programme which allows matrix computing, modelling and circuits simulations.

4.2. Circuit measurement

The influence of current flowing in a signal lamp on signal light relay operation can be examined by measurement. The measurement gives us a possibility to use real components of the signal circuit with the exception of supply conductors. The cables length affects correct operation of the circuit as indicated above (see chapter 2). It is very complicated to use a full length of cable in laboratory circumstances. For these reasons we use simulations of supply conductors by equivalent T-network.

Figure 4 shows the scheme suitable for measurement and analysis. The figure depicts a possible substitution of signal bulb by an LED lamp. Failures of the LED lamp were simulated by a potentiometer because it was impossible to induce failure state of the LED lamp during measurement.

5. Results analysis

For analysis acceptance it is necessary to set the most unfavourable conditions. These conditions can be as follows:

- Because of a failure the LED signal has moved to a non-luminous state, but the current consumed by electronic circuits of the lamp is flowing through the circuit. The state is more unsafe than a failure state after turning on, the signal will not move to the luminous state. The current necessary for the signal relay operation is higher than the relay release current.
- The supply voltage of signal circuit is maximal. As the maximal we can consider the voltage for daytime supply mode increased by 10% tolerance.
- The load is connected to signal transformer terminals on which the current through the secondary transformer winding will have the most unfavourable effect to relay release.

If in these conditions the signal light relay will not release, the failure state can be considered to be an unsafe state. If in these conditions the relay releases, the state is safe.

Figure 5 shows the results of analysis under the mentioned conditions. The curves show the current flowing in signal light relay winding versus the power lead length. The black curves (the lower group of curves) represent the current via relay in the failure state – filament broken. The grey curves (the upper group of curves) represent the current via relay in the failure state of LED lamp in circumstances that the electronic control circuits of LED lamp consume maximum 150 mA. The graph shows the signal light relay release current value too.

As a limit length of the power leads we can assume the length, where the current via the relay is below the relay
release current value. In the circuit measured the limit length of the supply cable is 7 kilometres.

The figure shows, that if the length of supply cable is set by standard [3], the light signal supervisory relay reliably releases in the worse operational circumstances.

6. Conclusions

The modernisation of interlocking gains importance not only in national but in international conditions, too. The decision on partial or full modernisation of interlocking systems is mainly conditioned by economic standing of railways.

The preservation of original safety integrity level is an important aspect in the case of partial modernisation of interlocking system.

The article deals with properties of modern LED lamps construction dedicated for replacement of older signal lamps with bulbs. The construction of these lamps could improve first of all optical properties and extend the service life. The construction must not make the safety of signal circuit worse.

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ABSTRACT
This paper attempts to offer the reader a consistent overview of the flight inspection in the Slovak Republic and the centre of excellence of aviation at the University of Žilina. For the flight inspection, special items have to be taken into consideration when selecting the tested aircraft.

KEYWORDS: accuracy, aircrafts, air transport, flight inspections, ICAO, CNS, ATM safety

1. Introduction to flight inspection
The Aviation System Standards must identify specific requirements based on their operational needs. Appropriately equipped aircraft and helicopters, from service providers or other sources, may be used when required to complete flight inspection requirements. The general characteristics of a flight inspection aircraft should be as follows:

- Equipped for night and instrument flight.
- Sufficient capacity for a flight inspection crew, observers, ground maintenance and/or installation personnel, and required electronic equipment with spares.
- Sufficient range and endurance for a normal mission without reservicing.
- Aerodynamically stable throughout the speed range.
- Low noise and vibration level.
- Adequate and stable electrical system capable of operating the required electronic and recording equipment and other aircraft equipment.
- Wide speed and altitude range to allow the conduct of flight inspections under normal conditions as encountered by the users.
- Appropriate for modifications for flight inspection of new and improved navigation services.

For the flight inspection, special items have to be considered when selecting a test aircraft. The aircraft must have a cabin size where all the equipment can be installed as well as have seats for the inspection personnel that can be easily adjusted. Besides the normal inspection equipment, one has to take into consideration that the systems and the cabin need air conditioning and sufficient electrical power. Certain hot regions, such as the Middle East, require more power for cooling. This causes that generators are required with sufficient electrical power both at 115 Volt AC, 400 Hz and for various DC power supplies (12V, 24V). Additionally, standby power equipment has to be installed in order to make it feasible to shut down the inspection system or to terminate the flight inspection at a defined point if the normal power breaks down.

Another point of concern for the system development is the aircraft skin, because a lot of antennas have to be mounted outside the aircraft and these must not be influenced by each other. The cable channels for the antenna cable, as well as the power and signal cables, have to be separated sufficiently. This normally implies a total separation of aircraft basic instrumentation and flight test instrumentation, which cannot be done completely because some receiver antennas cannot be mounted twice on the aircraft. The aircraft engines may influence the antennas, computers, or other flight...
inspection instrumentation in terms of both electromagnetic interference and vibration. The aircraft itself must be able to reach altitudes up to 10,000 feet at undetermined velocities.

The operation in extreme weather conditions is normally not a basis for selecting an aircraft, but inspecting radio navigation systems in countries near the equator or in very hot and moist or humid areas need special equipment, including, for example, water for the inspection personnel. In the arctic zone, the equipment must work under very cold weather conditions.

Different types of flight inspections – a periodic inspection, site evaluation, commissioning, reconfiguration – have naturally different requirements for the aircraft type and workload. In addition, the type of radio navigation system that has to be checked determines the type of equipment required onboard the aircraft. The number of radio navigation systems that must be flight inspected for a country is another decision basis on which to select one or more aircraft for the flight inspection. As noted previously, some countries do not have their own flight inspection aircraft and crew. These countries have agreements with, for example, the United States to perform the flight inspection. The next table shows the types of aircraft used for flight inspection in different countries.

This is only a small list of countries and aircraft used for flight inspection.

### Table 1. Types of aircraft in different countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Type of aircraft</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>Convair 580, Sabreliner 80, Sabreliner 40, Beechcraft F-90, Beechcraft BE-300, British Aerospace BAe-125-800.</td>
</tr>
<tr>
<td>France</td>
<td>ATR 42</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>HS 748 Series 2A Model 238</td>
</tr>
<tr>
<td>Netherlands</td>
<td>Fairchild Metro II</td>
</tr>
<tr>
<td>Germany</td>
<td>Beechcraft Super King Air 350</td>
</tr>
<tr>
<td>Slovak Republic</td>
<td>Let L-410 UVP-E</td>
</tr>
</tbody>
</table>

Source: [own work]

### 2. Flight inspection in Europe

The flight inspection work is a governmental job. Therefore, each country tries to form a unique flight inspection group. However, some of the countries are very small and have only a few installed radio navigation aids. Each state has its own policy for the flight inspection. As examples, a short description of the flight inspection in Great Britain and Germany follows.

#### 2.1. The Flight Inspection in the United Kingdom

In Great Britain, as in most other countries, the flight inspection is split into military and civil parts. The military flight inspection group is in Boscombe Down near Salisbury. They only test the military radio navigation systems, ground installations, and aircraft systems. For the inspection and testing work they use special equipment adapted to the required accuracy. All military aircraft are cleared to CAT III ILS. For the future landing system, the MLS and DGPS systems would be tested. The main interest for the military groups is the TACAN radio navigation systems because they are also used for tanker aircraft. For this usage the electromagnetic influences have been evaluated and removed. As described for the French military inspection group, in Great Britain also the carriers must be flight inspected.

The civil flight inspection group has its base at Teesside airport and is named CAA (Civil Aviation Authority). Since 1992 this group has been the only civil organization approved to carry out flight tests on radio navigation aids in the United Kingdom.

Presently the CAA delivers their service to each customer needing flight inspection. The CAA uses two HS 748 Series 2A Model 238 turboprop flight calibration aircraft. The inspection equipment was defined by the CAA itself in 1969 and the first redefinition took place in 1987. In 1990 the new system has started working and uses a Hewlett Packard HP9000 computer for the calculation work. A console and a graphical display are the main input and output devices for the system together with a printer, an optical disk, and a 32-channel analogue recorder. The radio navigation receivers transmit their data to the main computer via an RDE (remote data exchange) and a CDE (central data exchange). Each RDE can collect 52 parameters in parallel with the aircraft equipment. Additional radio navigation receivers are installed for the inspection system. Because the general aviation uses mainly two different ILSNOR receivers (BENDIX RNA 3 AF and COLLINS S /RV4), these receivers are also installed in the inspection aircraft to evaluate possible differences between these receivers. The inspection aircraft is also equipped with all other radio navigation receivers as well as with two MLS receivers. For MLS inspection a BENDIX ML301 receiver is installed. The reason for installing a MARCONI CMA2000 receiver relates to special problems during the inspection of the London City Airport.

To calculate a high accuracy flight path, an infrared tracking system MINILLIR has to be installed at the inspected airfield. With this radar and a link to the onboard system, the position-fixing equipment can fix the position to within 23 cm and 0.003 degrees of angular
displacement. They can also simulate all inspection flights on their ground system, which is equal to the airborne inspection system. Therefore special effects and errors can be analysed on ground.[1] The CAA has checked ILS, VOR, DVOR, DME, MLS, DMLS, MADGE, TACAN, NDB, SSR, MSSR, SRA, ADSEL, and DABS. Naturally they are also involved in the use and inspection of GPS and DGPS. In the UK, the ILS has to be flight inspected twice a year and about 52 DME and VOR stations must be flight inspected as well. The CAA does the flight inspection for the UK and Ireland.

The following organisations are approved by the CAA to provide Flight Inspection in the UK.
- Cobham Flight Inspection Ltd
- Flight Calibration Services Ltd

Cobham Flight Inspection Ltd are approved to flight inspect the following navigation facilities:
- Instrument Landing Systems (ILS) CAT I, CAT II and CAT III
- Microwave Landing Systems (MLS)
- Distance Measuring Equipment (DME)
- VHF Marker Beacons
- Non-Directional Beacons

Flight Calibration Services Ltd are approved to flight inspect the following navigation facilities:
- Instrument Landing Systems (ILS) CAT I with a nominal Glide-path Angle between 3 and 3.6 degrees.
- Distance Measuring Equipment.

2.2. German Flight Inspection

Until 1993 the German civil flight inspection service was done by the GmFS at the German Air Force field at Lechfeld. In March 1993 a future flight inspection organization was presented to the DFS (Deutsche Flugsicherung), and in 1994 the new DFMG (Deutsche Flugmessgesellschaft) was founded. This private company is a Joint Venture between the DFS and AERODATA. The aim for this cooperation was to reduce the costs of flight inspection in Germany and to increase the efficiency.

The operating base for the flight inspection company changes from Lechfeld to Braunschweig where the AERODATA, the German Federal Aviation Authority, a pilot pool, and 24-hour service of a relatively small – but efficiently operated – airport are situated. The aircraft type changed from a HS748 to a King Air 350. In 1995, the new flight inspection system (FIS) produced by AERODATA, and using GPS as a reference system, was installed into the two King Air aircraft. The instrumentation and installation of the flight inspection system as well as the procedures for flight inspection were changed to improve the efficiency and accuracy of the whole system.

In 1996, preparations for the certification according to ISO 9001 began with the objective to optimise the processes of the DFMG and, if required, to make them transparent to certification authorities and customers. The work began with
- an analysis of the actual situation,
- the development of a quality management handbook,
- a benchmarking process.

These initial activities were to be completed in 1998. A completely new task for the German flight inspection organisation was the marketing of flight inspection services. First positive results were achieved by providing flight inspection services in Switzerland and Austria, the Netherlands and Luxembourg, in Spain, Macedonia, Lithuania, Kiev, Sofia, Bucharest, Macau, Kuwait, Yemen, Sudan and Egypt, and, of course, in Germany.

On 1 October 1997, swisscontrol became a shareholder of the DFMG. At the same time, the company name was changed to FII Flight Inspection International GmbH. On 1 January 1998, Austro Control also became a shareholder of FII. With their accession, both countries gave up their own national flight inspection organisations. [7] So the FII has three shareholders: AERODATA, swisscontrol and Austro Control. The DFS has close connections with the FII on the basis of a cooperation agreement and can thus be regarded as if it were, de facto, a shareholder. [2]

2.3. The Flight Inspection in the Slovak republic

Flight inspection is performed with modern AERODATA AD-FIS-10 Flight Inspection System capable to flight inspection of:
- ILS CAT I-III
- VOR
- DME
- NDB
- Radars including SSR
- VHF Communications
- PAR
- PAPI

Flight Inspection System Consists of:
- AD Computer
- MO Storage unit
- 2 Special Flight Inspection Navigation Receivers RNA34AF
- 1 Modified DME interrogator
- 1 Modified ADF receiver
- 1 Modified SSR transponder
- Oscilloscope
- Spectrum analyser
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Reference system:
• On-board GPS receiver
• DGPS ground reference station AD – GPSREF – 4
• Laser tracker Aerotrack IBEO Lasertechnik

The ground reference station was designed to receive GPS signals and to transmit GPS data to the airplane for DGPS corrective calculation (GPS errors – atmospheric delays, multipath…). The GPS receiver is a high precision stand-alone 12 channel receiver by NovAtel, and is used for L1 frequency 1575.42 MHz C/A code. [3]

The reference station must be built-up exactly at the surveyed position. An improved precision of flight inspection necessary for flight inspection of the ILS is achieved by using a laser tracker. The laser tracker is a highly dynamic – polar locating system used to automatically and continuously determine the position of the reflector placed at the nose of the airplane during the ILS calibration measurement. The laser tracker provides the elevation, azimuth and range information of the approaching aircraft. To avoid a possible lack of precision, the laser tracker must be installed on a solid ground near the threshold of the runway. To define the horizontal reference for all measurements, the laser tracker uses one of the reference reflectors installed at a defined position. If flight inspection with a laser tracker support shall be performed, the location of the laser tracker points, the reference reflector and of all navigation aids on the airfield must be known in the threshold coordinate system. All these parameters can be determined with an airfield survey. Once an airfield survey has been performed and all distances have been evaluated, the laser tracker and reference reflector must be built-up at the exact points for all future inspections.

The measuring range of the system is better than 13 km in good visibility. Fog, rain and snow, as well as steamed up reflectors, will of course reduce the range. However, DGPS technology enables to reduce the required distance of tracking by laser down to approximately 4 km. [4]

2.4. New Research Aircraft at the University of Žilina

This chapter describes our structural funds project oriented at flight inspections systems and the air transport environmental impact. The Flight Inspection mission is comprised of many documents, for example ICAO DOC 8071 vol I, and FAA TI 8200.52.

Technical Requirements

**Performance**
• ICAO Document 8071
• FAA Flight Inspection Manual OA P8200.1
• UK CAA CAP 670

**Capability**
• Precision Approach: ILS, MKR (Up to Cat III), MLS, SCAT-1, LAAS, GBAS
• En-Route / Approach: VOR, DME, NDB, TACAN, Loran-C, VDF, UDF, RNAV/ FMS, WAAS, SBAS
• Visual: VASI / PAPI
• Communication: VHF, UHF, HF, SATCOM
• Radar: PSR, PAR, SSR, MSSR

**Positioning Reference**
• Automatic Position Reference System (APRS) DGPS/INS/LRF
• Carrier Phase Measurement DGPS-RTK
• Stand-alone GPS or Galileo
• Digital Radio Telemetry Theodolite
• Interface capability to any digital, analogue or manual Position Reference
• Digital maps
  Mechanical design
• Modular and Portable
• Quick disconnect to smaller sections of less than 50 Kg.

3. Conclusion

The improvements in satellite navigation systems like GPS, GLONASS and GALILEO with regard to coverage, accuracy and reliability have cut down the further development and implementation of the new Microwave Landing System MLS. But the application of global navigation systems as the only means of navigation to long range, terminal area and landing is still not yet completely solved. Among others, the most problematic potential risk is that of intentional interference. Thus, most of the conventional navigation systems like INS, VOR, DME and ILS will endure for quite a while.

In this report the function of the conventional radio navigation systems and the problems for testing these systems are described. Especially the different error sources for the en route and terminal area navigation systems are discussed. One of the chapters shows the main radio frequency problems: coverage and multipath and the different measurement methods for these errors. A description of the flight test procedures and flight test methods shows the state of the art for the flight inspection of the actual generation of radio navigation systems. The flight inspection systems and the flight inspection aircraft of different countries used for the testing of radio navigation systems are also outlined. The flight inspection policy changes in many countries, so in this report the authors can only describe their known actual situation of flight inspection policy briefly.

"Flight inspection in a world of change" was the title of the ninth flight inspection symposium and this title characterizes very precisely the problems of flight inspection. Up till replacement the different radio navigation systems like DME, VOR, TACAN, OMEGA, LORAN-C, ILS and MLS have to be inspected.

In the future more and more of these systems will be replaced by the GPS system. Therefore this report describes the function and problems of the GPS and the add-ons like DGPS, LADGPS, WAAS etc. The satellite navigation systems also enable considerable improvements to the flight inspection systems. New systems equipped with differential mode GPS using carrier-phase positioning achieve real-time on-line flight path measurements with errors below 20 cm only. For measurement purposes the mentioned risks of the GNSS are of no significance. If interference occurs the measurements can easily be repeated. [6]

Modern flight inspection systems have reached a higher standard regarding accuracy and automation. Thus, few improvements can be made in the near future.

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Bibliography

Reducing the Impact of Stroboscopic Effect on the Results of Vehicles’ Plate Recognition Using Super-Resolution Techniques by Non-Coherent Camera Triggering

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ABSTRACT
The use of super-resolution algorithms can increase the resolution of image subject to further analysis in relation to the physical resolution of the camera recording the video sequence. A typical recording of such sequence is done with a fixed time interval (pre-determined number of frames per second). This can cause the shift of the plate image for subsequent frames by the total number of pixels, resulting in inability to take advantage of super-resolution algorithms that require shifts or rotations by a fractional part of pixels both vertically and horizontally. A possibility of reducing the impact of this effect by non-coherent triggering cameras is suggested in the paper.

KEYWORDS: register license plate number recognition, super-resolution, camera triggering

1. Introduction

Register License plate recognition is one of the most typical tasks performed by the machine vision systems used in the transport domain [1]. Such systems may be used for various purposes, not only for the identification of the vehicles that violated traffic regulations. Some other applications are the automatic control of parking gates and barriers, automatic accounting and fleet monitoring in the storehouses etc. Presently, such recognition is often used ad the are many various applications of different methods based on the digital image processing and machine vision.

The recognition task is usually implemented as consisting of several stages performing a decomposition of the problem into smaller and simpler parts. The first task is related to the selection of the vehicle’s shape from the image. For this purpose the background estimation techniques may be used, which are based on the analysis of the differences between the consecutive video frames. In order to eliminate the influence of noise, only the pixels with colors differing from their equivalents in the previous frames more than by a specified threshold are assigned as representing the vehicle.

This part of the process can be implemented without any additional complicated algorithms, since the knowledge of the exact shape of the vehicle is not necessary.
The second task is to find the recognition plate on the image with eliminated background. This stage is quite complex and usually belongs to the most difficult ones. Since the recognition tablesplates can be placed in various positions, not necessarily in the central part between the light, wrong results may be obtained. Problem may occur due to changes of the lighting conditions, presence of a dirt on the tableplate etc. Nevertheless, in many algorithms the central position of the tableplate is assumed in order to speed up the process of its detection.

The proper detection of the register license plate is necessary for its extraction from the image, so the further processing can be performed using only a fragment of the image representing the plate.

In many countries there are some regulations related to the main types of the register license plates allowed for use as well as some additional types. They can be characterized as containing one or two rows of symbols, usually alphanumerical, with various density. Before the recognition of each symbol it is necessary to determine the type of the plate. Since the symbols are located in the specified places for each type of the plate and they are well separated, the image analysis procedure allowing proper detection and division of the image into the fragments representing each symbol is not complicated. For this purpose, even the binary image analysis and morphological operations can be successfully applied.

After the detection of each symbol the smaller images representing each of them are analyzed separately using the pattern recognition algorithms. For this purpose a number of various methods can be used, such as the comparisons with patterns, shape analysis based on graphs, statistical algorithms and soft computing techniques (neural networks, evolutionary algorithms, fuzzy logic).

Since the symbols are standardized by some norms, the most of such algorithms can lead to good accuracy in practical applications, also for contaminated images (bright and dark spots, presence of noise, blur).

The symbols recognized by one of the algorithms mentioned above are then combined into the string representing the recognized plate number which can be further verified in some of the systems e.g. using the connection with a database.

### 2. The influence of resolution and super-resolution approach

The recognition task is relatively simple if the high resolution images of register license plates are available. Assuming the camera is located far from the road, even for the high resolution cameras the number of pixels representing the register table is low. In such situations neither the typical recognition algorithms nor a human cannot recognize the number properly.

One of possible solutions is the use of the narrow-angle lens but it is worth noticing that such approach leads to the limitation of the working area of the system. The application of higher resolution cameras may be financially inefficient, especially of some cameras are already mounted. Besides, in such case the requirements of the system’s operator usually increase, so there is always a need of a better quality and better accuracy.

The increase of the amount of data which can be used for the plate number recognition corresponds to the increase of the physical resolution of the analyzed image. One of the possible solutions is the increase of the number of cameras (preferably identical ones) but the cost of such system is relatively high and the final result depends on many factors such as e.g. relative locations of the cameras [2]. Another idea is the use of partially unstable single camera in order to obtain random shifts of consecutive frames but this approach is troublesome and increases the computational cost of background estimation.

Instead of the use of a single image for the plate number recognition (or several cameras) a sequence of images can be used, even acquired with lower resolution (many cameras offer such functionality). Using such video sequence with the same element (register license plate) visible on each frame, the application of the super-resolution algorithms is possible, similarly as for the other configurations described above [3-7]. As the result a single high resolution frame is obtained. An essential advantage of such approach is the fact that the resulting image is achieved with increased physical resolution in contrast to standard interpolation methods which artificially increase the number of pixels, which do not contain additional information.

![Fig. 1. Example of a high resolution image containing a fragment of a register plate and resized low resolution one. Source: [own work]](image-url)
The video sequence used by the super-resolution methods should meet several conditions. The first requirement is related to the relative positions of the camera and the object, which should differ for each frame. Assuming the motionless camera, the object should move, so stopping the vehicles is unnecessary. The best results can be obtained for random disturbances of relative locations with uniform distribution. The consecutive frames should also have similar brightness and colors and the number of them is also very important: much better results can be obtained using e.g. 10 frames instead of 3.

The changes of the scale for the input images are allowed, but the super-resolution algorithm has to perform an additional scale matching in that case. Some limited affine deformations of the image is also allowed, but it increases the total amount of computations [8].

Acquisition of the video sequence containing the register license plate in motion is usually done by the industrial cameras. Some more advanced cameras are equipped additionally in the mechanism of synchronic triggering. Assuming the moving vehicle and a relatively short video sequence (several frames) a constant shift of the plate in consecutive frames may be possible for some vehicle’s velocities depending on the geometrical configuration of the camera and the vehicle’s motion path. Such an phenomenon is similar to the stroboscopic effect and causes poor matching within the super-resolution algorithm, especially in the vertical direction. In such case the final effect of the super-resolution procedures may be unsatisfactory.

For the reduction of the impact of the stroboscopic effect described above, the random sampling in the time domain should be used. Assuming that the time when the register license plate is visible is long enough for the acquisition of several frames needed by the super-resolution algorithm, a slight decrease of their number can be made without significant influence on the final results. In such situation the triggering for each frame should be delayed by a random period leading to the non-coherent (asynchronic) triggering. The only limitation is the possibility of automatic camera’s external triggering, but such additional input is common in most presently used models.

### 3. Experiments and results

In order to verify the correctness of the proposed approach some tests have been performed using some synthetic images containing random combinations of two letters and five digits, what is typical for most register license plates in Poland. A number of images have been rendered and four exemplary ones are presented in Fig. 2. The physical resolution of the images is 600×200 pixels.

In order to simulate the camera located far from the road the images have been down sampled to 30×10 pixels and blurred as well as contaminated by Gaussian noise. Zoomed resulting images are shown in Figs. 3 and 4.

For each of the test images four types of sampling, simulating the movements of the register plate in the video sequence, have been used:

- **uniform** – the random translations by one or more pixels without any fractional parts (synchronized camera triggering),
- **partially random** – 10% random vertical random shifts are allowed (simulation of the movement towards the bottom part of the image),
- **partially random in two directions** - 10% random vertical and horizontal random shifts are allowed (almost synchronized triggering),
- **random** – any shifts in two directions are allowed (asynchronic triggering of the cameras).

The assumed model of contaminations contains the Gaussian noise simulating the distortions on the plate e.g. related to the presence of dirt, snow etc. The blurring convolution filter is used for the simulation of further decrease of the resolution (4 pixels moving average filter is applied), which may be related e.g. to air trembling, blur on the CCD or the decrease of the optical density. The additional Gaussian noise is also used in order to simulate the acquisition (measurement) noise.

Apart from these distortions another pseudo-random number generator of uniform distribution is used in order to simulate the random changes of the sampling period.

![Fig. 2. Example synthetic high resolution images used in our experiments](own work)

![Fig. 3. Example low resolution images used in our experiments](own work)

![Fig. 4. Example low resolution images with additional noise](own work)
The sampling distance of the $i$-th frame is calculated as:

$$T_i = T_{i-1} + T \cdot (1 + S \cdot rand),$$

(1)

where $S$ denotes the allowed disturbance (10% or 100% in our experiments) and $rand$ is the pseudo-random number within the range $<-1; 1>$. The constant sampling distance for the constant speed and frame rate is denoted as $T$.

The idea of the coherent and non-coherent sampling is illustrated in Figs. 6 and 7. Presented images indicate the fragments of acquired frames representing the register plates. It is assumed that their size is constant due to the far located camera, so that:

$$L \gg \sum_i T_i.$$  

(2)

The reconstruction has been performed using the Anti-Lamenessing Engine (ALE) software based on Irani-Peleg back projection algorithm [3,4]. For this purpose 16 randomly shifted (according to the assumptions discussed above) low resolution frames have been
used for each type of sampling and each register license plate. Example results are shown in Figs 7-10 for each type of sampling.

A useful information related to the process of super-resolution reconstruction can be the average matching percentage being in fact a measure of similarity of the low resolution images used during the calculations. The results obtained for the four exemplary plates are presented in Table 1. Analyzing these values one may be surprised by the fact that the lowest values of matching have been obtained for the random sampling leading to certainly the best quality of resulting images. This is caused by a specific property of the super-resolution algorithm which uses primarily the data related to dissimilarities of the input images. In that case the average matching cannot be interpreted neither as the quality metric nor its exact opposite.

Regardless of the fact that lower values indicate more differential information present in some input images, which may be used by the super-resolution algorithm, even lower values may suggest the completely different images. In that case the average matching should be combined with some of the image quality assessment techniques [9] in order to obtain more useful information, which may be used for the automatic and reliable assessment of the results obtained by the super-resolution algorithm.

### 4. Conclusion and future work

Super-resolution algorithms can be applied not only as supplementary methods for the register plate recognition systems but also for the improvement of vertical road signs recognition [10] or vehicles’ tracking.

Table 1. Average matching percentages.

<table>
<thead>
<tr>
<th>Sampling method</th>
<th>Average matching for exemplary register plates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uniform</td>
<td>AG37283 – 87.6%</td>
</tr>
<tr>
<td></td>
<td>HX17048 – 90.6%</td>
</tr>
<tr>
<td></td>
<td>JF57504 – 89.9%</td>
</tr>
<tr>
<td></td>
<td>VS31175 – 90.9%</td>
</tr>
<tr>
<td>Partially random (10% of pixel’s height vertical)</td>
<td>AG37283 – 91.0%</td>
</tr>
<tr>
<td></td>
<td>HX17048 – 90.6%</td>
</tr>
<tr>
<td></td>
<td>JF57504 – 90.9%</td>
</tr>
<tr>
<td></td>
<td>VS31175 – 91.3%</td>
</tr>
<tr>
<td>Partially random (10% of pixel’s width and height in both directions)</td>
<td>AG37283 – 87.6%</td>
</tr>
<tr>
<td></td>
<td>HX17048 – 90.7%</td>
</tr>
<tr>
<td></td>
<td>JF57504 – 91.0%</td>
</tr>
<tr>
<td></td>
<td>VS31175 – 90.6%</td>
</tr>
<tr>
<td>Random</td>
<td>AG37283 – 86.5%</td>
</tr>
<tr>
<td></td>
<td>HX17048 – 85.7%</td>
</tr>
<tr>
<td></td>
<td>JF57504 – 86.0%</td>
</tr>
<tr>
<td></td>
<td>VS31175 – 88.8%</td>
</tr>
</tbody>
</table>

For the automatic verification of the results obtained using various methods, both for motion estimation [5,6] and reconstruction [3,4,7] some specialized image quality assessment methods would be useful. Since the typical usage of such methods is related to the assessment of images containing some typical distortions such as noise, blur, lossy compression etc. they may be even useless for this purpose.

The main contribution of some recently proposed image quality metrics, such as e.g. Structural Similarity [11], is much better correlation with subjective evaluations in comparison to classical Mean Squared Error and similar metrics [12,13]. Such well correlation is not necessarily equivalent to high recognition accuracy of register plates. Since in some systems the recognized images are binarized, the applicability of modern metrics is limited.

Another problem related to the image quality assessment is the full-reference character of most metrics. It means that the full knowledge of the ideal image without any distortions is required for the comparisons. In practical applications the use of the super-resolution algorithm
is based only on several low resolution video frames and the high resolution reference image is not available. In such case the automatic choice or modification of some parameters of the algorithm or the camera has to be performed using the data which is available. In such case the only possible solution of automatic image quality assessment is the use of some no-reference (“blind”) methods [14]. Unfortunately, such existing methods are rather specialized and sensitive on only one or two types of distortions e.g. blur [15] or JPEG compression [16], so the development of a “blind” image quality assessment method for super-resolution images seems to be an interesting direction of further research.

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Bibliography


Onboard Unit (OBU) in an ITS System on the Basis of Coopers Project

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ABSTRACT
This paper will present an On Board Unit (OBU), which is an integral part of planned ITS – acronym COOPERS. It will describe the structure, construction and components, ways of communication with the infrastructure (V2I) and with other vehicles (V2V), communication with on board information from CAN and OBD, usage of GPS signal, gyroscope, and user interface. The usage of OBU in the project enables to introduce new functionalities.

KEYWORDS: ITS architecture, ITS, OBU

1. Introduction
Assuming a complete set of requirements for the implementation of COOPERS services, including functional and non-functional ones, and an unlimited budget, one could construct ideal in-car and roadside equipment with perfect services fulfilling all on which the requirements are based.

COOPERS project vision:
Vehicles are connected via continuous wireless communication with the road infrastructure on motorways, exchange data and information relevant for the specific road segment to increase overall road safety and enable co-operative traffic management.

European road network faces a traffic demand increase up to 50% over the next 15 years. At the same time road operators have the national and European obligation to improve the level of service, to improve safety and to decrease the number of fatalities and injured persons in road accidents by 50% till 2010.

That is why new techniques and methods are requested to move increasing number of vehicles safe, efficient and environmentally sustainable through the existing network.

Co-operative systems enabled by enhanced telematics (vehicles and infrastructure) allow to handle the dense traffic safely and efficiently.

Complementing the current research on the in-vehicle technology and vehicle to vehicle communication (V2V), innovative solutions for the communication between infrastructure and vehicles (I2V) have to be established to explore these options targeting a better use of the available infrastructure capacity. Figure 1 presents a recommended COOPERS configuration – the In-car network + RSU:

- Communication technologies: Infrared, CALM 5, GSM/GPRS, DAB – broadcast communication, DVB-H – broadcast communication alternative to DAB, RDS-TMC – broadcast communication (comparison of existing RDS-TMC installations with DAB);
- In-car network: T&TT On Board Unit from ARS as an automotive PC to run the COOPERS services; Robust Positioning Unit (RPU) from PWP Systems for vehicle positioning; OBU – 3 from EFKON as the communication gateway; CAN connection; additional sensors like gyro-meter …;
- CAN/additional sensors. OBD-II (On Board Diagnostics) is an on-board diagnostic system which is used in several vehicles and which is mandatory for new vehicles sold within Europe (and USA).
- Infrastructure/ Roadside: roadside controller from SW ARCO (implemented by SMC/SW ARCO Motorway Controller); CALM Gateway module from EF...
KON; Sensor Management from ASCOM will be used. The roadside configuration as posted above will only be installed when a local computing power is needed or IR communication is installed on the dedicated roadside. The existing roadside sensors may be used as they are. Especially if they are directly connected to the TCC, no change of the existing installation may be feasible. The CALM Gateway module is connected to the SMC. The information transferred to and from the SMC which has to be transmitted over short/medium communication technologies is forwarded by the SMC to CALM Gateway module or the TCC.

The project uses the cooperative synergy of existing technologies and equipment to attain the road safety improvement. However, the implementation of services efficiently and with adequate quality depends not only on the quality of the technology and technical devices themselves, but also on the availability of experience within the team of those COOPERS partners who are responsible for designing, development and testing the COOPERS subsystems.

The project uses the cooperative synergy of existing technologies and equipment.

1.1. I2V Communication Link

DAB/DMB/DVB-H

Digital Audio Broadcast (DAB) is a technology to broadcast audio and many other types of digital services in several standardized manners. Its latest enhanced Digital Multimedia Broadcasting (DMB) is a standard to carry the content and enriched services to a mobile user, as well as the introduction of a more sophisticated audio codec. DAB/DMB is required for wide range communication. A lot of safety related information must be provided to all road users and DAB/DMB is the cheapest technology for this. Unfortunately it lacks the ability to respond to a received message. Alternatively to DAB the DVB-H technology will be implemented within COOPERS. This will be applied on test sites where DAB is not available.

CALM IR

CALM (Continuous Air interface, Long and Medium range) is a family of standards which determine a common architecture, network protocols and air interface definition for wireless communications using cellular second and third generation, infra-red, 5 GHz, and 60 GHz communications. Other air interfaces may be added at later date. These air interfaces are designed to provide parameters and protocols for communications in the ITS Sector, as follows:

- Data rates of 1 and 2 Mbit/s, the standard provides up to 128 Mbit/s.
- Vehicle speed in excess of 200 km/h.
- Communication distance up to 100m
- Latencies and communication delays in order of milliseconds.

CALM IR is a medium range communication and is the perfect complement to DAB/DMB and GSM/GPRS.

CALM M5

CALM M5 is the European/International version of American WAVE (Wireless Access to the Vehicular Environment) standard including IEEE 802.11p. When CALM M5 becomes available it would be a preferred medium to support the aspects of COOPERS. At first glance the technology should enable COOPERS services to be hooked on and therefore CALM M5 will be evaluated in the COOPERS project.

TPEG protocol

For the communication between TCC and OBU COOPERS needs a common message format and decides to use the TPEG (Transport Protocols Experts Group) specifications for this purpose. The TPEG is a bearer and language-independent TTI (Traffic and Travel Information) service protocol that has a unidirectional and byte-oriented asynchronous framing structure. There are basically two formats for TPEG messages – tpeg ML and tpeg binary. The difference between them concerns only the format and not the content, as both variants are designed to map on onto each other precisely. Therefore the differences concern mainly the size of the data used and the
accessibility. As a lot of software tools and libraries already exist it is comparatively easy to handle messages in the XML format as long as there are hardware resources and bandwidth. However, in an area of limited resources, one can save memory and/or bandwidth by using the binary format. For this reason it is possible to use both. The TPEG is a modular toolkit and consists of the following applications:
- RTM – Road Traffic Information,
- PTI – Public Transport Information,
- Loc - Location referencing, used in conjunction with applications.

2. HMI – Human Machine Interface

A design of HMI is illustrated in Figure 2. General status panel displays the GPS status and current date and time. Concerning the event icons, thumbnails of the existing events are displayed in a minimized form. The currently active event thumbnail is surrounded by a brown rectangle. The thumbnail is automatically cleared on expiry of the event. Tapping on the thumbnail displays the corresponding event. The event details panel lists out the event information. It displays the events graphically. Instructions or recommendations are displayed on the red rectangle at the bottom of this panel. The orange arrow denotes that there will be more information. The planned route is displayed on the navigation panel. The current position and location of the vehicle is also displayed. The route is annotated with thumbnails of traffic events. The actual speed and the prevailing speed limit are also displayed on the navigation panel. The distance to the next turn is also shown, Fig. 3.

3. Automotive PC and in car network

The automotive PC, Figure 4, has the primary purpose to collect COOPER’s services. AP and the applications are created to test and validate the COOPER’s services.

The following services are defined:
- Weather conditions – to provide in-vehicle, dynamic information to warn drivers of hazardous road surface conditions ahead caused by ice or frost;
- Fog warning – to provide in-vehicle, dynamic information to warn drivers of poor visibility caused by fog;
- Accident warning – to warn drivers of a road accident ahead with in-vehicle, dynamic information and inform the emergency service providers for efficient recovery;
- In-vehicle variable speed limit information – to provide drivers with real-time, in-vehicle information on appropriate speed for the current conditions, which are based on traffic flow, traffic speed, weather and others inputs;
- Lane banning (LB) – according to the type of vehicle and the network condition, to provide drivers with real time, in-vehicle information about lanes which are not accessible, e.g. HGV are not allowed to drive on the off-side lane on motorways. Also some network section has dedicated lanes for public transport;
- Keeping Lane (LK) – to provide real-time, in-vehicle advice for drivers not to change on specific road links;
- Auxiliary Lane Accessibility (ALA) – to provide real time, in-vehicle information to inform drivers on a specific motorway section about the availability of auxiliary lanes for emergency stopping or driving;
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- Traffic congestion warning (TCW) – to provide in-vehicle, dynamic, information to warn drivers of congested traffic ahead;
- ISA with infrastructure links – to inform/warn drivers of vehicle speed limit and help them match their speed to prevailing traffic/road conditions;
- Road charging to influence traffic demand – the aim of these services is to support road charging through Electronic Fee Collection; to inform drivers about predicted costs;
- International service continuity – an exchange network between neighbouring control centres to ensure continuity of service for travellers;
- Estimated Journey Time – to calculate and inform drivers about the estimated journey time;
- Recommended next link – to recommend an alternative link in special situations/scenarios;
- Map information check to inform of current update for digital maps;

Illustration and technical specifications of prototypes of the Automotive PC and the envisaged HMI design is shown in Fig. 4.

4. RPU Robust Positioning Unit

The RPU provides an access to the following data sources: GPS, Gyro (incl. GPS time), Odometer (revolution of all 4 wheels; incl. GPS time).

For the individual sensors the following requirements are posed from the view of the RPU to the properties of the measurements:

GPS module:

- Chip set should be: SiRF, u-blox Antares4 or equivalent sensitivity.
- The PPS output has to be connected.
- The receiver should be able to process EGNOS information.
- Independent determination of the position (triangulation) and the velocity (Doppler shift) information.
- Position determination should be computed in the module of “precise point position” (PPP).
- No smoothing or filtering should be applied inside the GPS module.

CAN bus:

- Provides the velocity of the vehicle in general.
- Provides the distance increments (pulses) of all four wheels (but at least of two non-powered wheels).
- Timestamps synchronous to the GPS-clock and with a time accuracy of better than 10 ms.
- Signals for the driving direction (forward and backward).

Fig. 4. Illustration and technical specification of APC and HMI
Source: [own work]

Fig. 5. Overview of interfaces provided by the Communication Gateway
Source: [own work]

- Sampling rate of 100 Hz.
- Resolution of 8 Bit per wheel revolution.

Gyro rate sensor:

- Measurement range of 50-150 grad/sec.
- Sampling rate of 100 Hz.
- Resolution of 12 Bit.
- Timestamp synchronous to the GPS-clock and with a time accuracy of better than 10 ms.
- Temperature signal for the gyro with a resolution of 0.1 degree.

According to above functionalities presented, the CGW (Communication Gateway) was defined, which receives the following messages, Figure 5:

- Messages from the OBU-II CAN.
- Traffic Control Messages (TPEG-RTM) from the COOPERS Service Centre sent over GSM/GPRS.
- Traffic Control Messages from the Road Side Unit (RSU) by means of IR (interface 3) and CALM M5.
- GPS data (NMEA – GGS and RMC Strings) from interface 5.
5. Test Vehicle Configuration

Figure 6 shows the concept of test vehicle configuration. There are all components mentioned above, which are necessary to provide a road test of presented equipment.

COOPERS Tests will partly be executed as pre-integration tests in the laboratories of Dornier Consulting (In-car network) and Applus+ (Road-side subsystem), and partly they shall be performed as integrated subsystem/system tests at all demonstration sites; these are

- Motorway from Nuremberg via Munich, Kiefersfelden/Kufstein, Innsbruck, Brenner to Trento with three sections (Bavaria, Austria, Italy)
- Motorway Rotterdam-Antwerp (Netherlands-Belgium)
- City Motorways in Berlin (Germany)
- Secondary roads in the "Region Darmstadt"
- Motorway A7 Vienne-Valence (France)

The demonstration site of the "Region Darmstadt" has the aim to extend the spectrum of road networks for COOPERS. On the example of the COOPERS service S5 "In-vehicle variable speed limit information" it will be demonstrated, how this service can support the driver on secondary roads as well. Therefore this service was translated to the special constraints of secondary roads and is described as the service S5a "Adaptive speed limit warning and curve warning on secondary roads". The second focus of the demonstration in "Region Darmstadt" is motivated with the integration of Galileo for COOPER’s services. For the COOPERS project the objective of robust positioning is of main interest for the European Commission and especially the potential contribution of Galileo to support the selected services. Therefore a unique approach has been designed to test the benefits of Galileo within the application, before the space segment of Galileo has been installed.

For the evaluation of the results from executed test trials, it is necessary to know the true trajectory or at least a very accurate and reliable estimate of it. Therefore, The Technical University of Lodz (LOD) has combined a high precision inertial measurement unit (IMU), which was aided through an external wheel pulse transducer (WPT) with high resolution and dual frequency GPS receiver. The measurements are recorded in parallel but strictly independent to the other system of the COOPERS OBU and the scientific development platform inside the PWP concept car.

The modules of reference systems can be found in three locations, a special dual frequency antenna with advanced reception characteristic on the roof, the Corrsys Datron WPT at the outside of the back wheel and the additional reference sensors including a recording laptop in the trunk of the vehicle. While the reference system does require the most installation space, the modules of the COOPERS OBU are rather small in size and have all been installed in the cabin of the vehicle. The assessment of technical performance of RPU will be executed by the LOD as a neutral instance for this task. In order to qualify the remaining error behaviour of the RPU by measurements, hard facts will be generated for the process of the technical assessment. The applied hardware components of Corrsys, IMU, and dual frequency GPS are very costly (more than 50 000 EUR) and do not qualify for an economic solution with respect to the task of robust positioning with COOPERS.

For the correct and precise determination of the performance of RPU during kinematic test trials with the concept car a reference systems is necessary that operates at the same time reference as the RPU. For this task SPAN system (Synchronized Position Attitude Navigation) has been applied by the TU of Lodz. While the SPAN operates on the basis of GPS time, most low-cost GPS receivers provide the UTC time. The timing accuracy in both systems is sufficient, but by definition there exists a time drift between the GPS time and UTC, which is currently determined with 15 lead seconds, that have to be compensated to achieve proper synchronization. The core of the SPAN system is an inertial measurement unit (IMU), which consist of fibre optic gyro (FOG) and three precise accelerometers. This sensor assembly can perceive the rotation and translation motion of the vehicle in all three axes, to cover the complete six degrees of freedom with respect to physical motion.

The measurements of all reference sensors are logged via the software tool from the SPAN unit, which is running on a separate laptop from LOD. The interface of the SPAN systems is kept quite simple and allows controlling...
the proper operation of the reference equipment during the test ride. In comparison to the RPU, the SPAN system has a quite long procedure for initialization, until all the single sensors are calibrated. The HMI of the SPAN has a similar view of cockpit instrumentation, which comes from the fact that costly equipment is used for aviation, rather than for land transport. This shows a high reliability that comes with the inertial sensor systems and proves again that a high effort is appropriate, in order to generate a reliable reference trajectory for robust positioning applications like the COOPERS-services.

5. Simulator study

A driving simulator is a complex tool that can be used for many different kinds of purposes. Typically it can be used for vehicle dynamics studies, driver behaviour studies, road design and visualization, man-machine interaction studies, virtual prototyping of vehicles and vehicle systems. The VTI built its first driving simulator already in 1975, and has since then performed studies within all of the mentioned categories.

A main part of the overall COOPERS project deals with problems concerning the data transmission (in its broadest sense). In contrast, it was decided that the driving simulator study would deal only with traffic safety issues. It was also decided that most benefits from this study would be achieved with a study of driver behaviour, comparing driving with the COOPERS onboard unit as opposed to driving without the COOPERS onboard unit. The comparison would be made in situations that could not be achieved in the upcoming field studies. Thus, the simulator study should be regarded as a study that is complementary to the field studies, with the purpose of retrieving information that otherwise could not be obtained. The simulator study should not be considered as a virtual test bed for developing the field study methodology or the HMI of the COOPERS onboard unit. However, since the driving simulator test would be carried out before the field tests, many results would be useful for the field tests at the demonstration sites, e.g. the design of the user acceptance questionnaires. And, although the simulator study was not designed with the purpose of developing the HMI design of the COOPERS system, the feedback from the drivers that took part in the simulator study may also lead to improvements in the HMI before the tests at the demonstration sites would be performed. The driving simulator study was carried out at the VTI using 48 Swedish test drivers, 24 men and 24 women. The drivers had to drive 40 km Swedish motorway without, and 40 km with the COOPERS system, while being exposed to some critical, and some not so critical events. These events, denoted scenarios, were chosen with the COOPERS services in mind. Some of the scenarios were chosen specifically for the simulator study since they were too rare or too critical to be achieved in real traffic driving in the upcoming COOPERS field test. Objective measures on driver behaviour were sampled, e.g. the speed and vehicle position on the road, including the eye movement pattern of the drivers. Physiological measures such as the ECG and skin conductance were recorded for evaluation of the driver’s stress level. The driver’s subjective experience from driving with the system and their perceived stress during the scenarios was also captured. Furthermore, an acceptance study was carried out, which will be reported elsewhere.

The primary aim of the study was to measure and compare driver’s behaviour when driving with the COOPERS system as opposed to driving without the COOPERS system. The driving behaviour was supposed to be studied in situations where a traffic safety problem might occur. Apart from the primary aim, the simulator study also enables the study of driver behaviour during more general motorway driving.

The four scenarios involved were created to include some of the COOPERS services earlier defined:
- “Congestion” - The driver approaches a sudden congestion that is standing still.
- “Fog” - The driver has to pass a 1 km long road section with heavy fog.
- “Ambulance” - An ambulance approaches the driver at high speed from behind and needs to pass.
- “Ghost driver” - The driver meets a vehicle driving in the opposite direction in his lane on the motorway.

The results of the present study show that when the system is active, the drivers adapt to the scenarios according to the information given through the system. For the congestion and the fog, the drivers lower their speed after having received a warning about the upcoming situation. The ambulance scenario showed a decrease in longitudinal acceleration and the time to collision in the ghost driver scenario was decreased when a warning had been issued through the system. This indicates that even for traffic events that are critical, the driver has an advantage by the system warning and has time and opportunity to adapt to the situation, hence creating a safer scenario.

All changes in drivers’ behaviour that were found in the simulator study can be considered beneficiary from a traffic safety perspective. Other possible benefits from a COOPERS-like system would be that the driver has an opportunity to better plan his route according to the circumstances on the road. If the driver receives information on upcoming traffic delays well ahead, he/she can choose a different route to avoid for example congestions or bad weather, hence making the overall traffic situation better.
6. Conclusion

Coopers project using OBU:
• Focuses on services and driver’s behaviour/user acceptance.
• Influences significantly driver’s behaviour.
• Influences driver’s behaviour positively.
• Is accepted by all drivers independent of the acceptance level.
• People are willing to pay for it.

An open system of ITS architecture and the OBU presented enables new features and standards of vehicle use. There is no problem to add another service, so called low emission; the next steps of authors will be focused on a low fuel consumption.

Bibliography

Integrated Control Tools Development for Sustainable City Transport System

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ABSTRACT
Sustainable development of City Transport System is described in the article. Control tools relating to planning, and management of Public Transport System are described. 3-levels Integrated Control Tools system usage is offered which allows carrying out the control of vehicles, to supervise work of each type of transport separately and to co-ordinate work of all passenger transport system in the city.

KEYWORDS: Sustainable City Transport System, Control Tools, passengers, consumption of fuel and electric energy

1. Introduction
Transportation of the passengers in large cities is of great importance for the urban and economic development of those. But the public transport is not the only type of it running in the cities, people use also private transport that increases traffic congestions increasing in their turn the consumption of fuel and electric energy.

Therefore the actual investigation under the present transport situation is selection of that type of transport meeting the requirements of the passenger transportation optimization. Particularly important it is under the conditions of transport network renovation. The renovation process is realized usually with the optimization of transportations according to the time parameter without reducing the comfort and costs. As the base of decision making procedure of the transport network development alternative selection co-modal transportation principle is suggested to use in optimization of the city transport. The elaboration of decision making procedure is important for intelligent transport systems and services development.

In this article transport sustainability means, that transport provides safe, economically viable and socially acceptable access for people, places and services while meeting objectives for health and environmental quality, protecting ecosystems and minimizing adverse impacts on global phenomena such as climate change [1]. Transport routes and vehicles should be convenient, safe and simple to use.

The purpose of this research: Increase of an overall performance of system of a City Transport, by development of Integrated Control Tools for Sustainable City Transport System.

Tasks of research:
• Definition of measured parameters for evaluation of Sustainability of City Transport System.
• Reduction of time of a trip of one passenger from point „A” to point „B” in comparison with an existing situation.
• Optimization of quantity of vehicles in system of city public transport to minimum quantity of vehicles in...
the considered system, capable to execute demanded number of inquiries of passengers.
- Increase in an overall performance of each vehicle.
- A problem of assignments. Appointment to a route of vehicles of different capacity.
- Scientific novelty - working out of three-level models of management of transport system.

The first level provides the control of a vehicle and traffic lights. In other words, at this level the control of transport system at level of objects of system is made: vehicles, traffic lights and inquiries about service of passengers.

The second level: integration and realization of management by transport system within one mode of transport.

The third level: work coordination, transport modes coordination and quality of inquiries about service of passengers (quality of service).

2. Sustainable Transportation Principles and City Transport System

Serious challenge for engineers and designers, and also for policy makers is observance balance between mobility and sustainability.

The principles of sustainability and environmental indicators evaluation [2] should be analyzed according basic transportation activities, which affecting the environment:
1. Infrastructure construction, maintenance, and abandonment (e.g., building roads);
2. Vehicle and parts manufacture;
3. Vehicle travel;
4. Vehicle maintenance and support;
5. Disposal of used vehicles and parts

The World Commission on Environment and Development is usually credited with the first definition of sustainable development. In [10] the Commission defined the sustainable development as the „development that meets the needs of the present without compromising the ability of future generations to meet their own needs”. The report continues: „It contains within it two key concepts:
- The concept of “needs” in particular the essential needs of the world’s poor, to which overriding priority should be given, and
- The idea of limitations imposed by the state of technology and social organisation on the environment’s ability to meet present and future needs”.

As it is mentioned in COST 356 [9], - hierarchy of objectives in the environmental field according to [11]

Master the environment;
- At global scale;
- Preserve an environment in favor of the human life;
- Limit the greenhouse effect;
- Limit the climate change;
- Protect the ozone layer;
- Preserve the natural resources;
- Limit the extinction of natural species;
- Limit the extinction of natural environment;
- Limit the energy consumptions;
- Limit the maritime pollution;
- Limit the production of non-recyclable waste;
- Concerning the human environment;
- Respect the areas «villages»;
- Preserve habitats from soiling.

3. Integrated Control Tools technical platform

The intelligent transportation system (ITS) by itself serves as bases for Integrated Control Tools technical solution development. The typical structure of ITS [3] is given in figure 1.

According to [4], such principles of sustainable transportation could be implemented, using ITS:
- Intergenerational equity
- Multi dimensional
- Dynamic
- Continuum

As it is mentioned in COST 356 [9], - hierarchy of objectives in the environmental field according to [11]

As it is mentioned in COST 356 [9], - hierarchy of objectives in the environmental field according to [11]

Fig. 1. Modeling and simulation process flow in TRANSIMS
Source: [own work]
Properties of the agent should provide necessary functions of ITS. The main properties of agents:

- Independent execution and interaction with other agents and/or applications, supervision over environment;
- Ability to use abstraction;
- Ability to use knowledge of a subject;
- Ability to adaptability for purpose achievement;
- Ability to be trained at environment;
- Stability to errors and wrong signals;
- Functioning in real time;
- Interaction with Supra agent.

Constraints of ITS implementation are: environment, ecology, resource, technology.

Examples of Technologies and functions which are now integrated with ITS:
- Automatic number plate recognition;
- Cellular Phone Tracking;
- Global Positioning System;
- Loop Detectors;
- Video Imaging;
- Automatic Vehicle Location;
- Automatic Vehicle Identification;
- Micro Simulation.

ITs system is a powerful tool for traffic flow organization, ITS system application could be different. However, the priority of Riga transport network development is to co-control railway transport in city transport network [5].

Regional rail [5] can carry considerable number of passengers without overloading transport infrastructure, more particularly Riga road network.

Railway transport is very important to the mobility of people and it is based on the well-developed infrastructure. There are 6 railway lines, including 4 electric lines (Riga-Skulte; Riga-Aizkraukle; Riga-Jelgava; Riga-Tukums) crossing Riga region. These lines are provided with 16 railway stations as well as 26 passengers’ stops within Riga district.

In despite of the enormous loses of passengers during the 90-ties it still plays a considerable role to the traffic in Riga metropolitan area in particular for regional towns Jurmala, Ogre, Olaine, Salaspils, Saulkrasti as well as for dense populated recreation areas namely Jurmala, Carkava, Saulkrasti, Sigulda.

Interest in ITS comes from the problems caused by traffic congestion and a synergy of new information technology for simulation, real-time control, and communications networks.

Traffic congestion has been increasing worldwide as a result of increased motorization, urbanization, population growth, and changes in population density. Congestion reduces efficiency of transportation infrastructure and increases travel time, air pollution, and fuel consumption.
3.1. Three-levels Integrated Control Tools system

Three-levels Integrated Control Tools system usage is offered which allows to carry out the control of vehicles, to supervise work of each type of transport separately and to coordinate work of all transport system in city boundaries.

Supra software agent (Supra agent) in this article is software agent with coordination function. Supra software agent coordinates task realization, in distributed level coordination made by subsystem, in centralized level several coordination agents are used.

Scheme of interaction of Supra software agent is given in Fig.4.

The development of control tool was done in three level:

- Control tool of vehicle;
- Control tool of transport mode;
- Control tool of transport modes co-modality.

The control methodology application depends on control level. In vehicle control (fig. 5.) based on regulation theory approach are used mainly.

Continuous programming methods usage requires to use computer based network, information technologies, based on possibility to realise on line control of systems, such as intelligent transport systems (ITS). ITS allows to make predefined decisions in emergency case, in heavy traffic situations, during repairing works and in other situations. Applying ITS allows to control traffic online and to make decisions immediately, when it is needed. ITS can be used as a data source for existing situations in view of long term decision making.

4. The mathematical formulation of the task

The important problem of control could be formulated in the following way, using intelligent agent demonstrated in Fig.5.

Figure 5. demonstrates control scheme of transport system, St – is transport system; where $W^{(I)}$ - feedback (transport control system); $W_x$ – input of the transport system (resources, passengers, signals), $W_y$ - output of the transport system (resources, passengers, signals) $W_v$ – influence of environment.

The operation of the transport control system is provided according to the priorities of passengers ($Z^p$), $W_y$->$Z^p$, taking into account its interaction with other systems according to logistic criteria. Modeling of intelligent transport systems for the control of all the system is analyzed in the connection of public transport with other systems and intelligent agents structures.

Following variables have been named:

- $S_e$ – system of resources;
- $S_p$ – set of passengers with subsets $S_{p1}, S_{p2}, ..., S_{pk} \subseteq S_p$;
- $k=1,2,...$;
- $S_t^{m}$ – transport system mode with vehicles $S_{t1}, S_{t2}, ..., S_{tn} \subseteq S_t$;
- $S_t$ – transport system;
- $S_{e\pi}$ – total consumption of recourses by vehicles $S_{e1}, S_{e2}, ..., S_{en} \subseteq S_{e\pi}$;
- $t$ – time, $t1, t2, .. ti$ – moments of time;
- $Z^p$ – priorities of passengers;

![Fig. 4. Scheme of interaction of supra software agent](Source: [own work])

![Fig. 5. Model of the control task for public transport vehicle](Source: [own work])
W - environment
Wv – influence of environment;
W (I) – feedback (control system of transport);
Wx – input of transport system (resources, passengers);
Wy – output of transport system (resources, passengers);
A – set of intelligent agents (intelligent agent network) with subsets A1, A2, ..., Am, Ap1, Ap2, ...
A – Supra intelligent agent
Stn ∈ Spk Stej (Stn, Spk) → min (exists when Stn, when for each Sp exist Spk (Stn, Spk).
Target function Stej → min, Stn > Stdirekt
By the means of Supra intelligent agent provides the development of resources consumption efficiency increasing procedure for public transport system and takes the task of optimum in dynamic:
Stm1x Stm2x …x Stmi x Sp -->Z°p, and
Stm1 (Wx) →min.

5. System integration issue

Requirements for transport modes development require integration of all transport modes, including its specific automation systems and existing equipment.

In railway domain, where European CENELEC Standards such as EN 50126, 50128 and 50129, European Research Projects and Networks and finally the establishment the European Railway Agency have helped and are still helping to streamline and normalize the safety and interoperability sector.

At the present stage of development, in Latvia it is impossible to use the European control system of movement of railway transportation ETCS. The main reason of it is incompatibility of railway on – field devices and control systems. Now, carrying out passenger and freight traffic in the countries of Europe, on border the mobile structure on such which meets both width of railroad tracks, and other requirements varies, but, it is obvious that it requires a lot of time and leads to a long delay of cargo on border. In this connection the railway transportation becomes slower, than motor transport. Historically the situation has developed so that in each European state there was a railway standard.

Therefore, to co-ordinate all requirements to railway systems of Europe and to realize functionally compatible system, the unified control system of railway transportation ETCS has been developed. In this system the uniform standard of the railway equipment and used equipment which is considered is provided, making modernization of railway system of the European states. In the given research the using of existing equipment Eurobalises and communication via GSM-R for railway transport (Fig. 6) control of safe movement of trains are used.

The functional model for public transport – tram as control tool of vehicle level is shown at figure 7.
In Riga city mostly trams TATRA and TATRA 3M are used. For driving such DC trams as well as AC electric motors with semiconductor converters [8] for rotational frequency control are used.

Control devices with contactors and rheostats widely used earlier have been changed for semiconductor regulators which control voltage value supplied to motors. Control of motors according to the requirements has to include tram control possibilities as well as traffic light control, as well as passengers flow control. The tram control equipment scheme is shown at figure 7.

The another transport mode, which are currently equipped with distance tracking equipment in Riga are buses. Bus control system are developed on Control tool of transport mode level.

The bus control system could track of bus route, using GPS receivers, but currently bus movement are not optimized in on – line mode.

Currently public bus system control in additional requires on board equipment with application of GPS, all of which utilize of three basic components of the GPS; absolute location, relative movement, time transfer.

On bus equipment for Riga bus control system (ASOS) are shown at figure 8.

The structure of such control system are shown at figure 9. The ASOS system are first implemented control system in Riga.

The next stages of co – modal passenger transportation requires introduce Control tool of transport modes co- modality. Such tool in Rigacity are useful to develop for all passengers transport modes: buses, trolleybuses, trams and railway.

6. Conclusions

There is various possibilities and tools to increase of an overall performance of system of a city passenger transport have been described in the article. There is 3-levels Integrated Control Tools system usage is offered which allows carrying out the control of vehicles, to supervise work of each type of transport separately and to co-ordinate work of all transport system in city boundaries.

The current transport control systems, it’s components on vehicle, transport mode and transport modes co- modality issues are analyzed for Riga city transports.

Bibliography


Transport safety of Slovak Railways level crossings

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ABSTRACT
Railway transport is one of processes controlled with a certain level of risk. It is apparent that due to a limited level of our knowledge, the technical level and limited funds we cannot count on absolute safety (zero risk) but we must admit that in a real technical system some error or fault may occur and its occurrence may mean a certain risk for the controlled process. The authors focus on proposing and presenting potentially usable measures that could increase the safety of traffic operation at the level crossings operated by the ŽSR (Slovak Railways). Technical and organizational measures are discussed separately. Some of proposed measures are specific for Slovak conditions only, however, to a certain extent some findings can be generalized and possibly applied in other countries, too.

KEYWORDS: safety, level crossing, accidents, transport, ZSR, technical measures, organizational measures

1. Introduction
Currently, there are 2220 level crossings (LC) on the ŽSR railway lines. Out of this number there are 1076 level crossings equipped with level crossing signalling (LCS) and 1144 not equipped with LCSs [1].

If a level crossing is not equipped with an LCS, then the safety of road users in the area of the level crossing is assured by organizational measures. The level crossing must be unmistakably marked by a warning cross (St Andrews cross) and the driver of a road vehicle is informed by a road sign that the vehicle is approaching the level crossing. Road drivers are required by law [2] to act with extreme caution when approaching and crossing the LC and make sure that it is safe to pass the level crossing. Maximum speed limit for road users in the area 30 m ahead of the LC and on the LC is 30 km/h.

When a level crossing is equipped with an LCS, there are more ways to inform the road users about a train approaching the level crossing:
• acoustic warning (mechanical or electric device producing audible signal – a bell, horn or electronic bell);
• light warning (two red complementary flashing lights);
• mechanical warning (half-barriers across a part of the road or full barriers across the whole roadway width).

Only the LCS with a light warning as a basic warning and optional mechanical warning as a supplementary warning are discussed in the paper. Those types of LCS are used on ŽSR lines with a line speed less than 140 km/h. On lines with a line speed equal to 140 km/h or higher only the LCSs with a mechanical warning along with a light warning as a basic warning are used. The construction of new level crossings on ŽSR lines with a line speed exceeding 160 km/h is strongly discouraged (currently there is only one level crossing on the line with the line speed of 160 km/h).
In order to keep road users reliably informed about movements of railway vehicles in a level crossing area, it is necessary to:

- provide them unambiguous information;
- keep LCS in operation in accordance with functional specifications (standard [3]);
- achieve maximum possible availability of the system.

There are some ŽSR specific problems that need to be solved in order to fulfil these basic requirements. Some of these problems are identified in this paper.

### 2. LCS actuation by a train movement

A concurrent operation of LCS and technical equipment that checks up on a presence of a railway vehicle in the control section of a level crossing is required. A pass of a railway vehicle over a level crossing is also monitored. The following devices are used for these purposes:

- Continual technical equipment (track circuits, axle counters);
- Point technical equipment (rail contacts, rail loops).

#### 2.1. Track circuits

At least three closed track circuits are needed to have road users unambiguously informed about the traffic in a level crossing area with bi-directional traffic. (Fig. 1).

The configuration shown in Fig. 1 is common for ŽSR lines, except that the middle closed track circuit that checks up on a movement of a railway vehicle over a level crossing is replaced by ASE equipment – Annulment Electronic Set (Fig. 2). ASE equipment is composed of two partially overlapping jointless track circuits [8].

Track circuits operation depends on a drop shunt of a track, which is affected by many variables (e.g. weather, railway traffic intensity, trains weight). Low intensity secondary tracks are seriously threatened by a loss of the shunt, which causes that no warning is started before approaching train. This is the main reason that no LCSs controlled by track circuits have been built on ŽSR lines within recent at least 10 years.

#### 2.2. Axle counters

Due to a recent strategic resolution that no new LCS controlled by track circuits shall be built, the replacement of track circuits, which were formerly used by LCS, is a current problem. The use of two axle counters with overlapping counting sections is a possible solution to this problem. Section overlapping makes checking up on a movement of a railway vehicle over a level crossing possible and subsequently, with respect to this information, a warning state of the LCS can be safely terminated.

A hazard caused by two trains running in opposite directions on a bidirectional railway track has been recognised during the analysis of various process situations (Fig. 3). Figs. 4 to 6 illustrate this problem.

Let us assume that train T1 enters track section TS1. As a consequence, LCS goes from the initial to warning state (Fig. 4.). Furthermore, let us assume that train T2 enters track section TS2. The level crossing remains in the warning state, but the LCS logic evaluates the situation as if train T1 entered section TS2, therefore occupying section TS1 as well as TS2, which does not correspond to the situation on the track (Fig. 5.). Now if due to any
reason train T1 changes its direction of movement and clears track section T1, the LCS will go to the annulment state that terminates warning. Train T2 will subsequently approach the level crossing with no noticeable warning whatsoever – which is a hazardous state. A similar outcome results from the analysis of the opposite direction. This operation of the LCS is contradictory to requirements stated in the standard [3] and also with essentials of interlocking systems in general.

The risk related to the situation mentioned above could be reduced if the LCS had relevant information about a direction of running trains. On the other hand, the LCS logic must reckon with the possibility of a failure of axle counter. No possible failure of an axle counter should cause a potential hazardous situation.

2.3. Point technical equipment

The standard [3] allows the use of point technical equipment to control LCSs. However, these devices have no means to check safely the clearance of an approach section or the movement of whole train over a level crossing. For instance, there is a chance (Fig. 7) that in the case of disconnection of a wagon(s) from the train, by the time the decoupled section enters a level crossing, it will have been in an annulling state, therefore with no warning activated (because the train have passed level crossing already). The risk resulting from this situation could be partially reduced by setting off the warning in the case of unexpected occupancy of the S3 sensor (or S13 in the opposite direction). However, the risk resulting from this situation has been rated as tolerable.

From the safety point of view it is necessary to check the direction of a train movement in the level crossing area by technical equipment (point devices in this case).

3. Active signal

An active signalisation is specific to the ŽSR. An active signal is represented by a flashing white light located on a warning board. Its sole purpose is to inform a road vehicle driver about clearance of all sections of the level crossing. There are some major downsides of the active signalisation using:

- Majority of foreign drivers are not familiar with this sort of signal.
- Standard [3] states that every LCS has to be equipped with an active signal save for exceptions declared in this standard. It is a fact, that approximately 40% of all ŽSR LCSs are not equipped with active signals. An incorrect interpretation of the previous standard (the predecessor of [3]) has led to the practice that the use of an active signal has justified insufficient range of vision on a level crossing. Former road law, that was valid until 1990, suggested that a railway company is responsible for safety of the traffic when the active signal flashes. Road users were not required to make sure if the passage through a level crossing is safe. A lot of drivers (especially older) still claim that, even though the currently binding law [2] stipulates otherwise. If there is a flashing white light activated on a warning board, it is compulsory for a driver to drive at the maximum speed of 50 km/h through a level crossing and 50 m ahead of it.
- Ambiguity in meaning of information provided to a road user. The white signal (active signal) is located on a warning board along with two red signals (basic light warning). If an LCS is not equipped with an active signal, then a disabled state of the LCS (in this state LCS is not capable of warning road users about an approaching train) could be misinterpreted as a default state (no train in the level crossing area that could endanger safety of the road traffic). Furthermore, in some cases (at night for instance) drivers are not able to distinguish whether the LCS is equipped with an active signal or not.
4. Information for a driver

There are few ways how a driver could be informed about a state of an LCS. An engine-driver could be informed via:

- an employee at an operation control point (e.g. the nearest railway station);
- a main signal;
- a special engine-driver’s indication signal.
- a locomotive signal through special transmission channel (this solution is not applicable due to economical reasons).

A common drawback of these solutions (except for the last one) is that relevant information is transmitted at certain points on the track. If such a failure occurs that it prevents an LCS from launching a warning and a train has already passed a transmitting point, then the train will approach an opened level crossing.

4.1. Informing by means of an employee at an operation control point

This is the most imperfect way how to inform a driver about the state of a level crossing. Its typical use is on a track with a semi-automatic block or on a track without a line signalling system at all. An extra communication line is needed to ensure communication between an operation control point (OCP) and LCS. The employee is not only informed about the state of the LCS but also has means for a remote control (open or close) of the level crossing. If an emergency lockout of the LCS occurred due to a critical failure, the level crossing can be remotely opened only if all passing engine-drivers have been previously informed about the failure. If the train has already passed the OCP, then the level crossing cannot be remotely opened unless the train safely clears the level crossing section (this information could be sent to the OCP from the next OCP for instance). Considering the fact that the distance between the LCS and corresponding OCP is up to 20 km, another drawback to this solution is that the warning time of the level crossing could be very long.

4.2. Informing via a main signal

Solution shown in Fig. 9 is used on tracks equipped with an automatic block system. The block section signal ahead of an LC in the direction of moving trains is situated at a breaking-down distance from the LC. The section signal is coupled with the LCS. In the case of a critical failure of the LCS, the section signal shows a stop signal with permissive meaning. A similar solution is also used if the level crossing section overlaps an adjacent station section (where LCS is coupled with an entry or departure signal). In the case of a critical failure of the LCS, the absolute stop is signalled and the next train movement is possible only after a station dispatcher has given the train a permission to continue.

4.3. Informing via a gate signal

One possible solution how to avoid the possibility of the train to approach an open level crossing is to transmit the information about the LCS state the directly to the engine-driver on a locomotive. A special signal is used for this purpose – a driver’s indication signal (which is sometimes referred to as a gate signal).

Former function of the gate signal was to inform a driver that the LCS went to the warning state as the train had entered the level crossing approaching section. In that case the gate signal had to be located somewhere inside the approaching section, but not closer to the level crossing than a braking distance DB. The diagram in Fig. 10 clarifies this principle. Distance DV is the minimum required signal visibility distance between gate signal and the approaching section boundary.

The solution mentioned above is safe, but it is not applicable at high-intensity traffic tracks where it could lead to problems with the train traffic schedule. The same problem arises if there is high level crossings penetration in the area or mixed passenger and freight traffic. Also the financial aspect of this solution is not negligible. Another considered problem is caused by the approaching section required length DA. Those are serious problems that discouraged the ŽSR from a wide use of this application of the gate signal.
Currently valid standards and laws allow the gate signal to be used in a way in which the driver is notified whether the LCS is in an operational state or not. Therefore it is possible (but not necessary) to position the gate signal outside the approaching section (Fig. 11). The requirement on minimum braking distance DB (between the gate signal and the level crossing) still has to be fulfilled. However, in this case the length of the approaching section is independent of the distance between the gate signal and the level crossing. The advantage of this approach is obvious: the level crossing closed time can be shorter in comparison with the previous mentioned method. Another major advantage of this approach emerges when more than one level crossing is protected by just one gate signal.

A critical condition of this approach is that the LCS must start warning immediately after an approaching section is occupied. The actual level of technical equipment fulfils this requirement. An example would be the LCS with a multi-channel structure and periodic tests of a warning lights board, in which just one order from one channel is sufficient for the warning to begin. On the other hand only a few newly built LCS systems meet this condition.

The application of this solution should be well considered before using it with an older, relay based LCS systems that are used on ZSR lines. Those systems do not facilitate any periodical checking procedures capable of checking the warning lights circuit integrity. The ability of the LCS to reach a warning state immediately after an approaching section has been occupied has to be proved by safety pass.

Figs. 12 and 13 show functions of the level crossing closed time versus both the gate signal operation and the track and road crossing angle. The level crossing closed times are valid for the LCS without barriers operating on an unidirectional track.

5. Possibilities of level crossing safety improvement

Transport safety on level crossings depends upon technical measures and organisational measures. The main task of technical measures is a risk reduction, whereas organisational measures are supposed to regulate road users and road users are supposed to adhere to these measures in return. The operation policies of a railway transport at level crossings are summarised in rules [4]. Technical requirements on LCS are specified by the standard [3].
5.1. Technical measures

All functions performed by current LCSs are realised with the level 4 of the safety integrity level (SIL4). Increasing the SIL is highly ineffective given a massive disproportion between the SIL improvement and funds needed to achieve this improvement. In addition, the improvement in SIL does not necessary lead to the improvement in transport safety at LCs. The contribution of LCS systems to failures at level crossings is insignificant – only 0.1 per cent of all accidents are caused by LCs at ŽSR. On the contrary, modifications of LCS or addition of new functions to LCS that primarily do not affect SIL in any way (do not increase technical safety) could enhance transport safety at LCs. Such modifications improve the observance of rules declared by organisational measures and also may compel road users to follow these rules. All these measures may eventually contribute to safety at level crossings or, might at least unify information (range, content, form) provided to road users. A few suggestions, how to ensure increase in transport safety at LCs, comprise:

- Installation of barriers wherever possible, even though it demands more financial resources during the whole life cycle (vandalism, maintenance). Level crossing closed time is also longer [5], nevertheless the application of barriers is well justified. Given statistics [7], the number of accidents at LCs with barriers is markedly lower as compared with the number of accidents at LCs without barriers.
- An LC should be closed for the time necessary for the longest and slowest road vehicle to pass the LC. This requirement poses a problem especially at tracks with mixed freight and passenger transport (high-speed tracks, where trains are moving with notably different speeds). If those tracks are installed with LCS with conventional approaching control principle (point starting), then the LC is pointlessly closed for an unnecessary long time when slow trains approach. Therefore road users are often tempted to cross even a closed LC. This problem could be effectively solved by means of a speed discriminator [6].
- Informing an engine-driver with the aim of minimizing a possibility of a train approach to an open level crossing. If the driver is aware of the LC failure mode, he can adjust the train speed to be able to stop ahead an unexpected obstacle. A gate signal or coupled main signal informing about an operative state of the LC (not about a warning state) could be used to cope with this problem.
- Level crossing area check by a closed-circuit TV system. This solution is practicable only if the driver is provided with relevant information about an obstacle so that he can effectively brake and stop before an accident could happen. The reliability is the issue in this case, because false warning and consequent emergency brake activation could lead to injuries among passengers.
- Unambiguous interpretation of the information provided to road users. If there is a critical failure of a ŽSR level crossing, then the LC is closed unless the driver has been already informed about failed LC. Meanwhile the LC is in the warning state (if technically possible). If the engine-driver is informed about the failure, then the LC must not be in the warning state and it is possible to open it. The transport safety requires closed LC until the approaching driver is informed about the failed LC. He must be informed at a sufficient distance so that he can decelerate or even stop if necessary. The LC that is closed for a long time negatively affects the road drivers and leads to a situation that they cross the LC in the warning state.
- Different design of warning board layout with different signalling of the warning state is used in the countries of the EU, which leads to confusion of the foreign drivers. However that is the problem that no technology could ever solve. An active signal is a similar problem, which is the speciality of the ŽSR railways. In addition, not all LCs are equipped with warning boards with active signals; its effect to the transport safety is more negative than positive.
- High availability of the LCS that minimize the chance of a disabled state of an LC, in which safety at the LC depends only on adherence to the rules (whether by ŽSR employees or road users). There are some cases of LCs with poor geographical layout, so road user’s complaints of insufficient range of vision are sometimes rightfully justified.

5.2. Organisational measures

In accordance with [2] road drivers are bound to act with extreme caution when approaching an LC and when crossing it. They are also bound to verify that the LC is safe to pass. Given this interpretation of the law it is virtually impossible to make organisational measures any stricter. An absolute verification of adherence to the organisational measures and strict disciplinary action when those measures are violated by road users are the key to the safety enhancement at level crossings. A systematic preparation and further education of users of road transport is required.

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Bibliography


Reliability of data obtained from video systems of traffic surveillance

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ABSTRACT
The paper presents a way for estimating the reliability of data obtained with video systems of traffic surveillance. It describes the elements of factors determining the reliability of this indicator and presents a method for determining it using a computer simulation. This indicator can be used for assessing the quality of services.

KEYWORDS: telematics, information reliability, traffic surveillance

1. Introduction

In transport telematics, the information reliability has a considerable impact on the traffic safety. In particular, this applies to the case of traffic surveillance systems based on video images in real time. The present paper will discuss measurement errors affecting the reliability of vehicles’ flow parameters. It is assumed that such parameters are measured using motion masks. That is, using the method of difference detection of changes in the image.

1.1. Motion mask

A matrix of image differences (Fig. 1) is the matrix defined as a difference between the functions of brightness of each i(x,y) pixel in two successive frames of a scene’s sequence:

\[ A_i(x,y,t) = i(x,y,t) - i(x,y,t-1) \]  \hspace{1cm} (1)

(for all the pixels in the image: x=1,2,3,...,w; y = 1,2,3,...,h, where ‘w’ and ‘h’ values are image resolutions, while ‘t’ and ‘t+1’ are two successive moments of taking the frames into consideration).

A motion mask is defined as a processed matrix of image differences. Considering an image to be a matrix of values indicating pixels brightness, it can be assumed that a movement between images takes place only when a difference of brightness of frames from two different moments t and t+1 is other than zero. Mathematically, the difference between images may be defined as a change in pixel brightness over time. Therefore, it is the value of the partial derivative

\[ \frac{di(x,y,t)}{dt} \]

(function i(x,y,t) is a brightness assigned to a pixel of coordinates (x,y) at a time t). Since in the case of computer image analysis, we are faced with a discrete case, both in the case of the domain and the function, the subtraction of values corresponds to the calculation of a partial derivative in relation to time: i(x,y,k+1) – i(x,y,k), where ’k’ is an index assigned to successive images in a sequence.

An object motion mask is a fragment of the motion mask obtained as a result of the movement of the given object. One of the types of object motion masks is a vehicle motion mask.

We can isolate several types of motion masks that can be used for obtaining various pieces of information from an image. In the case of the methodology presented here, we applied a vehicle motion mask depending on four conditions.
1.2. Measurement Assumptions

As the mask method supposes a measurement based on the analysis of a motion mask, we need at least two images from a video sequence in order to effectuate a measurement. That is, it is possible to state that a measurement can be performed only after the acquisition of the full number of images necessary for this measurement. This propriety will be further called the first assumption.

The next (second) assumption will be the necessity to identify the vehicles. A measurement is possible only when we process the image of the same object (vehicle). That is, when we have properly identified it. It is particularly important while measuring the speed using visual methods when it is necessary to acquire information on a vehicle position in two different moments.

1.3. Measurement errors

Measurement errors affect the reliability of such measurement. A measurement often needs to be done within the limits of a certain error, for instance, a measurement of distance between vehicles.

- Errors resulting from the discrete nature of image.
- Errors resulting from the discrete nature of image changes over time.
- Errors resulting from a camera position in relation to moving vehicles.
- Errors resulting from inappropriate parameters of detection.

2. Causes of errors occurrence

In the previous section, we enumerated the errors occurring while measuring using the method based on motion masks. In this section, such errors will be described in detail.

It has been assumed that the following algorithm for the motion mask segmentation and speed measurement will be analyzed as to error occurrence. The following algorithm shows the whole analysis of the image of several vehicles motion with the measurement of their speed. The analysis is carried out in two stages:

- First, we calculate two successive motion masks using the formula:

\[ m(x, y, t) = \begin{cases} 1 & \text{when } |i(x, y, t+1) - i(x, y, t)| > P(|\Delta I|) \\ 0 & \text{otherwise} \end{cases} \] (2)

where:

- \( i(x, y, t) \) – elements of images, \( x = 1(1)w, y = 1(1)h; \)
- \( w \) and \( h \) – respectively, width and height of an image;
- \( P(|\Delta I|) \) – differences of brightness threshold;
- \( m(x, y, t) \) – element of matrix of a motion mask.

- then we search for fronts of objects’ motion masks in the calculated motion masks on the road.

As a result of the algorithm application, we obtain:

- the number of objects, images of which are correct for the analysis,
- coordinates of the fronts of two successive, but different motion masks of objects (or of their ends, as a function of the measurement mode).

We calculate two motion masks for three successive frames of the input sequence \( M_t \) and \( M_{t+1} \).

Algorithm’s data:

- \( M_t \) and \( M_{t+1} \) – motion masks matrices;
- \( G \) – trial window with dimensions \( lw \times lh \);
- \( lw, lh \) – width and height of the trial window \( G \), respectively;
- \( w, h \) – width and height of an image, respectively;
- \( wp \) – width of a traffic lane on the image;
- \( S_v \) – surface threshold (number of 1’s) in the window \( G \);
- \( S_d \) – threshold of deviation from zero for a change of the number of points with the value of 1.

We calculate the coordinates of the ends of two successive motion masks of each object and we write them down in the vectors \( x_{s1(n)} \) and \( y_{s1(n)} \), \( x_{s2(n)} \) and \( y_{s2(n)} \), where \( n \) is an index of a mobile object, \( n = 0, 1, \ldots, L \); \( L \) is a number of vehicles’ motion masks on the image.

As a result we obtain four coordinates \( x_{s1(n)} \) and \( y_{s1(n)} \), \( x_{s2(n)} \) and \( y_{s2(n)} \) of the fronts of vehicles’ motion masks. The variables \( n_1 \) and \( n_2 \) contain indexes, the value of which equals the number of detected fronts of vehicles’ motion masks. \( n_1 = n_2 \) means that the algorithm has detected the same number of motion masks in two matrices of masks.

The pairs of coordinates \( x_{s1(n)} \) and \( y_{s1(n)} \), \( x_{s2(n)} \) and \( y_{s2(n)} \) with the same indexes \( n \), indicate the beginning and the end of a vehicle speed vector, respectively.

2.1. Measurement errors resulting from the discrete nature of image and its changes over time

The nature of video sequences is discrete in space and in time. It follows from it that while locating a vehicle on a scene’s image, an error occurs as to the dimension magnitude of a pixel. The same applies to the time between successive images of a sequence. This error can be represented in the way shown in Fig. 2.
2.2. Measurement errors resulting from a camera position in relation to moving vehicles

Fig. 3 shows one of the problems resulting from the geometry of the scene as it is viewed by the camera. The camera is placed above the vehicle. In the drawing we see that a vehicle length measurement changes as a function of a vehicle position. The length measurement, as well the localization of the front and end of the vehicle may be effected with an error resulting from the scene's geometry. The drawing shows that the vehicle length, as viewed by the camera $l_p'$ is different from the $l_p'''$. This error results from the fact that it is impossible to assume the constant height of the vehicles passing by.
2.3. Measurement errors resulting from incorrect parameters of motion masks processing

In order to remove noises inducing images differences, a threshold of differences detection for successive frames of video sequences is applied. Fig. 4 shows how such threshold affects the motion detection. Any threshold decrease will induce an increase in motion detection sensitivity, while its decrease will induce the contrary effect. The application of such threshold will affect the precision while indicating the motion mask position, because any change of its value affects the magnitude and the location of motion zones positions.

In order to eliminate undesirable detections, we applied the second threshold, i.e. a non-zero threshold of motion masks elements. It induces the elimination of little motion zones created by disturbances or by movements of objects smaller than vehicles. The application of this threshold will induce a decrease in detection zone sensitivity to motion masks changes. Consequently, it will induce the errors occurrence on the border of the motion zone. This problem was represented in Fig. 5 showing the detection of a motion zone as a function of three different values of the threshold of non-zero elements of the \( S_g \) mask.

The correct localization of the position of a vehicle motion mask also depends on the width of changes detection zone in this mask. The larger a zone, the less precise the detection is. Fig. 6 shows two diagrams. One diagram for the detection window of the width of 1 pixel, the second one for the window of the width of 5 pixels.

On the other hand, a larger zone improves the certainty of the border detection by elimination of partially erroneous elements of a vehicle motion mask. That is, those having a value bigger than 0 for the pixels which do not belong to the vehicle image.

### 3. Measurement reliability indicator

After the analysis presented in the previous section, it is possible to try to determine the measurement reliability indicator. It can be determined on the basis of the impact of each error on the measurement. Fig. 7 shows the process of measurement reliability indicator calculation.

The measurement reliability indicator can be expressed by the following general formula:

\[
S_i = \frac{1}{2} \frac{L_i - L_{i-1}}{L_{i+1} - L_{i-1}}
\]

![Fig. 4. Brightness threshold in motion mask calculation](Source: [own work])

![Fig. 5. Surface threshold in motion detection](Source: [own work])

![Fig. 6. Motion masks of object detection by a moving window:](Source: [own work])

a) detection window is 1 pixel in width;

b) detection window is 5 pixels in width
where: $D_i$ is the next factor affecting the reliability and $n$ is a number of such factors.

Two assumptions should also be attached to the reliability. They could be represented as zeroing coefficients. In this way the indicator formula would be as follows:

$$D_{\alpha} = A_1 \cdot A_2 \cdot \prod_{i=1}^{n} D_i$$  \hspace{1cm} (4)

where: $A_1$ is an indicator for the first assumption and can have the value 0 or 1; $A_2$ is an indicator for the second assumption and can have the value 0 or 1.

The strength of the impact of various errors is different and it would be worth preparing a special set of coefficients for each error. If we develop the previous formula with the next coefficients, we will obtain:

$$D_{\alpha} = A_1 \cdot A_2 \cdot \prod_{i=1}^{n} k_i D_i$$  \hspace{1cm} (5)

where: $k_i$ is a coefficient for each factor affecting the measurement reliability.

4. Determination of the measurement reliability indicator using computer simulation

An indicator simulation can be carried out using the actual data in the form of known probability distributions of erroneous measurement occurrence outside the tolerance limits. In this case, the simulation algorithm for estimating the reliability indicator would be as shown in Fig. 8.

It can be rather difficult to obtain the above-said distributions; therefore, we propose the algorithm presented below, which will register incorrect measurement events while segmenting the motion mask and indicating the vehicles’ position. To this end, the algorithm in Fig. 1 has been modified and presented in Fig. 9.

Front outside and no front outside is the information from a different system of vehicles localization detection. $E_i$ is a table for registration of differences (precisely, the xor function) between the detection due to this system and the detection due to the outside one.

Using the registration of detection or non-detection of vehicles fronts by the outside system of detection, it is
possible to build a 0-1 table indicating whether the outside system has detected a vehicle front in the same place. Locating several such recorders in the analyzed system, all the incorrect detections can be registered. When the differences are written down as the road function, it is possible to assess subsequently how big is an error due to the analyzed system in proportion to the standard one. Such error can be used for indicating the Di factor of the measurement reliability indicator.

5. Conclusions

The present paper shows an attempt at estimating the reliability of traffic parameters measurement using visual systems. As the result of the analysis of the selected system detecting the position of vehicles and measuring their speed, we have defined two assumptions for such measurements and four sorts of errors occurring while using the above-said system of motion parameters measurement. We have defined the indicator allowing determining the measurement quality (service quality).

Further steps include the implementation of the presented algorithms and analysis of the results obtained from actual measurements.

Bibliography


Fig. 9. Algorithm for mask segmentation and speed measurement with elements for registration of front detection, different from those of the outside system
Source: [own work]
Road user protection via intelligent camera surveillance

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ABSTRACT
Because of increasing traffic volume and complexity, road safety is now more than ever a hot topic on the government agenda. Traffic managers at all levels are organizing today debates with the following central topic: how can we better protect the road user?

One of the solutions to improve pedestrian safety is via Video Image Processing technology. This video detection technology detects faster than any other detection technology. By analyzing the video images in real time, you immediately receive a clear image of potentially dangerous situations. Result: the danger of the incident is substantially reduced and secondary impacts are prevented.

Is video detection a cure-all? Just like any other ITS technology, this detection technology must be used correctly. Different applications require different cameras and different camera positions. One must not start implementing video detection technology without a complete understanding of the costs and benefits associated with these systems. If the correct guidelines and parameters are taken into account and implemented correctly, video detection has proven to be very reliable and can offer great solutions to the end user.

KEYWORDS:

1. Introduction

Every year, more than 1.2 million people die on the world’s roadways, and as many as 50 million others are injured. Nearly half of those killed each year are pedestrians, motorcyclists and passengers on public transport. As well as the devastating loss of life, pedestrian accidents cost countries financially – the level of injuries affects global GDP by up to 3%. In low- and middle-income countries, road traffic accidents can cost US$64.5 billion per year.

2. Road User Protection in Urban Environments

The number of fatalities is highest in urban areas, which is logical, as urban areas are where the numbers of pedestrians are higher and more concentrated. And although many pedestrian deaths occur at locations where vehicle speeds tend to be fairly high (for instance, freeways) and drivers are not expecting to stop, there are a significant amount of crashes at intersections.

Studies in the USA have shown that 36% of older pedestrian deaths occur at intersections (compared to 21% of deaths involving pedestrians under 70). Factors contributing to this include older pedestrians taking longer to negotiate intersections, as well as the increased possibility of diminished hearing, vision and reaction time.

Younger pedestrians are also at risk on the roads, with the almost clichéd example of a child running out between parked vehicles being a factor in many vehicle-pedestrian collisions. Around 500 children die in traffic accidents every day, many of whom are pedestrians. Of course, it is not only deaths that we should be concerned about. Hundreds of thousands of people suffer debilitating injuries...
in road accidents each year. The majority (around 80%) of serious pedestrian injuries resulting from automobile collisions are head injuries. Those that are lucky enough to survive a collision often become permanently disabled, either from losing a limb or other serious injury.

There have been many studies relating who is at fault in these situations: for instance, in most intersection collisions, the pedestrian is judged to be at fault. Regardless of fault though, most people agree that much more needs to be done to protect vulnerable road users. In a civilized society, walking to work in the morning should not mean risking death or disfigurement. And people on foot have just as much right (and arguably more need of) the same levels of protection that are offered to those traveling in vehicles.

3. Work Conducted so Far

Governments across the world are focusing their efforts on education. One crucial aspect that will bring down the death and injury toll is to modify behaviour. This means encouraging drivers to behave safely (through a variety of strategies, including reducing speed and not driving while impaired by alcohol, drugs, or even tiredness) and also targeting pedestrians – from a very young age – to make them become responsible road users.

Automobile manufacturers are investing millions of dollars into designing safer vehicles. Redesigning bumpers is a key part of this research, as are concepts such as external airbags. Vehicle-based pedestrian detection sensors are also being heavily researched.

Road designers, town planners, architects and traffic managers are now taking greater responsibility for protecting pedestrians – ‘Safer by design’ seems to be the mantra sweeping through this sector. Design improvements range from simple, cost-effective solutions, such as adding more pedestrian refuges to roads to more high-end deployments, such as placing pedestrian sensors in the pavement to control traffic signals.

One technology-focused solution that has the potential to improve pedestrian safety on a large scale is intelligent camera surveillance, using Video Image Processing technology. Already a staple tool within traffic management applications, people are beginning to recognize the benefits that this technology could bring to pedestrian safety. Video detection technology is proved to detect quicker than any other detection technology. Analyzing the video images in real time allows users to immediately see a clear image of any potentially dangerous situations. This has the knock-on effect of the danger of the incident being substantially reduced, and also helps to prevent secondary impacts.

4. Geography Lesson

Video detection experts definitely note a pressing need to deploy this technology in Europe. Once it has proved popular and effective there, it is likely to take off on a large scale in countries such as the USA. One reason for a high demand from Europe is purely historical: European cities are hundreds of years older than American cities and have narrow streets that were never designed for automobiles to use. Consequently, pedestrians are more vulnerable here than elsewhere.

For many years, Europe has also been using inductive loops or in-pavement sensors for traffic management and detection applications. But the dominance of loops has not been without its pitfalls. They can be troublesome to install and maintain, which therefore means high labor costs, so have not proved to be the cost-effective solution they were...
originally touted as. Installation usually means disrupting traffic flows, which causes huge headaches for those individuals attempting to manage their road networks.

Another problem with loops is that they quite often have a high failure rate. Coupled with their inflexibility, it is amazing how much money and time has been invested in them. One of the reasons why loops took such a huge market share was that when they were first being deployed, customers just didn’t have the choices they do today. Nowadays, there are a variety of competing solutions being deployed for traffic detection purposes – from radar and wireless sensors to video.

5. Fast Incident Detection And Direct Visual Feedback

Why, then, is video detection for pedestrian safety the best way forward? In other mission-critical applications, video detection has proven to be a valuable and reliable tool for traffic managers. Video detection technology today is seen as the standard and field-proven technology for automatic incident detection in tunnels. In a tunnel, every second counts – and no other technology detects incidents faster than video. In addition, the combination of both numerical data and visual image control sets video detection apart from other systems. The immediate visual feedback received from video systems allows fast incident response, which is a huge bonus for managers needing to make rapid-fire decisions. Pedestrian inside a tunnel are detected within seconds. The link now to urban environments is quickly made.

Successfully used for many years to detect pedestrians in tunnels, it is a natural progression to start putting this technology to work in urban environments.

6. Vital guidelines

Is video detection a cure-all? Just like any other ITS technology, this detection technology must be used correctly and for specific applications. For instance, different applications (data collection or incident detection) require different cameras and different camera positions. One must not start implementing video detection technology for traffic management and safety without a complete understanding of the costs and benefits associated with these systems. If you have been tasked with installing an incident detection system for the first time, there are a number of important issues to consider.

6.1. Understanding the basics

Understanding the basics of video detection technology is the first step. Intensive research allows detailed and realistic goals to be determined. As AID technology offers a wide range of possibilities, it is an absolute must to bring all parties (video detection supplier, system integrator and end customer) together to fine-tune the needs and wishes. Partners come together to state clear goals for the specific project. Discussions are held on defining acceptable detection rates, detection features (such as stopped vehicles detection, pedestrian detection, smoke detection and so on), system architecture and communication. Also important is to create a detailed plan that outlines who does what and when.

For Automatic Incident Detection projects using up to 50 cameras, six to eight months should be allowed for complete installation. This encompasses time for installation, configuration, fine-tuning, testing and evaluation.

6.2. Camera: the eye of the system

As video image processing depends on the quality of the image received, a high-quality input source is required – the camera functions as the eye of the system. Determining the type of camera, the camera position and the number of cameras that need to be installed is a crucial phase for having a performing detection system. Prior to installation, Traficon provides assistance for this process and can also perform testing on cameras to determine their detection performance.

6.3. Easy integration

When implementing a video detection system, easy integration with the overall management system is an absolute must. A detection system needs to be a modular system with an open protocol to improve the ease of integration into a SCADA system.
7. Conclusion

The success stories from other applications – Automatic Incident Detection systems in tunnels - speak volumes in predicting how valuable the video detection technology could be for pedestrian detection. It is not luck that Traficon has been involved in video detection since the late-1970s: it is a fact that time and time again, this technology helps to save lives, keeps traffic flowing smoothly and provides accurate and reliable data.

This is not to say that video detection is a cure-all. But if it can save even one pedestrian from being killed or injured, then isn’t it worth giving it a try?

Bibliography

GPS use to determine accurate speed

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ABSTRACT
The paper presents the importance of measurements and research in the road traffic as well as the most often used methods of speed measuring. Possibilities of GPS system use for speed measurements are described. Possibilities created by this method usage to determine the speed in the road traffic are shown.

KEYWORDS: mobility, road traffic measurements, speed, methods of speed measurement in road traffic, GPS

1. Introduction

In the Middle Ages a European tramped about 200 meters per day. At the end of the 19th century he tramped already 500 meters. Nowadays an average distance which is passed during day by a European is equal to 50 kilometres. Big part of that distance a human covers by participation in the road traffic.

Participants of the road traffic are pedestrians and different type vehicles driven by humans. Pedestrian and vehicle traffic depends on many factors, determined as "road conditions" [3,4,7]. "Road conditions" is a group of factors which are directly or indirectly related to the road, which influence efficiency, economics and traffic safety [7,9]. Road conditions meant in such way are characterized by road features and also by traffic parameters, which are a function of, among others, road features. Traffic parameters are connected with roads’ features. The traffic speed and its density are the parameters especially important from the road traffic description point of view [5,6].

2. Measurements of and studies on the road traffic

Measurements of and studies on the road traffic are one of basic traffic engineering sections. They are the basis for analyses and decisions connected with road solutions planning and designing and they are helpful at solving problems related to the traffic management and organization [5,6,7,9]. The first road traffic measurements were conducted in France in the year 1844 [7]. They were repeated every few years with the purpose of establishing relations between the traffic volume and roads construction and maintenance.

The date of the first road traffic measurements in Poland is unknown. It is only known that at the end of 19th century vehicles were counted on main high roads in some cities of Poland, which appeared in those administrative sections during conferences, markets and church fairs.

From the beginning of seventies, as a result of increase in transport problems caused by the growth of vehicles number and by the increase in society mobility, different type of measurements have been made. The range of measurements and studies performed, especially in relation to urbanized areas, changes with motorization development. Directions of conducting measurements and studies on the road traffic have been devised, thanks to what it is possible to compare results of measurements made by different entities in different places [5,6]. Generally we can claim that traffic studies are conducted for very different ad hoc and long-term goals, and needs and requirements in that field are very diverse in different countries [3,8].

The range of research and analyses conducted now in
Poland and their usage depends on goals of their performance. Basic purposes of traffic research include [4,5,7]:

- getting to know and describing rules of traffic,
- providing data for analyses of traffic needs and of changing tendencies for areas of transport research,
- providing data to design and operate elements and equipment of transport system,
- analyses of traffic as a sociological phenomenon.

So the basic aim of measurements and traffic research is getting the information about transport system operation and behaviour, which can be put down to transport system elements. Another practical use of measurements and research is the implementation of task connected with town planning and different types of economic analyses.

The most frequent measurements and road traffic research include: traffic intensity measurements, speed measurements, measurements of time loss and measurements of parking [4].

3. Speed measurement methods

Speed is the most essential attribute of road traffic [5,6]. It can be a determinant of road traffic quality and its consequences with reference to participants and in the social dimension [7]. It decides about comfort, economics and road traffic safety. The following speed types are mainly studied [5,10]:

- temporary speed, that is a speed in a determined road section,
- speed of driving or walking, that is an average speed of an object (e.g. vehicle) movement on a road section without the time of stops,
- journey speed, that is an average speed of an object (e.g. vehicle) covering a road section, taking into account the time of stops.

Drive and journey speed is marked out in an indirect way, on the basis of drive (walk) speed.

Speed measurements are made by different methods with external and internal equipment, stationary and non-stationary [3,5]. The choice of equipment is made depending on the type of speed measured. We have also to determine if we are interested in a single vehicle or in the whole vehicle stream.

In the case of temporary speed measurements we need to distinguish two situations [5,9]:

- when the speed of a single vehicle is measured on the same determined profile during a determined time,
- when the speed of a single vehicle is measured on many profiles of the section what is related to current vehicles arrangement at the observation moment.

The following ways of measurement can be used to perform measurements in the first case:

- measurement of time needed to cover a short part of the road (on the assumption that this speed does not change) with the use of stopwatches, detectors (pneumatic, induction, magnetic, optical, radar) or video-detectors; measurements with drive detectors usage need their installation before,
- direct speed measurement by a radar meter or by its reading from a speedometer in the moving vehicle on the measured section.

Measurements of the drive speed and journey are most often taken at the same time and determine time of vehicles movements and stops. The measurement depends on multiple drives on the studied section by a test vehicle at a speed close to the speed of other participants of road traffic [3,7]. Any type of vehicles which appear in the stream of vehicles on the analyzed section can be the test vehicle.

An observer in the vehicle has measuring equipment which assures identification and data registration, enabling to ascribe those values to proper points in space. The information about the time of driving (time of starting and stopping) and of stops is registered, reasons of stops caused by the traffic organization and other reasons disturbing fluent driving.

The values of time of driving and of stops in individual parts of the measurement section can be counted for that section and its parts, journey speeds. If we make many drives it will be possible to determine average values of measured speeds. The values obtained can be shown in a road vs. time graph, thanks to what we can estimate traffic conditions on the section.

Speed measurements are also performed to determine the speed profile and speed line. Those measurements are made by multiple drives on the analyzed section in a test vehicle [6,7]. The test vehicle should have proper equipment allowing a temporary speed registration of the moving test vehicle. The data obtained can be shown as a speed dependence on time in the form of a graph [7]. Because of simultaneous graphic recording of driven road length this dependence can be converted to a speed profile. It allows making analyses of traffic conditions of vehicles streams.

An alternative method of speed measurements is the use of video cameras with a scanner, which allows speed measurements and classification [3,7]. The advantage of video detectors is the possibility of serving many traffic ways by one measuring device, the disadvantage – lower efficiency at night and in bad weather conditions. Because of that the video detectors are more often used in cities [9].

Methods of speed measurements mentioned above require special equipment which is installed in vehicles,
adapting means of transport to speed measurements, using special measuring vehicles with proper equipment installed during vehicles fitting out or building proper measure systems in the transport infrastructure. In the case of measuring vehicles it is required to buy a properly equipped vehicle or to adapt a vehicle to speed measurements. Such measurements cannot be made without previous preparation.

4. Speed measurements using GPS

GPS that is the Global Positioning System is a satellite system which assures precise determination of the position, speed and time. Twenty four satellites NAVSTAR (they are on 6 levels at a height of 20180 km, at 55° angle of inclination) which run around the Earth and transmit a radio signal which allows determining the actual position. The signal is available worldwide and the usage is free. Measurements accuracy fluctuates from a centimetre (geodetic receiver, differential GPS) to several dozen meters (simple navigation receiver without a differential correction) [2,8].

The minimisation of the equipment, higher precision and the reliability of operation cause that the GPS becomes a precise global system, commonly used by different users and for different objectives. Nowadays at the world there are more than 4 million GPS users.

The GPS - Global Positioning System – is a system which uses methods of navigation parameters measuring. The method is based on the distance measurement to at least three known points – satellites, which position is known by the user at any time. The straightforwardness of radio waves propagation and their steady speed of propagation provide conditions for the distance measurements method. Navigation parameters are measured directly by the measurement of propagation time of radio signals of known structure transmitted by a navigation satellite and received by the user's receiver. The condition for proper operation of a navigation system using the distance method is [2]:

- elimination of time scale fault in the receiver;
- proper synchronization of user's receiver time scale with the time scale of GPS system.

The measurement of distance between a navigation satellite and user's receiver is made by transmission of known structure signal by the satellite transmitter and next comparing the signal received with its replica in the receiver. As a result of that we obtain the propagation time of electromagnetic wave, which multiplied by the speed of electromagnetic wave propagation gives the distance between the object and satellite [2].

GPS receivers calculate also the object’s speed on the basis of relative speeds of the receiver and satellite measurements. Usually receivers update data of pseudo-distance and relative speeds on a second. The purpose of navigation is to calculate the receiver position, speed and time in the GPS scale. The time passing between the moments of signal transmitting and receiving is directly proportional to the distance between the satellite and receiver, so it is necessary that both the satellite and receiver use the same time as a reference. The receiver uses a reconstructed GPS time scale to measurement data received from the satellite. Receivers have no high-stability model as for example an atomic model, which is on satellites. Instead, receivers have quartz oscillators. The lack of time scale generated by this oscillator conformity with the GPS scale is corrected on the basis of measurement results of four pseudo-distances. This allows solving a system of four equations with four unknown: three receiver coordinates and the correction of receiver time scale. The counted speed is similar, but with the use of relative speeds instead of pseudo-distances.

The system fixes the receiver speeds:

- on the basis of its position change,
- using the Doppler effect – that is on the basis of electromagnetic wave frequency change caused by object’s movement.

To improve the positioning by GPS so-called Differential GPS is added, a system of referential ground bases, which allows determining the position with higher accuracy. More advanced space specifications are also used which take into account:

- Sagnac effect,
- real Earth shape, which is not an ideal sphere,
- Earth gravitation and magnetic dynamics which is a result of its rotary movement in relation to the north-south axis.

Differential systems work using both methods:

- In real time – conducting corrections to the receiver by radio waves; they are conducted by a working base receiver of known antenna coordinates,
- Remembering results of measurements made by a moving receiver and a base receiver and later computing the correction data for the moving receiver.

Using this method in real time a precision of 0.2 – 0.5 m is obtained [1]. Its use requires: base receivers, moving receivers and a contact canal to corrections transmission [2]. The measurements precision can be additionally increased using a GPS receiver with an external antenna, which allows eliminating more disturbances.
Using the available, GPS referenced, navigation systems on a portable computer it is possible to perform measurements in one vehicle.

After making the measurements and saving the data on a portable computer it is possible to get the following data:

- time of measurement start and finish,
- length of way,
- average and maximum speed,
- minimum and maximum height above sea level,
- information about lay of the land;

- referenced to entire data:
- real time,
- distance from the beginning of measurement,
- geographical data,
- speed,
- value of measurement quality.

After measurements the data obtained can be transformed using e.g. EXCEL. The scope of analysis depends on the objective of the measurements and of studies on the road traffic. Examples of data and results are shown in Figures 1-6.

An additional advantage of this measurement method is the possibility to illustrate changes of speeds and interesting road traffic parameters in reference to longer measured sections. Because of data collection and registration it is possible to perform different analyzes of basic road traffic parameters.
5. The References Section

The GPS use allows making speed measurements without modification of a vehicle collecting the information about road traffic parameters. At every moment it is possible to make such observations without the necessity to buy special equipment or special test vehicle. Only a standard means of transport, proper GPS receiver with an external antenna and a portable computer, where measurements data will be registered, are needed. Thanks to measurements made in such a way it is possible to obtain different data with a satisfying precision. Then it is possible to interpret the results properly in reference to e.g. time or road profile. This data working out depends on the purpose which decides about the measurements necessity.

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