# MORYNE

## D6.2: *INTERIM REPORT ON INDUSTRIAL AND ECONOMIC IMPACTS*

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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*

| Version | Date | Description |
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| 1.0 | 07/03/2008 | The impact of the usage of road sensors<br>Interim report on environmental and social impacts of the usage of road and vehicle sensors |
| | | |

**Table 1: Document Status Sheet**

# 2 Reference Documents, Abbreviations and Definitions

## 2.1 *Reference Documents*


[1] MORYNE Description of Work

[2] **Marjainé Dr. Szerényi Zsuzsanna** [2003]: A nem piaci javak közgazdasági értékelése. Segédanyag a „Környezetértékelés" című tárgy előadásaihoz. pp12-15;

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

[4] **Prezenszki J.; Gál Gy.; Tokodi J.**: Logisztikai központok irányítási feladatai, az integrált irányítás fokozatos megvalósításának elve és módszere. Logisztikai Évkönyv, Magyar Logisztikai Egyesület, Budapest, 1998;

[5] **Tokodi J.**: Theoretical Issues of Integrated Logistics Information System, 2001;

**National Development Agency:** Methodological directive for the cost-benefit analysis of road projects.

[6] **Dr. Károly Szűcs, Pál Kőfalusi, Sándor Németh**: Brake systems (1997)

[7] KTI studies.


## 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 road transport management and the transport safety

## 3.1 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.

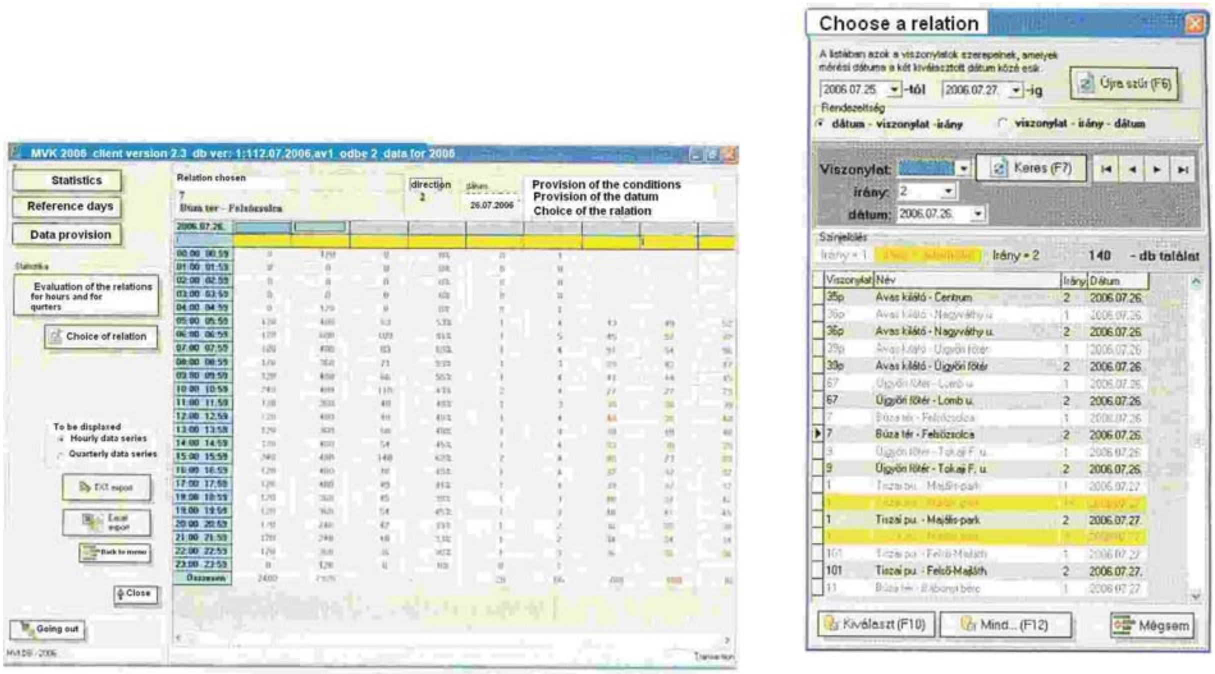


Figure 1: Data series in hourly breakdown

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.

  

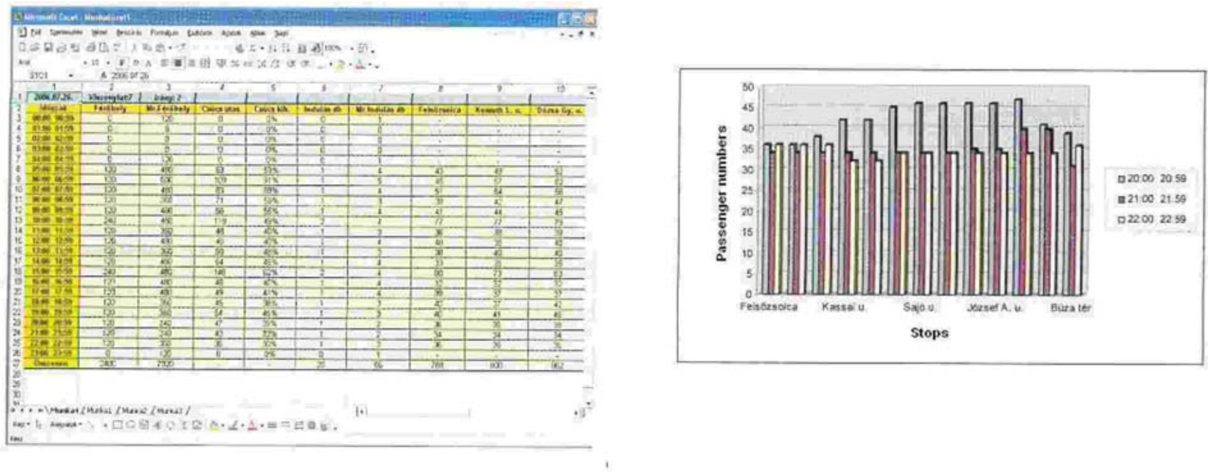


Figure 2: Data series in hourly breakdown

The expert designing the network or the time table 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.

## 3.2 *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)

| Categories | on the national public road | on the roads of the municipalities |
|---|---|---|
| Light vehicles | 3 421 | 2 954 |
| Heavy vehicles | 10 034 | 10 919 |
| *Passenger cars* | *3 066* | *2 588* |
| *Freight transporting vehicle* | *6 382* | *6 382* |
| *Bus* | *31 303* | *38 108* |

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

| Categories | on national public roads and on roads of the municipalities |
|---|---|
| *(Passenger cars of business purpose (proportion 18%)* | *3905* |
| *Passenger cars of non business purpose (proportion 82%)* | *1458* |
| *Passenger cars, average* | *1899* |
| *Bus (15% business passengers, 85% other passengers)* | *1361* |

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

| | 2007-2008 | 2009-2013 | 2014-2021 | 2022- |
|---|---|---|---|---|
| Assumed yearly growth of the GDP | 4,4% | 4,2% | 4% | 3,5% |
| The yearly specific travelling time-value increase | 3,08% | 2,94% | 2,80% | 2,45% |

  

*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/ $10^7$ vehicle-km)

| **Road category** | **Fatal accident** | **Accident with heavy injury** | **Accident with light injury** | **Accident with only material damage** |
|---|---|---|---|---|
| Main road in suburb, with 2x2 lanes and junctions | 0,491 | 1,572 | 1,88 | 11,28 |
| Main road in suburb, with 2x1 lanes and junctions | 0,415 | 1,328 | 1,588 | 9,53 |
| Non-principal road in suburb | 0,254 | 1,239 | 1,317 | 7,9 |
| Road in the centre | 0,348 | 2,723 | 4,049 | 24,3 |

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

Table 5: Specific accident values in 2006

| **Character of accident** | **Specific accident value** |
|---|---|
| Mortal accident | 261,1 m HUF/victim |
| Heavy injury | 18,1 m HUF/injury |
| Light injury | 1,3 m HUF/injury |
| Only material damage | 0,6 m HUF/accident |

Table 6: Estimated growth of specific accident value

| **Year** | **2007-2008** | **2009-2013** | **2014-2021** | **2022-** |
|---|---|---|---|---|
| Yearly growth of specific accident value | 4,4 % | 4,2 % | 4 % | 3,5 % |

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 me 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:

  $$EVNP = \sum_{t=0}^{n} X_t \; I(1 + i)^t$$

  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

  $$EVNP = \sum_{t=0}^{n} X_t \; I(1 + i)^t = 0, \text{ then } i = ERR.$$

  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 Csévéző 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 wit 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.

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

# 4 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.

  