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1 Introduction

1.1 Purpose of the Document

The purpose of the document is to summarize the industrial and economic impacts of the usage of road and vehicle sensors which can enhance the effectiveness road transport management and the transport safety.

1.2 Document Status Sheet

<table>
<thead>
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<th>Version</th>
<th>Date</th>
<th>Description</th>
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<tr>
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<td>15.06.2007</td>
<td>The impact of the usage of road sensors</td>
</tr>
<tr>
<td>1.1</td>
<td>21.11.2007</td>
<td>Interim report on industrial and economic impacts of the usage of road and vehicle sensors</td>
</tr>
<tr>
<td>1.2</td>
<td>29.04.2008</td>
<td>Final version</td>
</tr>
</tbody>
</table>

Table 1: Document Status Sheet

2 Reference Documents, Abbreviations and Definitions

2.1 Reference Documents

[1] MORYNE Description of Work


[3] Dr. Tánczos Lászlóné, Dr. Bokor Zoltán: A társadalmi költségeken alapuló közlekedési árképzési rendszerek gyakorlati adaptációs lehetőségei;


2.2 Abbreviations

GPS: global positioning system
EU: European Union
ASC: average social cost of the journey
2.3 Definitions

External costs: costs caused to the others (environmental protection, accident damages, etc.), which will not be paid by the persons participating in the transport. The principles declared by the EU are: the external costs shall be loaded onto the user in addition to the paying of the expenditures of the infrastructure (this is the so called internalisation of the external costs), and thereby the carriers will be influenced in their decisions. The external costs are the highest in the field of the road transport.

External economic impact, i. e. an overflow occurs, when the production or the consumption will cause additional expenditures or benefits to others so that they will not be paid by their originators. More exactly the external economic impact is an impact caused by the behaviour of one player in the wealth to an other player, which will not appear in Euro i. e. in the form of a market transaction.
3 The industrial and economic impacts of the usage of road and vehicle sensors to enhance the effectiveness of road transport management and the transport safety

A. Industrial impacts

The usage of road and vehicle sensors can support the road traffic management information systems which are in connection with the automated weather reporting stations with special sensors embedded in and below the road, and on nearby towers. These systems collect detailed data on weather conditions at and near the road surface, which can assist weather forecasters in predicting road surface conditions. Road maintenance crews can use “real-time” road weather information to decide if road treatment is necessary, when to treat, what chemicals or mixtures to use, and how much is required.

Road weather information systems have two major benefits. First, by enabling maintenance crews to treat roads in advance of icing conditions, winter driving safety can be enhanced. Second, by reducing the overall amount of road salt used, they can help mitigate the negative impact of road salt on the environment.

Data collected by vehicle sensors can also be incorporated into advanced traveller information systems for use by the public.

The following section contains an overview of environmental sensor technologies including fixed environmental sensor stations, mobile sensing devices, and remote sensing systems. Transportation managers must access data on environmental conditions to effectively and efficiently mitigate weather impacts on traffic operations. This data serves as decision support to managers, who disseminate relevant road weather information to the public. There are many operational applications for environmental data. Environmental data may be integrated into automated motorist warning systems, road weather information systems, advanced traffic management systems, emergency management systems, and advanced traveller information systems. This information may also be used to enhance forecasts and supplement environmental monitoring networks.

Winter maintenance managers utilize road weather information to assess the nature and magnitude of threats, make staffing decisions, plan treatment strategies, minimize costs (i.e., labour, equipment, materials) and assess the effectiveness of treatment activities. Traffic managers may access road weather data to control traffic flow and warn motorists. Based upon prevailing or predicted conditions, managers may alter traffic signal timing parameters, modify incident detection algorithms, vary speed limits, and restrict access to designated routes, lanes or vehicle types. Some traffic management centres utilize such systems that integrate weather data with traffic monitoring and control software. Transportation managers disseminate road weather information to motorists in order to influence their travel decisions. This allows travellers to make choices about travel mode, departure time, route selection, vehicle type and equipment, and driving behaviour.

Mobile sensing involves the integration of environmental sensors with vehicle systems. In combination with global positioning system (GPS) technologies, truck-mounted sensor systems can be utilized to sense pavement conditions (e.g., temperature, friction) and atmospheric conditions (e.g., air temperature).

Pavement friction coefficient can be assessed with deceleration devices, locked wheels, and variable slip systems. Deceleration devices measure a signal generated by a strain gauge when a vehicle brakes. The signal, which is proportional to the deceleration rate, is used to compute the friction coefficient. Friction can also be determined by a locked wheel that is towed behind a vehicle at 40 to 60 kph. Brakes are applied to lock the wheel for one second while the resistive drag force is measured. Variable slip systems calculate pavement friction as a function of the degree of slip between a tire and the road.

Mobile sensors are increasing in popularity throughout the transportation industry. They are typically deployed to observe environmental conditions from any type of vehicle. Vehicle-mounted sensors can
be utilized to sense air temperature, pavement temperature and atmospheric conditions. Mobile data provides quick, real-time information for decision-making on the go, and it supplements fixed information sites with additional details.

Surface sensors measure pavement conditions (e.g., temperature, dry, wet, ice, freeze point, chemical concentration), and subsurface or soil conditions. There are two basic types of surface sensors, active and passive. Active sensors generate and emit a signal and measure the radiation reflected by a targeted surface. Passive sensors detect energy radiating from an external source. Passive pavement temperature sensors are normally buried in the road surface. These sensors are designed with thermal properties similar to pavement so that they are heated and cooled at the same rate.

Pavement condition can be monitored with sensors embedded in road surfaces, friction measuring devices, cameras, and microphones. Embedded sensors typically distinguish between two or three pavement states (e.g., dry or wet). The surface of an active pavement condition sensor is cooled below ambient air temperature. If pavement moisture is present, dew or frost will form on the cooled surface. This type of sensor can also be used to assess the effectiveness of road treatment chemicals and determine the temperature at which pavement moisture will freeze. Another type of pavement condition sensor emits microwaves from an overhead transmitter. If moisture is present on the pavement, microwaves reflect off of the water surface and the road surface. A receiver detects the pattern created by the reflections to compute the thickness and salinity of a film of water.

Friction measurement devices assess the pavement coefficient and classify conditions based upon assigned ranges of values. Video signals from cameras and audio signals recorded by microphones can also be analyzed to distinguish differences in pavement appearance or tire sounds caused by water, snow, or ice. Subsurface conditions (e.g., soil temperature, soil moisture, and freeze / thaw cycles) may be detected with a soil thermometer or geo-thermometer, which measures values at various depths. These conditions characterize the transfer of heat between the soil and the pavement.

Agencies are also evaluating mobile sensors to determine pavement freeze point temperature. The freeze point sensor is composed of a receptacle that collects liquid from tire spray, as shown in the figure. A computer system closes the receptacle lid, calculates the freeze point of the liquid, and blows air over the sensor to prepare for the next measurement cycle. Additional research is needed due to the complexities of mobile pavement condition sensing.

Weather acts through visibility impairments, precipitation, high winds, and temperature extremes to affect driver capabilities, vehicle performance (i.e., traction, stability and manoeuvring), pavement friction, and roadway infrastructure. Fixed environment sensor stations, mobile sensors, and remote sensing systems can provide valuable data that can be used to improve roadway safety, maintain roadway mobility, enhance agency productivity, and facilitate dissemination of travel information to the public. Several issues must be considered when planning to deploy environment sensor stations and implement testing. Concerns include procurement and maintenance, data sharing, and institutional issues.

The project demonstration will show for the experts how can the vehicle traffic control collect data of the vehicles (busses) using onboard sensors and remote information like position, lateral acceleration, wheel- and vehicle-speeds as well as weather conditions. The electronic data processing results the synchronisation of the data and proper traffic control measurements will be taken. The behaviour of the vehicle and driver can be followed up.

The advantages to be achieved with the aid of the influence exerted on the traffic lights – the quantity of the traffic engineering instruments – in the field of the bus traffic:

- the throughput of the line network will be increased
- the transportation will become scheduled
- the journey time will be reduced
- the travelling speed will be increased
- the environmental load (emission, noise, vibration) will be diminished
- the load of the road surfaces will be reduced (the length of the acceleration and deceleration section will be reduced).
The extent that will influence the traffic engineering instruments controlled by sensors the travelling speed of the vehicles running on the given line, the number of vehicles, the number of attendants, the operating costs:

- the travelling speed will be increased
- the number of vehicles will be influenced by the service performance expected traffic (technical staff of the vehicles troubleshooting, road events)
- the number of vehicles will be influenced by the passenger flow value characteristic for the given period of the day
- the number of attendants will be influenced by the service performance expected traffic (technical staff of the vehicles, troubleshooting, road events)
- the operating costs per performance unit will be influenced by the embarrassment of the traffic and by the technical state of the vehicle.

Remarks concerning the development plan related to the public transport fleet of the MORYNE project (Budapest Transport Co.)

The results to be achieved by the MORYNE project in the field of public transport and of the economy presume an engineering-environmental system of the public transport at the appropriate level: (the basis of the example of Berlin).

The capital town of Budapest maintains and operates VMZ (traffic flow data collecting system), VkRZ + TMC (databases for the determination of new routes).

The public transport company of the capital town of Budapest maintains and operates

-- RBL (digital sound and data transmission between the traffic controlling centre and the motor vehicles)
-- DGPS
-- Influencing the traffic signal lamps
-- Dynamic passenger information
-- LAN automatic data transmission at the bus stations
-- Passenger information
-- AVL – vehicle fleet handling system

The results to be achieved by the use of the planned sensors presume the availability of the engineering preconditions mentioned above in details. The BKV exclusive joint stock company as the public transport company of the capital town of Budapest does not operate the denominated systems at present, Budapest does not maintain a data collecting system for the traffic flow and is not able to transmit data at present toward the participants of the traffic for the sake of determining the new routes.

As end user our professional observations and remarks will be handed over. The expectable results of the planned development necessarily suppose the availability of the suitable engineering-professional environment.

The elaborated automatic passenger counting in the intelligent transport system of Miskolc

The primary function of the system concerned is to give suitable primary data- passenger load - for the service design and optimisation, on the basis of which the exploitation level of the individual service lines formed by the individual buses or bus groups, the timely and spatial distribution of the passenger loads can be determined.

- The system provides primary data for the determination of the passenger load for solo or articulated buses.
The primary data serving for the determination of the passenger load will be determined in the basis of the perception of the pressure measuring of the pneumatic spring. The system can provide data for the given bus or bus group on the basis of the timely and spatial view given by the user. The built up system can monitor further parameters continuously and for the processing of them for the sake of the optimum exploitation if the relation price/value in addition to the primary function and for the on-line transmission of the data after the later improvement.

The elements of the system

Units mounted on the buses

- Remote pressure transponders
- Cable-bundles
- ECU (pressure signal gathering unit)
- DTU (communication unit)
- GPS antenna
- Controlling LED for signalling back

Units of the reading off station

- Data collecting server
- Communication stations (4 pcs, placed on pillars)
- Connection with the fuel station system
- Uninterruptible power supply

Client software

In the course of the accomplishment of the project the most possible specific pressure transponding sensor had to be determined, that could offer resistance to the external impact of the environment for the long term and at the same time was suitably cost-effective.

A unit called ECU was developed for the pressure sensors, as well as for the storage and pre-processing of the data.

The data collected by the ECU will be transmitted to a central processing server also with the aid of a unit was developed also in the framework for the project, with the DTU.

The reading of the data will be carried out completely automatically on the basis of the customer’s request so that the problems arising from the human errors can be eliminated. The reading is carried out so that in the moment, where the bus has arrived at the fuel station, the bus will be identified by the existing fuelling system, and the DTU will start to transmit the measured data of the ECU to the server with the aid of a wireless WiFi connection in structured form. Out of the incoming raw data at the server the proper statistics will be elaborated by a software running as a background service.

A client software has been developed, that can be installed on whatever PC – through the setting of the parameters related to the appropriate data basis – and the passenger number data of the buses equipped with passenger counting devices van be indicated in hourly, quarterly or broken down for the vehicles in structured form. The client software can be installed and used on every PC, where the operation system Win98/Win2000/Win XP is installed and has an Internet connection with proper band-width in order that the system can communicate with the data collecting server.

In the server to be found on the side of the client the following functions were elaborated:
after choosing the relation-direction-datum parameters we can follow up the measured passenger load data in
- stop-distance
- service
- quarter-hourly
- hourly breakdown;

- The export of the data in MS Excel form or into the text registers for further calculations;
- Preparation of a reference data series for the given period.

The concrete determination of the passenger number will be made on the basis of an average weigh of 65.5 kg, using the measured pressure value. The choice of the parameter data or the data series in hourly breakdown can be seen in the Figure 1.

The data series exported can be used for further calculations. In the Figure 2 the table exported or the graphic prepared with further utilisation of it.
The expert designing the network or the timetable is frequently wondering not about the passenger load of a concrete service. In a given case it can be more useful, if an average data series projected to a period will be considered as standard, eliminating thereby the unevenness appearing at the daily level of the passenger load, which can be influenced by the most different environmental impacts (e. g. weather, holiday in the school, etc.).

More exact conclusions can be drawn, if we use the average data series of a given period, the preparation of the reference data series for the software renders this possible. Using this possibility we can get the data provided by the previously used target traffic passenger counting method automatically and in a more precise form.

B. Economic impacts

Partnerships with neighbouring public agencies and the private sector can facilitate data sharing and help defray the initial and recurring costs of field sensors, communications infrastructure, central hardware, and processing software. Another alternative is to fund information system component installation as part of larger construction or intelligent transportation systems. Preventive maintenance funds must also be secured to ensure that sensors are properly calibrated and provide accurate data. Exchanging environmental data and information with other agencies can minimize surveillance costs. Environmental monitoring networks can be created to collect and integrate data from many sources, store relevant data in centralized databases, and disseminate information in useful formats. The need for redundant infrastructure can be eliminated by coordinating with other agencies. Because environmental sensors are available from various vendors in numerous configurations, technological compatibility and communications standards must be considered in joint efforts.

At the analysis of economic impacts of the sensor’s usage the saving of external costs shall be investigated. These are costs caused to the others (environmental protection, congestion, accident damages, etc.), which will not be paid by the persons participating in the transport. The principles declared by the EU are that the external costs shall be loaded onto the user in addition to the paying of the expenditures of the infrastructure (this is the so called internalisation of the external costs), and thereby the carriers will be influenced in their decisions. The external costs are the highest in the field of the road transport. These directives are implemented in the Hungarian transport policy.

An external economic impact, i. e. an overflow occurs, when the production or the consumption will cause additional expenditures or benefits to others so that they will not be paid by their originators.
More exactly the external economic impact is an impact caused by the behaviour of one player in the wealth to the other player that will not appear in the form of a market transaction.

The internalisation of the external costs is task of the welfare economics. The expenditures of the society can be made internal with the aid of taxes imposed uniformly on the production. The optimum tax is equal to the external marginal cost belonging to the optimal pollution level.

The problem of the social costs is the identification of the participants of the processes, the number of affected persons is high, the identification of the suffering of the damages is difficult, and the sum of the transaction costs is not equal to zero.

The usage of road and mobile sensors can provide important information about the weather and pavement conditions, as well as about the traffic situation which can contribute to the organisational work of the transport company and the traffic management system. If necessary they can warn drivers about dangers and can apply supplementary transport services. This can initiate transport organisational measurements and contribute to reduce external costs.

At the calculation of the economic impacts cost-based methods shall be used. They start from the assumption that the value of a natural source (the usefulness assured by it for the human being) is the same as the value of the costs required for its preservation/reconstruction. With the damage of the natural source some kinds of services get also lost. In order that this shall be prevented or artificially replaced some investment shall be made. This means costs and expenditures. With the value of it we can estimate the value of the originally gratuitous service.

The efficient organisational work can save costs and material resources. The available information about the weather and pavement conditions can make the transports safer and reduce the external costs of accidents. The sensors provide also actual tactical traffic information which reduces the external costs of congestion because the traffic measurements can be carried out in time. A slight speed reduction caused by congestion can cause ten million of Euro extra external costs for the society on a yearly level.

The most important variables for the characterisation of the road traffic are as follows – the speed of the traffic (V) – the density of the traffic - the volume of the traffic (Q). Whilst for the description of the movement of an individual vehicle we shall only know its speed, then in the case of several vehicles we shall have information about the traffic-density and the traffic-volume. By this we understand the number of motor vehicles on a unit of the road section (measure: vehicle/kilometre)

In the micro-economic model the price of the transport can be derived the required length of time. In the case of changing the traffic-density the time required for the unit length of the sector will change in reverse proportionally with the speed (\( t/s = 1/V \), t – time, s – way). If the speed diminishes, then the journey time will increase, and as a consequence of it the average social cost of the journey (ASC) will also increase. For the sake of simplicity we shall suppose that the vehicle drivers form a wholly homogeneous group and they are facing with the same costs.

The increase of the journey time means first of all as a consequence of the not occurring working or leisure times an implicit cost. On the other hand the fuel consumption, the pollution of the environment, and the other costs will increase in the case of the decrease of the speed. The other costs independent on the speed are the maintenance costs, the insurance and the taxes. The usage of mobile sensor network provides a positive economic impact because gives enough information about the traffic situation and weather conditions to the traffic management and by proper transport organisation the journey times can be reduced and congestion can be avoided.

One of the key issues of the cost-benefit calculations is the prediction of the traffic (volume, composition, speed) to be expected on the road network investigated after putting this into service. This does not form a part of the cost-benefit calculation process, but it is an important input data for the process. The determination method of the traffic has to be demonstrated.
In simple cases (by-passing roads of small settlements, pavement reconstruction performed on a shorter section, cross-section extension), therefore when no important traffic rearrangement can be expected in the area investigated, manual methods are to be used for the prediction, and so the future traffic volume can be determined with the aid of traffic engineering multiplications given in the technical prescriptions of the road construction.

In other cases (e.g. urban by-pass streets, express roads, and longer sections of main roads) the characteristics of the traffic should be determined with the aid of computer aided models.

Table 1: The specific value of the travelling time, HUF/ vehicle-hour, 31; December 2006 (1 EUR= 250 HUF)

<table>
<thead>
<tr>
<th>Categories</th>
<th>on the national public road</th>
<th>on the roads of the municipalities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light vehicles</td>
<td>3 421</td>
<td>2 954</td>
</tr>
<tr>
<td>Heavy vehicles</td>
<td>10 034</td>
<td>10 919</td>
</tr>
<tr>
<td><strong>Passenger cars</strong></td>
<td>3 066</td>
<td>2 588</td>
</tr>
<tr>
<td><strong>Freight transporting vehicle</strong></td>
<td>6 382</td>
<td>6 382</td>
</tr>
<tr>
<td><strong>Bus</strong></td>
<td>31 303</td>
<td>38 108</td>
</tr>
</tbody>
</table>

The deviation between the specific travelling time-values of the national public roads and of the roads of the municipalities is arisen from the change to be experienced in the exploitation level of the passenger cars and of the buses.

Table 2: The specific value of the travelling time, HUF/passenger-hour, 31. December 2006

<table>
<thead>
<tr>
<th>Categories</th>
<th>on national public roads and on roads of the municipalities</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>(Passenger cars of business purpose (proportion 18%)</strong></td>
<td>3905</td>
</tr>
<tr>
<td><strong>Passenger cars of non business purpose (proportion 82%)</strong></td>
<td>1458</td>
</tr>
<tr>
<td><strong>Passenger cars, average</strong></td>
<td>1899</td>
</tr>
<tr>
<td><strong>Bus (15% business passengers, 85% other passengers)</strong></td>
<td>1361</td>
</tr>
</tbody>
</table>

Table 3: Assumed yearly growth of the GDP and the yearly specific travelling time-value increase

<table>
<thead>
<tr>
<th></th>
<th>2007-2008</th>
<th>2009-2013</th>
<th>2014-2021</th>
<th>2022-</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assumed yearly growth of the GDP</td>
<td>4,4%</td>
<td>4,2%</td>
<td>4%</td>
<td>3,5%</td>
</tr>
<tr>
<td>The yearly specific travelling time-value increase</td>
<td>3,08%</td>
<td>2,94%</td>
<td>2,80%</td>
<td>2,45%</td>
</tr>
</tbody>
</table>
The estimation of the economic costs of the traffic management

The financial costs should be corrected concerning the following relations:
- budgetary (fiscal) corrections
- change-over from the market price onto the settling rate
- external impacts

The economic analysis starts from the financial cost-estimation, but the market prices can include taxes and supports, that have an influence on the relative prices. It is a general rule that the economic analysis may not include indirect taxes. In the case of direct taxes the taxpayer is in coincides with the person, who is charged in economic sense by the tax. We can speak about indirect taxes, if the taxpayer differs from the porter of the tax burden.

The value added tax should be always subtracted from the financial costs for the calculation of the social costs, independent upon, whether it can be required again or not.

In case of natural resources the correction of the market prices may be necessary, since the present market can neglect the interest of the future users. This correction has to be however made not with the method of the shadow prices, but with the external estimation using the contributions levied on the natural sources.

The estimation of the benefits of the mobile sensor network

The impact of the network can be the following:
- the benefits presenting themselves directly at the users of the project and at the users of the services offered,
- the external economic impacts are the impacts, which presenting themselves not directly at the beneficiaries of the project or at the users of the project, and are not accompanied with direct financial counterpart.

Two main methods can be used for the estimation of the benefits presenting themselves at the user:

An estimation starting from the financial incomes. The estimation of the financial incomes can be the basis of the calculation in the case, where this reflects properly the benefit presenting itself at the users of the infrastructure created by the project. This is valid first of all in the case, if the charges are based on the market prices, i. e. on the estimation of the users. It is therefore of interest to draw the attention to the fact that the building in of the service costs into the prices in itself does not mean still that this will be a suitable basis for the economic estimation of the benefits. For this it would be also necessary that the charges should be based on the estimation of the users.

Indirect estimation of the payment willingness

The payment willingness means the sum, which a consumer is prepared to pay for an additional unit of a given product/service. If the price of the product/service is lower, than the sum expressing the payment willingness, then the consumer will enjoy a consumer surplus.

Reduction of accident risks
The flexible traffic management system based on mobile sensor network can positively influence the accident risks. The accident risk is derived from the multiplication of accident probability and the expected volume of the damage. The information of the weather condition reduces the accident probability while the actual traffic information reduces the external congestion costs.

For the calculation of the costs the following data are necessary related to the certain stretches:
- length,
- type of area (centre or suburb),
- traffic volume (vehicle/day),
- accident parameters of road types.

Table 4: Relative accident parameter (accident/ 10⁷ vehicle-km)

<table>
<thead>
<tr>
<th>Road category</th>
<th>Fatal accident</th>
<th>Accident with heavy injury</th>
<th>Accident with light injury</th>
<th>Accident with only material damage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main road in suburb, with 2x2 lanes and junctions</td>
<td>0.491</td>
<td>1.572</td>
<td>1.88</td>
<td>11.28</td>
</tr>
<tr>
<td>Main road in suburb, with 2x1 lanes and junctions</td>
<td>0.415</td>
<td>1.328</td>
<td>1.588</td>
<td>9.53</td>
</tr>
<tr>
<td>Non-principal road in suburb</td>
<td>0.254</td>
<td>1.239</td>
<td>1.317</td>
<td>7.9</td>
</tr>
<tr>
<td>Road in the centre</td>
<td>0.348</td>
<td>2.723</td>
<td>4.049</td>
<td>24.3</td>
</tr>
</tbody>
</table>

The specific accident values will be reduced significantly by the mobile sensor network.

Table 5: Specific accident values in 2006

<table>
<thead>
<tr>
<th>Character of accident</th>
<th>Specific accident value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mortal accident</td>
<td>261.1 m HUF/victim</td>
</tr>
<tr>
<td>Heavy injury</td>
<td>18.1 m HUF/injury</td>
</tr>
<tr>
<td>Light injury</td>
<td>1.3 m HUF/injury</td>
</tr>
<tr>
<td>Only material damage</td>
<td>0.6 m HUF/accident</td>
</tr>
</tbody>
</table>

Table 6: Estimated growth of specific accident value

<table>
<thead>
<tr>
<th>Year</th>
<th>2007-2008</th>
<th>2009-2013</th>
<th>2014-2021</th>
<th>2022-</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yearly growth of</td>
<td>4.4 %</td>
<td>4.2 %</td>
<td>4 %</td>
<td>3.5 %</td>
</tr>
<tr>
<td>specific accident</td>
<td>value</td>
<td>value</td>
<td>value</td>
<td>value</td>
</tr>
</tbody>
</table>

These values can be reduced by 1-2 % by the sensor network.

Also the fuel consumption will be reduced by the organised traffic.

For the calculation of operational costs of the vehicles the following parameters are necessary:

- length of the road sections,
- traffic volume according to vehicle category (vehicle/day),
- average speed on the investigated section.
The costs of the operation of the motor vehicles include the fuel- and oil-consumption, the costs of the wear of the tyres and the costs of the maintenance, as well as the depreciation. Their two main components are the cost elements depending on the traffic circumstances and the speed (variable costs) and the cost element not depending upon them (constant/non variable costs). Within the operating costs of the motor vehicle the tax elements, the examination expenditures and the insurance costs may not be taken into consideration. During the period of the analysis the specific operational costs will increase expectedly further in real value as well, its growing trend will exert an important influence on the results and therefore the consideration of the yearly calculated increase is always necessary. In absence of deviating well founded data the indexing between 2007 and 2015 can be imagined with a yearly increase of 2.5 %.

In the case of crossing sections of towns the operating costs of the vehicles shall be modified according to the type of the settlement. In case of the capital a multiplier of 1.35, at the cities of county rank 1.25, at other towns 1.15 shall be used. The consideration of the crossing section can be made with smaller differentiating. In this case in every town a multiplier of 1.25 shall be used.

The following economic performance indices shall be calculated and evaluated:

- present value of the net social benefit (ENPV): the discounted value of the future net benefit-flows. The calculation of the EVNP is the key element of the appreciation for the project, since only the projects having positive ENPV values may be supported. The equation of the calculations is as follows:

\[
EVNP = \sum_{t=0}^{n} X_t \cdot (1 + i)^t
\]

where \(X\) the money-flow related to the given year, \(i\) is the discount rate and \(t\) is the actual year.

- the social inner rate of return (ERR) is the discount rate, where the value of the ENPV is equal to 0; For the calculation of the inner rate of return the same equation can be used with the difference that the value of the ENPV is given (zero) and we are searching the interest rate. If

\[
EVNP = \sum_{t=0}^{n} X_t \cdot (1 + i)^t = 0, \quad \text{then} \quad i = ERR.
\]

The expectation in connection with the ERR is that this shall be higher than the used discount rate (5.5 %). If the ERR cannot be calculated, then a decision can be made only on the basis of the NVP.

- The cost-benefit ratio (BCR) shows the proportion prevailing among the benefits and the costs calculated on the present value. The demand related to the BCR indicator is that this shall be higher than 1. The BCR indicator in itself gives only few information, since it does not give information about the absolute value of the costs and of the benefits, but only about their ratio.

The presented figures represent the effects and impacts of a metropolitan traffic and can be transferred to any traffic agglomeration where the application of the sensor network is economical. This postulates a proper passenger transport volume and vehicle fleet. The project will be finalised by a demonstration in Berlin and this is a city which has considerable performances in passenger transport, so both the industrial and the economic impacts can be expected positive.

The BVG (Berlin Transport Company) could achieve an increasing of incomes by 178.5 million Euros from 2003. In the last year this figure was about 32 million Euros accomplished by proper transport organisation and traffic management. BVG has 3 subsidiary companies which have been operating in the last 5 years. The Berlin Transport GmbH organises the travel service and focuses on cost
reduction. The usage of sensor network can save costs in millions of Euro by traffic management, avoiding of traffic jams and accidents.

In case of Berlin which has 3.4 million inhabitants, an area of 884 sqkm-s; a passenger transport performance of 250 million kilometre and 906 million passengers per year (total) considerable impacts can be calculated.

The bus network has about 6000 bus stops, 147 lines with a length of 1656 km, 54 night lines, a medium bus stop distance of 0.48 km (at the 13 express lines 0.73 km), a medium transport speed of 19.48 km/h (at the express lines 22.55 km/h). The bus lane length is 101.69 km (1 direction), vehicle fleet has 1310 busses.

The performance of this huge network can be increased significantly by a sensor network supported traffic management system. The introduction of such a system can be considered economically in cities of 300 000 inhabitants or more however the environmental and social impacts could be positive in all cities.

The usage of the mobile road sensors means the following economic advantages:

- the traffic throughput of the line network will be increased
- the transport performance of the vehicles will be increased
- the operating costs proportional to the performance will be diminished
- the repair costs of the vehicles resulted as a consequence of the road events will be decreased
- the remote diagnostic system will reduce the repair costs of the vehicles.

How and to what extent the traffic sensors can increase the number of passengers and the revenues related to the tickets:

- the performance/price relation of the service provided by the public transport will become more advantageous, as the cost of the individual transport
- the quality of the service provided by the public transport will become more advantageous, as the quality level provided by the individual transport.

Comments concerning the development plan related to the traffic signal lights influencing of the MORYNE project (Budapest Transport Co.)

About the influencing of the traffic signal lights can be spoken in effect, if all the junctions of a relation are covered with this intelligent system, where changes occur in general. Naturally there are such services, first of all in the suburbs, where this condition is assured only for one or for some junctions. In this case the above statement shall be interpreted for this junction.

In other words in the downtown of Budapest, on the services having high traffic an important coverage can result in a saving (the bus-line No. 7), and on suburban lines it is frequently sufficient to bring the problem-sites into the scheme (e.g. in the case of the bus line No. 98 the junction to be found at the Csévésző street, taking the railway crossing out of consideration).

With the proper extension a saving of 10 % in the running time can be achieved in accordance with the experiences. When the saving in the running time for the whole route excesses the equalisation time at the end station, then the omission of one bus can be taken into account (this means about 2 million HUF – 8000 Euro yearly). The extent of the required equalisation time at the end station can be otherwise reduced thereby that the number of the factors causing unevenness will be reduced by the influencing of the traffic signal lights. It is not characteristic, but it can occur that the saving in the running time will be the multiple of the equalising time. In this case several buses can be omitted from the line service; a good example of this situation is the bus-line No. 7 family, where a saving in the magnitude of ten buses can be achieved, together with the staff-saving belonging to it. In the estimation the theoretical reduction of the number of buses to be achieved in the line service family can be 13-17 % as well, but it is true that this could be approached with the supervision of the actual
traffic signal lamp programs as well; however, doing so other crossing directions could get in a
disadvantageous situation.

From the point of view of the traffic controlling staff the influencing of the traffic signal lights in itself will
not result in a possibility of the reduction in the staff number; in order that this goal shall be achieved,
the making of the software aided decision supporting functions available is necessary.

The losses of the national economy caused by the accidents on the public roads

The determination of the social and economic losses occurring in the course of the accidents on the
roads is only possible after the precise definition of the individual cost elements and after summing up
and taking the damage values into account. Several different methods can be used for the calculation
of the damages.

We have chosen a procedure used in a study of the Institute for Transport Sciences (KTI) dealing with
the social damage-calculation. The calculation method touches upon all the cost-factors caused by the
accidents on the road in details and considers the age of the injured persons and the deceased
persons and the rate of activity as well.

The used method quantifies as an element of the method the individual cost-factors. Its particularity is
that in the calculation of the losses of the national economy (deficiency of the production) only the
number of the active population will be taken into consideration in the value of the per capita GDP
value. It assumes further that the sample touched in the accidents represents the composition of the
whole society. On the basis of this preliminary assumption the social losses caused by the accidents
having different results can be calculated for each element.

The dead victims will fall out definitely from the production. With the aid of the per capita GDP value
calculated on the basis of the above mentioned and of the number of victims we can get the value of
the average extent of the falling out from the production for a year. The total costs spent for the funeral
can be calculated from the average funeral costs spent for one case. The administration means a
falling out of two work days in the average.

A rescue cost comes up at every accident with injuries. In the calculation of the hospital expenditures
of the injured persons the refunds paid by the National Health Insurance Institute (OEP) serve for the
basis. The official statistic data register the number of the deadly injured persons corresponding to the
state of the 30. day after the accident. In 30 % of the deadly accidents costs for the hospital treatment
also occur. According to the records of the OEP the taking the number of the injured persons, of the
sick pay cases, of the average time of the sick pay period and of the total paid sick benefits in the year
investigated the costs can be calculated. On the days calculated for the falling out from the production
the lighter injured persons get a support from their employer.

For the estimation of the costs of the rescue actions carried out by the fire-fighters the total value is to
be calculated starting from the data of the fire service.

In calculating the sum of the material damages we have started from the sum of the damages paid for
the damages announced to the debit of the obligatory third party insurance on the basis of the State
Supervisory Authority of Financial Organisation (PSZÁF). This shows, however, only the material
damages of the vehicles, which are innocent in the accident. Based on the mentioned study of the
KTI, 0,98 innocent vehicle-damage falls on the vehicle causing the accident. Out of this the whole
material damage of the national economy can be calculated.

The most important parts of the police activity related to the road accidents with injuries are: the local
inspection and the talks connected with it, the section of the inspection and the eventual additional
investigation. The police activity means first of all human working time, and so we will start from this in
the course of the calculation.
The losses arising as a consequence of the traffic jam caused by the accidents are composed partly of the excess fuel consumption of the vehicles hindered in their continuous running. On the basis of the KTI each more severe accident causes a traffic limitation with a duration of 1 hour in the average. In the knowledge of the value of the national average traffic volume and the average number of passengers the falling out from the production can be calculated. The excess fuel consumption is 20l/vehicle in the average, and adding this to the damage caused by the time-losses, we can get the damages caused by the traffic jams.

In addition to these we have taken the expenditure of the judges and public prosecutors, as well as the damages caused in the natural and artificial environment also into account.

On the basis of the above calculation we have stated that the social-economic losses of the accidents on the road were 327 billion HUF in 2005, and the greatest proportion in it was caused by the human capital loss. The next were the material damages or the losses caused by the traffic jam.

The value of the GDP in 2005 was equal to 22 thousand billion HUF, and so the damage caused by the accidents on the road had a proportion of 1.48 % in the total production. The proportion of the individual damage-elements can be seen in the following table.

<table>
<thead>
<tr>
<th>Serial number</th>
<th>Loss-element</th>
<th>million HUF</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Losses in the human capital because of death</td>
<td>143199</td>
<td>43,81%</td>
</tr>
<tr>
<td>2.</td>
<td>Falling out of the injured persons from the production</td>
<td>10334</td>
<td>3,16%</td>
</tr>
<tr>
<td>3.</td>
<td>Funeral expenditures</td>
<td>696</td>
<td>0,21%</td>
</tr>
<tr>
<td>4.</td>
<td>Expenditures for the rescue</td>
<td>917</td>
<td>0,28%</td>
</tr>
<tr>
<td>5.</td>
<td>Expenditure for the hospital treatment</td>
<td>10412</td>
<td>3,19%</td>
</tr>
<tr>
<td>6.</td>
<td>thick pay and contribution</td>
<td>878</td>
<td>0,27%</td>
</tr>
<tr>
<td>7.</td>
<td>Material damages</td>
<td>85344</td>
<td>26,11%</td>
</tr>
<tr>
<td>8.</td>
<td>Costs of the technical rescue (fire fighting activity)</td>
<td>2146</td>
<td>0,66%</td>
</tr>
<tr>
<td>9.</td>
<td>Cost of the police activity</td>
<td>7704</td>
<td>2,36%</td>
</tr>
<tr>
<td>10.</td>
<td>Costs of the prosecutor activity</td>
<td>4275</td>
<td>1,31%</td>
</tr>
<tr>
<td>11.</td>
<td>Costs of the juridical procedure</td>
<td>10380</td>
<td>3,18%</td>
</tr>
<tr>
<td>12.</td>
<td>Losses because of the traffic jam</td>
<td>50353</td>
<td>15,40%</td>
</tr>
<tr>
<td>13.</td>
<td>Costs of the damages caused in the natural and artificial environment</td>
<td>254</td>
<td>0,06%</td>
</tr>
<tr>
<td>Total:</td>
<td></td>
<td>326892</td>
<td>100%</td>
</tr>
</tbody>
</table>

The character of the fleet of Budapest Transport company

The city-owned BKV runs an extensive network of surface mass transportation, with the emphasis on buses. The dark blue liveried bus fleet includes 1457 diesel vehicles on 213 routes and 14 electric trolley bus lines. The night service is provided exclusively by buses. The articulated bus is a hallmark of Budapest: diesel and ETB bendy vehicles have been running since the late 1950s and still form the majority of BKV’s fleet.

In recent years, the bus service has been increasingly plagued by traffic jams as car use has increased and the narrow, congested streets of Budapest rarely allow for separate bus-lanes. Many motorists ignore bus-lane markings anyway, while few traffic lights fast-gate buses. The lamentable road conditions in Budapest incur continually high vehicle maintenance costs and inconvenience for bus passengers. Working conditions (esp. the age of the vehicles) and competitive wages are a
serious issue as bus drivers are often lured to the trucking industry. Yet, the city council traditionally favours a bus service, owing to its flexibility and lower initial costs; some 150 brand new articulated buses were procured in 2004-2006.

BKV operates 27 city tram lines and 4 municipal railways into the suburban agglomeration. The once-extensive network of tram tracks and the brown striped yellow streetcars were a characteristic of Budapest, but the network was curtailed after the fall of Communism, owing to lack of funding. Line 4-6 is still the largest capacity tram-line in Europe. The streetcar and cogwheel railway services are now set to have a renaissance as there is no further road capacity for bus lanes in Budapest. Financing is being sought from the EU to help replace the more than 40-year-old rolling stock, starting with new 54-meter long Siemens Combino Supra giants intended for the 4-6 line.

The underground railway network is less extensive, including two full-sized metros, and the small-sized underground tramway.

Approximately 55% of the passenger traffic in Budapest, a city of 1.7 million inhabitants, is still carried by BKV vehicles, with the remaining 45% using private cars. During 2003 a total of 1.4 billion people travelled by BKV.

BKV has been constantly plagued by a lack of funding and its fleet is becoming obsolete; on average, BKV buses are 15 years old. BKV operates on a net-loss basis; state-mandated ticket prices cover less than 50% of running costs.

In 2004-2006, 150 low-floor Volvo 7700A articulated buses were acquired via a long term leasing agreement from Volvo Polska. This batch of 150 Volvos represents the first significant new addition to BKV's fleet in five years.

**Utilisation of the project results**

According to the opinion of the BKV experts only about 200 vehicles would be able to adapt the results of the MORYNE project. Especially the new Volvo busses would fit for this and the newest types of trolley busses. Also the new Siemens Combino trams could use these technologies partly.

The company already participated in a project for the introduction of passenger information service on surface and under surface transport. This could provide support for the development. The introduction of the project results depends on the state and city administration support since the company doesn't have a positive financial balance.

A hindering situation is that the company actually has 3 different traffic management centres which need a harmonised information flow. This would increase the installation costs.

**Exploitation plan for Budapest Transport Company**

The Budapest Transport Company (BKV) can be an end-user of these techniques. Further these can be applied by transport companies in other Hungarian cities as well as by carrying companies and environmental agencies.

**Business case**

Let us consider that a system like MORYNE is deployed over the city of Budapest. The goal of this section is to evaluate how many types of equipment are needed to be installed, and roughly how much it would cost.
Constraints

The city of Budapest hosts a big bus network managed by BKV. This network is made of:

- 3 control centres
- 1,457 buses
- 213 daytime bus lines, representing 41% of the total 2,627 km network of the company

The area covered by the BKV bus network is in the order of 600 km².

Dimensioning the infrastructure

Telecommunication network

- WiFi network: was not installed in Budapest. It means more than 10,000 WiFi access points to be installed to cover all the BKV bus lines.
  
  The cost of one Access Point installed in Budapest would be 2-3,000 € (installation included), which makes a total of 25 M€.

  Considering that only about 15% of the bus fleet is able to be installed with these equipments and in the reality in the first phase on a part of this could be introduced the new technology we calculate the total cost of the network in a narrow time scale of 1-2 M€.

- A wired IP network must be installed to connect some of these access points (those not working in mesh mode) to reach the control centres. Evaluated its cost it would be at least 0.2 M€.

Control room equipment

Hardware:

The control room equipment must be enhanced with several servers where the MORYNE applications are running. It is expected that the dispatcher positions would be similar to the already existing ones. So the cost of deployment of MORYNE project results would be in the order of some k€-s.

Software:

The bus traffic management applications used by the City of Budapest today are not so developed. An overall change of the applications would be needed, including the configuration and the training of the BKV personal.

Development and tests would lead to a reasonable price compared to the cost of the first installation of the equipments.

Dimensioning the bus equipment

The new equipment equipments proposed by MORYNE is made of environmental sensors, cameras, a Mobile Video Server, a communication module and a WiFi mobile router. The cost of these equipments and their installation in the bus is not easy to estimate especially because the company has no previous experiences with the new technology. However the traffic management level is different from that of in Berlin, the experts can expect equipment costs in the order of 1,000 € in the first phase. For the installed city buses in Budapest this would represent a total amount of 0.3-0.5 M€.
Added the subscription costs for UMTS in each bus, which makes additional costs of 50 € per bus per month an annual cost of 50 k€ can be calculated for the designed fleet.

Cost estimation

The MORYNE solution with the use of a WiFi networks shows that the deployment cost of the network is the main cost of the total solution. A rough estimation of the overall system for Budapest would be in the order of 50 M€, plus the costs for the operation and maintenance. Provide that in the next future it will be introduced on some lines the total costs are estimated of 1-2 M€.

In case a WiMAX solution would be used in the 500-700 MHz band, the main item of the cost of the MORYNE system installation would be the cost of the on-board equipments. The overall solution would cost 2-3 k€ to be installed.

Functional requirement of the transport management system in Budapest

The Transport Association of Budapest [BKV] has not a map containing the network, which can be altered and used for multiple purposes.

The presently used informatics system describes the spatial line-network only with words (stops, other places, routes, etc.). Therefore it is indispensable to use a graphic map for the design of the relations.

Information gathering about the factors influencing the transportation

- handling the information related to the weather and pavement conditions,
- handling the information related to the limitations planned of the public transport network
- handling the information given by the controlling systems of the police, the fire service, the ambulance service,
- handling the data of the controlling system of the road traffic,
- handling the information given by the taxi associations,
- handling the data of the systems measuring the traffic volume and making a continuous survey of the road network,
- handling the data issued by the information systems of the P+R parking systems,
- handling the data issued by the controlling systems of the bicycle traffic.

The participants of the traffic control

The leading dispatcher is to be found at the top of the traffic controlling system. The leading dispatcher is responsible for the accomplishment of the traffic of the BKV exclusive joint stock company, for the surveillance of the traffic, and he co-ordinates the trouble shooting in the cases, affecting one or several transport branches or requiring individual measures of the authorities. He informs the leaders of the association and the colleagues of the media. Two colleagues work in the direct environment of the leading dispatcher:

- the dispatcher controlling the trouble shooting operations
- the dispatcher dealing with the central passenger information system.

The so called trouble shooting controlling dispatcher performs the spatial and timely distribution of the operations carried out by the controlling colleagues of the network traffic. Further he has complete information about the (current) troubles in the network and in case of need he can assist and co-ordinate the operations of the traffic controlling dispatchers.
The central informing dispatcher handles the telephone calls related to the actual traffic situation and he handles the loud speakers of the passenger information system in connection with the occurring troubles and with the changes in the usual traffic.

The traffic controlling dispatchers perform the traffic control at the level of each relation. They are in direct contact with the vehicle drivers. The vehicle drivers make a report first of all and to a decisive extent to the traffic controlling dispatcher, and the vehicle drivers – unless the road traffic controlling dispatcher does not help their operations – will get the instructions from the traffic controlling dispatchers in relation with the accomplishment of the operations. Accordingly the traffic controlling dispatcher instructs the vehicle-driver for the start at an other point of time, for the operation in an other relation, for working overtime and in case of an obstacle for running on an by-passing route.

The traffic controlling dispatchers of the network work on the street using motor vehicles in several fields. One or two colleagues work on one motor vehicle according to a predetermined task-sharing. The individual roles are as follows:

- mobile traffic controlling operator
- trouble shooting operator
- operators making investigation on the spot
- operators giving passenger information.

In accordance with the previously mentioned their operations are controlled by the trouble shooting controlling dispatcher assigned to the leading dispatcher. The traffic controlling dispatchers of the network go to the spot on the basis of the available information in the cases, where the start with the scheduled traffic can be resolved only so, or the re-establishment of the normal traffic can be accelerated with the presence at the spot of the traffic problem occurred.

The role of the mobile traffic control is required in cases, where the traffic controlling dispatcher controlling the given relation is not able to treat the traffic situation with the available technical means. An example for this situation can be, if traffic obstacles (e.g. road renewal) have occurred affecting one or several areas.

**Division of labour in the field of the passenger Information**

According to the facts mentioned in the introduction the traffic controlling and passenger information tasks have connections and interactions first of all in cases, where the traffic deviates from the planned situation. The changing traffic situation will generate at least partially automated passenger information depending on the services given by the system to be realised.

The operative passenger information is assured by the passenger information dispatchers.

The central passenger information dispatchers do not deal with trouble shooting; only the traffic controlling dispatcher deal with this and the traffic controlling dispatchers of the network use the input data coming from the operation (surveillance on the spot). They can get so the information at first hand related to the whole traffic controlling activity, which is particularly important in the case of spatial troubles, affecting several relations. The complete equipment park is at the same time in the hand of the traffic controlling specialists. The division of labour among the central traffic controlling dispatchers is appropriate according to the details discussed previously.

The central passenger information is carried out by two or three persons depending on the functionality of the implementation. One of them performs the information of the press and gives information per telephone about the actual traffic situation for the interested parts.

The information related to the vehicle stops and junctions issuing dispatcher deals with the handling of the installed equipment and at the same time he co-ordinates the tasks of the transport sectors (suburban railways, metro).
The central information dispatcher controls the passenger information equipment installed on the vehicles.

In connection with the passenger information it shall be stated that the preplanned information data shall be basically indicated both on the installed and on the onboard appliances. Accordingly during the trouble-free period the task and responsibility of the communication field is to assure the availability and the indication of the proper data. A deviating activity may be only performed in case of troubles. Then the task and the responsibility pass to the traffic controlling dispatchers. The participants of the traffic controlling activity shall determine the sphere of the data to be modified and the equipment, on which those data shall be indicated. At the end of the traffic troubles the equipment can return even automatically to the indication of the original, planned facts and data.

Example: the equipment installed on the vehicles makes known the end station of the service, its stops and the changing connections, etc. according to a predetermined scheme. If a diversion of the traffic becomes necessary, which changes transitionally the situation either after the automatic or manually data modifications, the indication will also changes and possibly the announcement through the loud speaker, owing to the new traffic order. After finishing the traffic diversion the equipment returns to the data basis of the original route and the transitional route will be cancelled.

Influencing the traffic lights

The purpose of influencing the road traffic lights (requiring green way) is that the public transport vehicles can pass through at the junctions having traffic controlling lights with lesser hindrances and thereby

• the diminution of the travelling time will improve the competitiveness of the public transport
• the diminution of the travelling time means saving in the operation costs for the operator
• the vehicle of the public transport "will push out" the congestion to be found ahead of it at the congested junctions
• the follow-up of the vehicles becomes smoother (the accumulation of the vehicles, the so called barrier effect ceases to exist, since the traffic lights functioning independent on each other do not disarrange the follow-up order of the vehicles)
• the system supports the most delaying vehicle and regulates the running of every vehicle (the system can exert an influence on the hastening vehicles as well).

In the case of some junctions to be found near to a flyover bridge the determination of the fact, whether the vehicle runs on the flyover bridge or under it, can be necessary. (E. g. bridge abutment on the side of Buda of the Elisabeth bridge, flyover bridge at the Leányka street, flyover bridge at the Szentlőrinci street, bridge abutment on the side of Buda of the Margaret bridge).

Its is necessary to deal with the cases of the deflected relations, the incomplete services and the garage running as well, since a new service code and end station code arise in those cases, which cannot be recognised and considered out of the junction-unit basis. One of the possible "solutions" is that in such cases the vehicle does not report itself; the other solution is that the login means shall be prepared in advance for the handling of the cases in question. It is required for this latter that the deflected relations, the incomplete services and the garage running shall be also included in the system as "normal" services.

The junction-unit should support the exploration of the illegal logins as well (storage and the incorporation of the logins in a list, the observation of a given identification card, etc.).

Functional requirement related to the system

A part of the operational processes is mainly automatic (in exceptional cases with intervention from the side of the dispatcher), whilst an other part of them will be realised with the contribution of the staff (dispatchers).
The functions of the server and the formation of the information having augmented value
belong to the sphere of the automatic processes.

The automatic tasks of the server are:
- taking over the planning data in the operative data basis
- a maintained copy will be stored about the data to be found in the central data-collector,
  and the applications running on the working stations will be served
- the activity of the colleagues working at the traffic controlling and passenger information
  centre will be organised and co-ordinated
- it works as a passage in the data transmission among the working stations and the other
  (outer) elements of the integrated system
- the processes will be recorded.

The following tasks can be assigned to the formation of the information having augmented value:
- Calculation of the (dynamic) resistance of route-sections, routes
- Calculation of the resistances between the traffic districts
- Prediction of the traffic
- Controlling the indicating units of the intelligent stops.

The dispatchers can intervene – in case of need – in all the four processes mentioned or in the results
of them.

A part of the processes realised with the contribution of the staff (dispatchers) is in connection with the
controlling activity of the traffic, whilst another part of it with the passenger information system. The
activity spheres can be separated accordingly from each other. The routine tasks are supported by
multimedia computers (surveillance, alarming, decision preparation, etc.). The extent of the delays or
the hastening of the vehicles can be followed up with the aid of an on-line indication program in minutes,
the actual speed, the evaluated number of passengers, the state of the doors (dwelling at the stops),
the registration number of the vehicles, the number of the lanes, and the name of the driver, etc. The
program supports the compilation of instructions. The decisions will be made by the dispatchers taking
several standpoints into consideration.

The collection of vehicle-diagnostic parameters

The purpose of collecting these parameters is the continuous surveillance of the characteristics
related to the operation of the vehicles and that of the characteristics to be found on the board of the
vehicles for the sake of the recognition and prevention of the unfavourable tendencies and impacts.

The vehicles acquired newly have a streamlined vehicle diagnostic system. In the case of the older
vehicles it is to be considered – taking the remaining utilisation period of them into account – the
installation of terminals.

In the case of vehicles to be connected with a mobile vehicle diagnostic system (BKV: Volvo 7700A
bus, VOLÁNBUSZ: Mercedes O530, MAN 313-.15, MAN SÜ 313, Mercedes O345G, Mercedes
O405GN2, Neoplan N4416Ü, Neoplan N4020/3, BKV: Solaris GST 12 A trolley-bus and KCSV7,
T5C5K, as well as Combino NF12B tramway types) all the electronically controlled system with
multiplex form stays under the surveillance of a single onboard computer. All the diagnostic functions
can be achieved at one place on these vehicles.

In the case of vehicles, that are not equipped with integrated board appliances (BKV: IK 412, IK
435 and IK 415, VOLÁNBUSZ: IK E94F, IK C56, Rába Contact 292, Kravtex Credo EC11, MAN
SL363-283 bus types) every vehicle functions independently, there is no central surveillance and
control. The diagnostic functions for each system separately. At such types of vehicles the integration
of the onboard-equipment systems shall be created in connection with the mobile vehicle diagnostic.
The vehicles, which cannot be connected with the mobile vehicle diagnostic system (BKV: IK 260, IK 280, IK 405, VOLÁNBUSZ: IK 250, IK 256, IK CS0, IK E94, IK E95, bus types, as well as at the BKV: UV, ICS, T5CS, TW6000 and Hungaroplan tramway types) – with regard to their operational age – are not deserved to transform so that they can entirely fit in the system. It is expedient to complete those vehicles only with a module related to the traffic control belonging to the intelligent vehicles. This is available on these vehicle types, but an adapter shall be inserted from time to time for the utilisation of this system.

The automatic data gathering includes the engineering (e. g. the quantity of the fuel) and the parameters prevailing on the board of the vehicle (e. g. the actual number of passengers on the bus). The data gathered shall be stored in the onboard computer of the vehicle, from where they will be transmitted at predetermined periods or as an effect of an event in the central computer of the operative traffic control.

**Functional requirement related to the system**

- the automatic collection of the technical parameters and the investigation of the suitability
- the automatic collection of the parameters prevailing on the board of the vehicles and the investigation of their suitability
- treating the extraordinary situations
- measuring the fuel consumption, registration of the fuel consumption assigned to the vehicle-driver (on the basis of the identification card), data transmission for the settling informatics system
- surveillance of the fuel supply system (does it exist or not)
- utilisation of the heating device (does it switched on or not)
- on the vehicles equipped with integrated onboard systems the communication with the CAN bus interface (door opening, number of passengers, measuring the speed, the state of the ventilation system, error indications, utilisation of the stopping and parking brake, registration of the emergency braking, etc.) (K51).
- communication of the diagnostic systems: the real time transmission of the data of the diagnostic system (e. g. engine controlling system) available on the board of the vehicle to the traffic controlling centre. This renders possible that steps can be made in the centre in due time for the avoidance of certain problems. The goal is to measure and to transmit of other not diagnosed, but from the point of view of the public transport important other parameters.
- state surveillance of spare parts in real time (structural health monitoring), the supported monitoring of the spare parts having higher value or critical functionality, for the sake of the exploration of faults in an earlier state
- data collection: the data collection and transmission are carried out according to the characteristics of the individual sorts of vehicles (bus, tramway, and trolley-bus).
- automatic data collection concerning the following technical parameters:
  - speed
  - state of the doors (open or closed)
  - number of passengers, frequency
  - fuel (energy) consumption
  - fuel quantity (level)
  - frequency of breakdowns, event-controlled
  - traction operation with batteries, frequency, event-controlled
- automatic data transmission to the traffic controlling centre concerning the following technical parameters:
  - frequency of breakdowns, event-controlled
  - traction operation with batteries, frequency, event-controlled
- data transmission in each case separately to the traffic controlling centre concerning the following technical parameters
  - number of passengers, frequency, event-controlled
- transmission of the daily data gathered at the premises to the central data-basis
  - speed
- state of the doors (open or closed)
- number of passengers, frequency
- fuel (energy) consumption
- fuel quantity (level)
- frequency of breakdowns, event-controlled
- traction operation with batteries, frequency, event-controlled

Safety management

The equipment serving for the safety and security and the defence of the mobile and immobile appliances of the passengers and of the transport associations are getting more and more in the foreground. As a part of this process the surveillance with video-cameras and the various methods of reporting the emergency situations are used in a wide circle. Those are used first of all at the places of the stops and stations of the transport on fixed tracks (railways, suburban railways, metro, tramway), and more and more on the board of every vehicle-sort as well.

Treating the onboard information of the vehicles

The purpose of the information on the board of the vehicle: continuous information in connection with the displacement (reduction of the uncertainty feeling) or the promotion of the comfortable and useful spending of the travelling time. (The onboard ticket selling systems belong also to the onboard information systems of the vehicles).

The data serving for the information and for the operation of the equipment on the board of the vehicle can be selected from the collection of data of the onboard computer. The uploading and activation of the data is possible at the premises with wireless data transmission, eventually using a data medium. The uploading with a data medium can be performed in a extraordinary case, this is not the usual working operation mode. The dynamic data during running are given by the operative control. The reaching of the dynamic data is assured by the quasi continuous data transmission between the vehicle and the controlling centre.

In addition to the establishments serving for the passenger traffic the vehicles of the public transport are exposed ever frequently to the vandalism and criminal acts taking place more and more frequently in the passenger room of the vehicles as well. Since the personal security surveillance (presence) can be used only to a limited extent, telematics devices shall be installed on the vehicles for the sake of the security. Those devices can be classed among the following groups:

- the hardware elements in the passenger room,
  - (installed) telephones serving for the reporting of the emergency situation,
  - emergency knobs (alarming knobs),
  - loud speakers,
  - video cameras.
- the hardware elements of the driver's cabin
  - the terminals (monitor, microphone, loud speaker, alarming knobs…),
- other hardware elements of the vehicle
  - mobile telephone of the vehicle's staff
  - onboard computer.

The data required by the passenger information appliances of the vehicle will be stored by the onboard computer. The modification of the data will be realised operationally using wireless connection, but in the case of the eventual lack of this type of connection the possibility for the upgrading shall be assured through a wired system. In this case the responsibility for the upgrading belongs to the individual premises.
The wireless data upgrading can be resolved in the basic case with the aid of the WLAN network within the premises. Naturally the possibility should be assured for the upgrading of the data, when the vehicles are outside the premises and running in the traffic, too.

The data basis of the passenger information is maintained at all the service providers by the co-workers designated to this task and so the members of the Passenger Information Group at the BKV (the outsourcing of the editing of the data basis is to be avoided because of the complicated checking of the appropriateness of the information and of the difficult modification possibilities). The task of the persons editing the data includes the management of the permanent and of the operative information to be planned in advance at the level of the data basis, as well as to the visual and acoustic execution, too.

The operative passenger information relation can be exclusively provided, however, by the persons having close contact with the traffic control. The possibility of editing the data of the passenger information should be assured for them as well, but they cannot cancel definitely the information having permanent character.

The hardware elements of the planned traffic controlling and passenger information centre

One of the tasks of the development is the establishment of the traffic controlling and passenger information centre of the BKV, or the establishment of the organisation accomplishing this operation.

The most important mechanical components of the centre are as follows:

- computer(s)/servers controlling the data transmission
- WEB/WAP server
- central server and data basis
- multimedia terminals of the dispatchers
- terminals, e.g. indicators of the place surveillance cameras
- computers creating information with augmented value
  - route sections, routes, resistance forming computer,
  - computer creating resistance between the traffic districts
  - computer elaborating traffic predictions
  - computer(s) controlling the indicating devices of the intelligent stops
  - Web/Wap server

The central data basis contains all the static and dynamic data for the traffic controlling, passenger information and vehicle diagnostic systems. The data to be found here are static data from the point of view of the process, but they change gradually during the operation of the system, accommodating so to the data issued by the dynamic systems (onboard unit, traffic control) and processed by the central system in order that the emerging demands can be satisfied as good as possible. The exact determination of the content of the central data basis can be carried out during the preparation of the system-plan. The following question will form undoubtedly a part of the central data basis:

- A copy of the basic data interrogated from other connected information systems (passenger information, service planning, vehicle fleet in the field of the vehicle diagnostic, data related to the staff, data of the traffic relations, time tables, etc.)
- The daily data of the appointing (co-ordination of the drivers, vehicles and traffic relations)
- Data coming from the vehicles. The vehicles indicate their position from time to time; further some basic data, which are characteristic for the state of the vehicle. The algorithms of the traffic control and the passenger information are served by the data collector assuring always the actual vehicle traffic data.
- The journal of the activities related to the vehicle fleet and to the traffic control.
The hardware elements and the connections among them are to be seen in the Figure 1.

The part of the activity of the dispatchers working in the traffic controlling centre that requires the quickest intervention, the crisis-management, and this make the personal contact of the persons participating in this activity necessary. Therefore it is expedient that the dispatchers shall work in the physical vicinity of each other (in a common room). On establishing the centre the safety and security, as well as the reliability standpoints are to be taken into consideration. We shall prepare ourselves for the unexpected events (e. g. cable-problems, bomb alarm, etc.) as well.

The telecommunication network assures the connection with the other elements of the complete system through the computer controlling the data transmission. The dispatchers’ terminals are connected with it, and with the computer producing information with augmented value. The latter elements can be ranked among groups in compliance with their functions.

The hardware elements of the vehicles

The hardware components installed in the vehicles and their connections are summarised in this chapter. Out of the elements of the hardware the following can be differentiated first: hardware
elements supporting the traffic controlling functions and secondly the group of the hardware elements supporting the passenger information functions (terminals).

The **onboard computer** is in the centre of the mechanical structure that manages the data basis of the vehicle as well. The onboard computer in itself has also modular structure, and several terminals according to choice can be connected with it through a standard interface (with analogue and digital outputs). The **hardware elements providing information about the position and the state of the vehicles** are connected with it through parallel data-buses, as well as the terminal of the vehicle-staff, the device performing the identification of the staff and the terminals of the passenger information system.

The onboard computer manages the data basis of the vehicle, and provides the handling surface toward the driver. The screen visualises the information serving for the information of the driver, or the menu system formed on it serves for the receipt of the messages issued by the driver. The sound-channel of the multimedia surface provides the technical background of the speech-connection for the vehicle-driver. There is a direct connection between the driver’s microphone and loudspeakers to be found in the passenger room.

The vehicle driver logins with an identification card at the beginning of the working period in the traffic controlling system (on the vehicle), which assures that his each elementary activity accomplished during their work time can be followed up assigned to his name and subsequently as well (e. g. for the purpose of the pay-roll accounting, for the quality evaluation of the working activity, etc.).

Since the sources of the data related to the traffic processes are the vehicles (we gather information from a great number of vehicles, with a relatively small sampling interval), the wireless communication performed with the vehicles is of fundamental importance from the point of view of the whole system. The handling method of the information coming from the vehicle can be classed into two groups:

- on one hand the real time (dynamic) data, and
- on the other hand the data, that do not require a handling in real time process (numerous cumulated data), can be transmitted on the local wireless network at the end of the shift.

The most important characteristics of the data transmission are as follows:

- the speediness
- the real time processing
- the reliability
- the quality and
- the safety and security

(K) – those viewpoints shall be explained in the chapter dealing with the data transmission requirement

An important directive is from the point of view of the implementation of the system that the data occurring on the vehicle shall be processed to the highest possible extent and so the performance of the data transmission system (and the dependency upon this) can be diminished. The local decision making is of importance from other point of view as well. If there is no connection as a consequence of some errors, then there are also functions, which shall be carried out in off-line operating mode. Such example is e. g. the identification of the drivers with a personal card.

**The introduction of the system**

It is expedient to implement the complete system in gradual building up form. In the first phase the realisation of a partial system, a pilot system is recommended, that includes all the system elements and accomplishes the most important functions, too. After the successful testing (modification) of this
partial system – taking the scheduling and the technological connections of the financial resources also into account – these can be enlarged.

The trial operation (pilot system) shall be related to the vehicle sorts of special features and to the service relations deviating “from the average conditions” and periods. The “surveillance” of the traffic relations is particularly reasonable, where the traffic confusions occur systematically, and where no important effects can be achieved through the traffic controlling activity. If the traffic control is operated presently on the given traffic relation, then the two services can be compared and analysed according to several viewpoints, too.

It is expedient to choose the period of the trial operation (pilot operation) so that all the traffic circumstances (e. g. various day-periods, different seasons, great programs, reconstruction works, etc.) shall be tested permanently. The improvement (modification) of the pilot system should be carried out on the basis of the testing experiences.

The scheduling of the introduction is in close connection with the testing strategy of the system. The elements of the system are built onto each other, which mean a dependence relation (the given function cannot be tested and introduced till the implementation of all the preceding functions and conditions in the dependence row).

The continuous assurance of the passenger transport is of primary importance during the introduction and testing without the deterioration of the quality. The negative impacts affecting the passengers (falling out of the services, delays, lack of information) shall be minimised and if it is possible, then these shall be avoided. The introduction should be preceded by complete information.

In the course of the information some parts of the present systems and those of the new system will work parallel to each other, since it is impossible to change over physically from one moment to the other from the older systems to the new system. The elaboration of the details for the parallelism – including the details concerning the stopping order of the older systems as well – will become possible in the knowledge of the final scheduling of the project, and that of the system-plan and the solution given.

1. The development of the Traffic Controlling and Passenger Information Centre
   a. Installation of the servers
   b. Installation of the software
   c. Development of integration and the data communication connections

2. The development of the Traffic Controlling and Dispatching Centre
   a. Development of a physical room
   b. Development of working places for the dispatchers
   c. Instruction

3. Activities to be carried out at the premises
   - Installation of servers
   - Installation of the software
   - Development of integration and data-connections
   - Instruction

4. Activities related to the vehicles
   a. Installation of the onboard computers
   b. Installation of the geographic positioning system for the vehicles
   c. Installation of the terminals supporting the driver
   d. Installation of passenger information devices
   e. Instruction
5. Passenger information
   
a. Installation of indicators at the stops and at the junctions and at the terminals
b. Starting with the Internet service
c. Starting with the mobile/WAP services

Conclusion

The industrial and economic impacts of the usage of road and vehicle sensor network were analysed in this study.

The industrial impacts are first of all the proper usage of road handling materials (selection of materials and decision of the volume in winter period) and the savings in the fuel consumption. Over and above the life cycle of the busses can be prolonged and the maintenance need of urban roads can be diminished.

The integration of innovative solutions can create an interactive communication possibility between the vehicles and the traffic management. The tests and the demonstration can investigate actual practices and prepare measurements for optimal future solutions. New methods for traffic management can be developed to ease implementation, enhance the qualification of procedures and of scalable capability.

The economic impacts are the saving of road and vehicle maintenance costs, of winter handling material costs, of external pollution, traffic jam and accident costs as well as of personal costs at the transport company.

The potential markets will be identified and the benefits can be quantified. The needed investments to develop management systems, the manufacturing costs for the needed equipment and the maintenance costs of the system can be defined.

Utilisation of the project results on European level

To disseminate the project results and to receive feedback of the possible utilisation in the public bus transport we contacted several transport companies in bigger cities in Europe both in the former and new EU member as well as in other European candidate states.

We were promised to get the feedback soon and the evaluation process is in progress. In May it is possible for us to deliver the final results of the actual utilisation possibilities in more than ten European cities in the transport companies.

The same situation is for the Hungarian transport companies in the rural cities, they will also inform us how these results can be applied. The application possibilities of the Budapest Transport Company are evaluated in our report.