Relations of Public Transport and Traffic Safety

P. Holló

KTI Institute for Transport Sciences Non-profit Ltd.
Road Safety Centre
Phone: 06-1/371-58-23
Email: hollo.peter@kti.hu

Széchenyi István University Transport Department
Phone: 06-96 /503-400/3353
Email: hollop@sze.hu

Excerpt: comparison of public and individual transport, evaluation on traffic safety basis

Key words: public transport, traffic safety, sustainability

1. Introduction

Recently, the term of sustainability has spread in almost all domains of the life, thus in the field of transport, too. Given the traffic congestions developed in dense urban traffic, it is clear that those responsible for traffic management grab all the opportunities in order to sustain the smooth and undisturbed flow of traffic. A growing number of environmental and traffic control arguments insist on giving preference to pedestrian and cycling traffic because they are environment-friendly and their gaining ground decreases the occurrence of traffic congestions. Of course, these transport modes can be attractive and may constitute a real alternative only in case of certain distance and weather conditions.

2. Road safety of different transport modes

Let us examine the development of the probability of a road accident, or of the incurred fatal injury risk for the different traffic modes. (It is worth examining the latter not only because fatalities are the most severe consequences of the road traffic accidents, but also because the definition of the fatal injury is almost the same in every country, so it makes possible an undistorted international comparison. Notably: the deceased within a 30-day-period after the road accident date are considered as fatal victims of road accidents. It is important to note that the major international databases using the so-called correction factors convert to the 30-day-value the data of some countries which have not yet used this definition.) Tables 1 and 2 show the results of an EU-wide comparison. [1]

Table 1.: Accident fatality risk of different transport modes in the EU in 2001/2002 (killed/100 million passenger-kilometres)

Road (total)		**0.95**
motorcycle/moped	13.8	
pedestrian	6.4	
cycle	5.4	
passenger car	0.7	
bus	0.07	
ferry		0.25
Air transport (civil)		0.035
Rail		0.035

Table 2.: Accident fatality risk of different transport modes in the EU in 2001/2002 (killed/100 million passenger-hours)

Road (total)		**28**
motorcycle/moped	440	
cycle	75	
pedestrian	25	
passenger car	25	
bus	2	
Air transport (civil)		16
ferry		8
Rail		2

Although the data in the two tables are clearly different, the accident fatality risk of different modes of transport on several points present a similar ranking order. (In both tables road traffic is the most dangerous while the railway transport is the safest; in both tables the accident fatality risk is the highest for riders of the motorized two-wheelers – motorcycles and mopeds.) Unfortunately, there are no recent data available in the literature however, it is very probable that the scale of the values, their ratio has not changed significantly since then. Before the data are analysed it is worth thinking which data of the two tables reflect better the real risk of fatalities. Despite the fact that in the profession there are in quite a great number those holding the view that the number of trips, or the time spent in traffic express well the user's exposure, it can be declared that the road safety experts widely agree that, as the matters actually stand in the field of transport sciences, the number of the kilometres performed (run or „travelled”) is the best approach, a measuring number for effective exposure. Also the author believes that the extent of exposure is best represented by the number of kilometres performed. Unfortunately, this measuring number is not a perfect one either, since for example by far it is not all the same in what circumstances is the distance concerned performed (on a safe motorway or in the conditions of congested urban traffic), however, no more appropriate indicator is available for the moment. Both tables jointly assessed when comparing the different transport modes the following conclusions can be drawn.

2.1. Fatality risks in road traffic

The two-wheeled motor vehicle riders/passengers are exposed by far to the highest accident fatality risk in road traffic. In comparison to passenger car occupants, the accident fatality risk for motorcycle or moped riders is 17.5 times (time related) or 20 times (distance related) higher, respectively.

Passenger car travelling is 1~3 times (compared to time), or 7~9 times (compared to distance) safer than cycling or walking, in spite of it the safety of passenger car occupants is 10 times (distance measurement), or 12 times (measured in time) lower if compared to that of bus travellers.

Consequently, already here it is worth emphasizing two things:

- on the one hand, the outstanding safety level of public transport;
- on the other hand, the extremely unsatisfactory safety levels of the so-called “sustainable” and environmentally friendly transport modes (walking, cycling). (The related recommendations are detailed later.)

On the basis of the results recommendations of the authors of the referenced study [1] are the following. If the distance travelled by walking or cycling prior to, or after getting to bus (or train) exceeds the 15 percent of the total travel distance, it is safer for the road user to travel the whole distance by a passenger car than by bus (or train). Namely, in this case the outstandingly high accident fatality risk of walking or cycling can be avoidable. Other road users (another passenger car’s driver, passengers, riders of two-wheeled vehicles /cycle, motorcycle, moped/, pedestrians) are killed mostly in accidents in which passenger cars are involved. Therefore, from community aspects the trips made by using the public transport means and previous/subsequent walking or cycling are safer than travelling by passenger cars. Consequently, when evaluating the results, a substantial difference should be made between the individual and the public (collective) accident/injury risks.

In 2010 30,700 people lost their lives as a consequence of road traffic accident in the 27 member states of the EU. Despite the fact that this means on average 44 percent decrease in comparison to the 2001 data (54,300 fatalities), the EU’s new road safety action plan foresees another 50% reduction by 2020 [2].

According to data 97% of the victims of fatal traffic accidents are killed in road accidents. The so-called fatality risk of road passenger transport (number of killed/1 million population) is almost hundred times higher than the sum of all the other transport modes in total (railway, shipping, air transport), because the accident fatality risk in road transport is significantly higher than in other transport modes. In the EU member states 88 percent of passenger transport is implemented on roads.

If the problem is analysed from the aspect of accident losses, in conformity with the EU Commission's estimation [1] 93% of the passenger transport related annual accident losses is caused by road accidents ahead of the losses resulting from traffic congestions and environment pollution.

Analyzing the fatality risks of different transport modes in the terms of health care it can be ascertained that the EU citizens besides cancer and coronary heart diseases, most frequently are fatal victims of road accidents, i.e. these three are the predominant causes of death. Moreover, most people need hospital care due to these three reasons as well. Clearly, under the age of 50 road accidents are the leading cause of death in the EU member states. The consequences of road accidents are the most serious even if the expected number of the lost years of one's life is analysed. Its main reason is that the average age of road accident victims is regretfully low (about 32 years).

It is almost a cliché to say that road transport is dangerous. If the number of fatal injuries is related to the time spent in road transport, fatality risk is 40 times higher than in a workplace and 12 times higher than at home. Even the risk of death of the safest road transport mode (travelling by bus) is more than twice the risk of death in the workplace (in relation to time spent in transport).

2.2. What is reflected by national accident data?

Let us examine the breakdown of the number of the fatal victims of road accidents by their participation in traffic.

An essential proof is offered for by Figure 1 which presents the number of killed in road traffic accidents in a breakdown by participation in traffic between 1984 and 2010.

It is not surprising that in most cases and in an increasing proportion the passenger car drivers or passengers were the fatal victims (almost 45% in 2010). To a certain extent this increasing proportion is the evident consequence of motorization. However, it seems that in recent years (as of 2003) the increasing rate of the safety belt wearing as well as the higher and higher passive safety level of passenger cars have started to stabilize the previously rising curve. The decreasing rate of the pedestrians killed in the long term can also be associated with the domestic development of motorization, i.e. less walking, more driving. The share of this group was about 26% in 2010. Here also, as of 2003, the trend decreasing in the long term seemed to be stabilized. The proportion of killed cyclists fluctuates around a constant value. The measures wanted and intended to improve the safety of cycling – probably because of the increasing popularity of this transport mode (i.e. due to growing cycle traffic) – had no provable results.

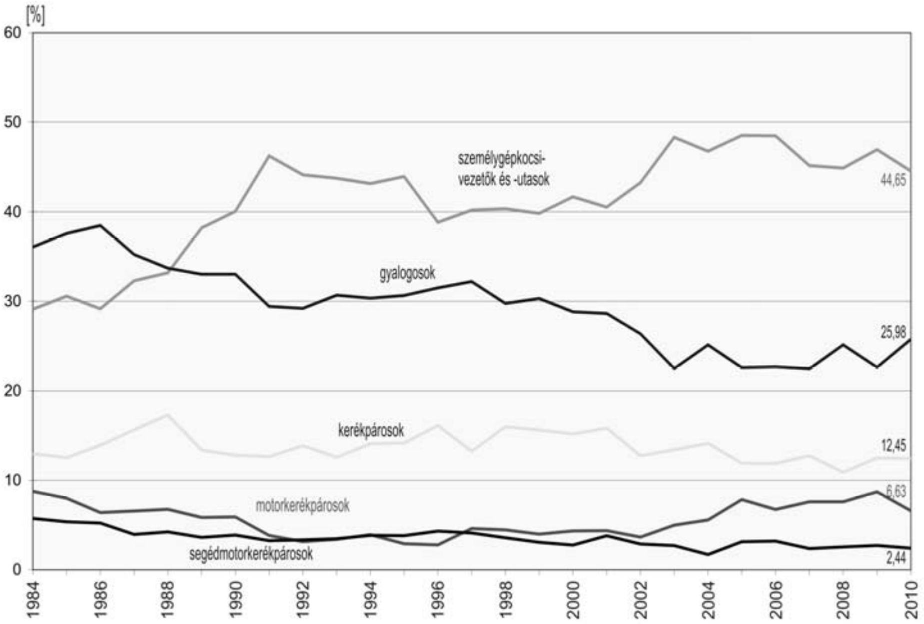


Figure 1.: Distribution of the number of killed as a consequence of road traffic accidents in a breakdown by mode of participation in traffic between 1984 and 2010

In recent years for a long time with a "head-to-head" development the curves of the two-wheeled motor vehicles (motorcycles, mopeds) diverged. [3]. While the rate of died moped riders remained relatively low (2.4% in 2010); that of killed motorcyclists – correspondingly to trends experienced worldwide – significantly grew, until 2010, then a decrease occurred [4]. 92.15% results if the right-hand side partial results are added. If considered that the transport modes in the figure without exception are individual forms, the safety level of public transport is outstandingly high. Further important conclusions can be drawn from the analysis of the values. For instance it can be found that the 44.65% rate of the passenger car occupants can be compared to the summed up 47.5% proportion of the so-called vulnerable road users (pedestrians, cyclists, motorcyclists, moped riders). If the Annual Accident Statistics of 2010 is opened [5], it turns out that 3 and 9 persons were killed in road accidents as bus drivers and bus passengers, respectively. This is but 1.62 percent of all killed in road accidents (740 victims) also proving the high safety level of bus transport. Consequently, the vulnerable road users and the passenger car occupants continue to be the main target groups of road safety activities. It is a fact, that in the years before 2010 the proportion of killed motorcyclists increased in Hungary as well, but this rate undoubtedly requiring an increased attention does not make yet these road users the number-one target group of prevention.

3. Public transport in transport policy

3.1. The national transport policy actually in force

In the currently in force Hungarian transport policy [6] reference is made in several places to public transport. For example, the chapter dealing with the provision of sustainable development emphasizes: "the preservation of the present share of the passenger transport within public transport through the development of its assets, infrastructure and service level as well as the modernization of the urban transport systems for the upgrading of the conditions of non-motorized transport." The degree of approvability of this effort from the points of view of both road safety and environment protection are well illustrated by the data above [1]. The Hungarian transport policy has obtained similar findings when it states that: "the improvement of the relations of the different transport modes is an important view point of the national transport policy. The appropriately developed points of meeting and interchanging of the modes of individual (pedestrian, cycle and passenger car traffic), and public transport (bus, railway, urban transport vehicles) help providing a higher quality, safer and more environmentally friendly transport with better and wide-ranging services for individuals, families and business trips."

3.2. The EU's road transport policy in force

Public transport is not specifically mentioned in the current road safety policy of the EU [2}. The different modes of road transport are compared in one place only. On page 11 of the section dealing with enhancing the safety of vulnerable road users it is assessed in what extent succeeded to moderate the number of killed as a consequence of road accidents by their participation mode in traffic between the years 2001 and 2008. The road safety advantage of public transport is clearly underlined by the fact that in the period referred to above the number of killed in bus transport decreased to the greatest extent, i.e. by 60%. The already excellent traffic safety of bus-passengers improved even further. It is worth mentioning that the number of killed in passenger cars decreased by 35% while the number of victims fatally injured in motorcycle accidents was reduced to the lowest extent, all in all by 4%.

4. International research

Because there is a big difference among the safety level of different transport modes [1], the idea emerged that it is worth analysing what could the different transport modes "learn" from each other. As a part of the seventh EU research framework programme the "EXCROSS" (EXploiting safety results aCROSS transportation modes) research project has been started recently. This project compares the different transport sectors just in terms of safety while endeavouring to exploit one of the sectors' safety-enhancing strategies and actions which proved to be successful in other ones as well. Here there are just a few topic-related ideas highlighted from the findings of the ongoing research.

As far as modal split is concerned the section on road safety emphasizes that in comparison with individual transport, public transport is obviously safer and more environmentally friendly, but less attractive. Therefore efforts in transport policy are focused on the improvement of the attractiveness of public transport worldwide, i.e. the wished to have it transformed into a clean, fast and comfortable mode. Another major finding is that the avoidable motor vehicle traffic shall be avoided. This is beneficial both in terms of road safety and environmental protection, but it contributes to ensuring sustainability as well. To this aim such options as e-learning, e-working can be used, i.e. those online forms of learning and working which do not require travelling. In addition, rational urban development can also help a lot in reducing the number of unnecessary trips. Lesser traffic does not only mean fewer traffic conflicts, reduced number of accidents, less traffic congestions, but also cleaner air and lower noise level.

5. A few words about the passive safety of bus passengers

Anyone who has already travelled abroad by a coach could experience that the safety belt is available for bus passengers, too. The analysis of bus accidents shows that mostly the unfastened passengers suffer fatalities, because they got fatally injured either by tumbling to one another, or by colliding with the inside of the bus, or by falling out the windows or often by getting under the bus. In my view, from many respects several sections of domestic legislation need updating.

Firstly, currently the safety belt should not be fastened in scheduled buses carrying passengers outside built up areas if the carriage of standing passengers is also allowed. Exemption to safety belt wearing is also given to children under 3. It is easy to see that these provisions do not guarantee maximum safety for bus passengers.

As far as the installation of buses with safety belt is concerned, the item (11) (f) of the Article 81 of the KÖHÉM Regulation No. 6/1990 (IV.12.) should be mentioned, according to it all passenger seats looking forward must be equipped with one of the following safety devices:

- Safety belt, or
- Properly designed backrest of similarly forward facing seat of sufficient strength, or
- Crash wall or crash rail of sufficient strength and properly designed.

It goes without saying that only the appropriate safety belt protects bus passengers against collision to other passengers or to the inside of the bus or from falling out the bus.

A special chapter would be addressed to the problem of school buses. According to the Hungarian Highway Code (KRESZ) all non-scheduled buses which are engaged in the transportation of preschool children or pupils of public institutions are classified as school-buses. Accordingly, to these buses defined tables should be affixed, the seats should be equipped with safety belts, children under 135 cm height should be fastened with child safety systems, while children at least 135 cm tall should be fastened with (adult) safety belts. However, the question is what the term “regular” means.

By these few examples I just wished to draw attention to the possibilities of further road safety improvement of the current domestic legislation.

6. Summary, conclusions.

Taking into consideration the traffic safety and environmental protection advantages of public transport, and in view of its preference that also contributes considerably to the sustainability of transport, efforts should be made in order to maintain and enhance its role. For this to succeed, the public transport should offer an attractive alternative vs. individual transport.

For professional comparison of the accident risk of the different transport sectors and transport modes reliable, exposure-describing data would be needed. Such data are referring to distance and passenger transport performances characterizing the vehicle- and passenger-kilometres. In the future, in any event, more attention should be paid to the collection of such data which are based on regular and representative samples.

Higher safety level supported also by the number of bus passengers could be made even more attractive by further updating of the domestic legislation.

During intermodal passenger transport developments the great differences existing between the accident risks of the different transport modes should be taken into consideration. The safety of pedestrian and cycle traffic should be improved. Not only because the safety level of these environmentally friendly, healthy and traffic sustainability supporting transport modes is not satisfactory, but also for optimizing the safety of public transport, since the accident risk is very high in case of cycling or walking while passing along or following the motor vehicles engaged in public transport.

References

[1] *Transport Safety Performance in the EU.* A Statistical Overview, European Transport Safety Council, (2003).

[2] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. *Towards a European road safety area: policy orientations on road safety 2011-2020*, {SEC˙2010) 903}, Brussels, 20.7.2010, COM˙2010) 389 final.

[3] Prof. Dr. Holló Péter: *Közúti közlekedésbiztonság Magyarországon. Közlekedéstudományi* Szemle, (2012), accepted.

[4] Dr. Juhász János: *A 2004-2010 között bekövetkezett személyi sérüléses motorkerékpáros közúti balesetek elemzésének tapasztalatai.* Közlekedéstudományi Szemle 2011/6., pp. 8-17.

[5] *Közlekedési Balesetek 2010*, Központi Statisztikai Hivatal, Budapest, (2011).

[6] *Magyar Közlekedéspolitika 2003-2015*, Gazdasági és Közlekedési Minisztérium, Budapest, 2004. március.

Traffic Safety based on Accident Statistics Concerning Road Vehicles and Infrastructure

T. Fülep, J. Óberling

SZE, 9026 Győr, Egyetem tér 1.
Phone: 503 308, fax: 503 400
e-mail: fulept@sze.hu

Abstract: The large number of traffic accidents and their grave consequences represent a real problem all over the world. A successful innovative activity in this field performed on a worldwide scale contributes to solving a critical social and economic issue. Due to the more easily available European statistical data, the paper is going to present the causes of accidents and examine possible solutions. Although a number of effective measures have been implemented in the field of traffic safety, the number of road accidents is still unacceptably high in the EU: a total of 1.3 million accidents per year result in close to 40,000 deaths and 1.7 million injuries. There is a large body of statistical data available (both from Hungary and from Europe) and several comprehensive researches discuss the types of accidents. Available analyses are going to be made on what kind of active or passive vehicle safety systems could have helped avoid the accidents. These analyses have and still define the main directions for legislation and technical developments.

Keywords: safety, accident, statistics, prevention

1. Introduction

Statistically, the primary cause of fatal accidents is traffic participants' bad behaviour (speeding, alcohol consumption, fatigue, unfastened seat belts, etc). In addition to encouraging public road travellers, another key objective is to create a safer vehicle fleet using technical innovations and to develop the public road infrastructure based on the latest infocommunication technologies. When analysing accident statistics, another unfavourable tendency is that even though the number of accidents caused by passenger vehicles is steadily decreasing (although not as drastically as expected), there has been a much lower change in the number of accidents involving commercial vehicles since the European Public Road Safety Charter was issued in 2001.

Analysis of European accident statistics shows that over two-thirds of all accidents resulting in fatalities or serious injuries could be prevented if vehicles were equipped with different driver assistance systems. The most important of these systems are ESP (Electronic Stability Program), LDW (Lane Departure Warning) and ACC (Adaptive Cruise Control). These systems are available as options for passenger cars and they even have versions adapted to commercial vehicles. Unfortunately, these have not yet become as common for commercial vehicles as they are for passenger cars, or should be to avoid accidents (or mitigate their impact).

Some of the next generation driver assistance systems are close to prototype or end-product stage for passenger cars. However, they would be very complicated and time-consuming to adapt for a commercial vehicle platform and would require serious innovation due to the different considerations for vehicle dynamics, manufacturing technology and operating conditions and the various business models. Having realised this, European decision-makers now have a schedule according to which it will only be permitted to launch those new motor vehicles that are equipped with the appropriate safety systems.

2. Accident statistics and infrastructure

Road infrastructure is the central element of a road transport system. It can be defined as the basic facilities, services and installations needed for the functioning of transport on highway, roads, and streets. Road infrastructure is a wide area and covers land use and network planning, (re)construction and design of road sections and intersections, signing and marking, maintenance, and, last but not least, quality assurance procedures like safety audits, safety impact assessments and safety inspections. In general, the road infrastructure would need to be designed and operated in such a way that road users understand what they can expect and what is expected from them, taking into account the limited human information processing capacity and resulting mistakes human beings are capable of.

Land use and network planning form the basis of a safe road infrastructure. Elements that need consideration are the distance between work and housing and the location of daily services, such as schools, homes for the elderly, medical centres and shopping areas, in relation to living areas. Furthermore, it is important that for longer and frequent trips, the fastest route coincides with the safest route, i.e. that the required distance on the more dangerous lower order roads is limited in favour of the safer higher order roads. One important improvement can be achieved by reconsidering the current road classification, allowing for a limited number of road categories only and avoiding multi-functional roads, and subsequently ensuring that the design and lay-out of a road reflect its true function. The latter may require upgrading some roads and downgrading other.

A part of the road that should not be forgotten is the roadside. Obstacles alongside the road, such as trees, severely aggravate the consequences of a crash, once a vehicle runs off the road. Paved shoulders increase the opportunity for a driver to correct and return to their lane in time. Obstacle avoidance roadsides or roadsides protected by guard rails prevent secondary collisions once a driver cannot correct in time. Flexible or break-away roadside fixtures such as light poles and signs reduce the chance of serious injury in case of a collision. When safety is considered from the beginning in the stages of the planning and design, the chance that remedial measures are required after implementation is small. Nevertheless, it is advisable to monitor the crash statistics in order to identify high risk locations. Further inspection of those sites often clarifies the problem and the ways to improve safety, if possible through low-cost engineering measures.

Vehicles and vehicle safety devices play an important role in traffic safety, since they can generate an enduring, sustainable effect. The design of a vehicle affects the protection of occupants in case of a crash and the chance of serious injury to unprotected, vulnerable road users. Additional safety devices, such as seat belts and airbags offer additional protection to car occupants. For two-wheelers, protective clothing and helmets help to mitigate the consequences of a crash. And last but not least, intelligent driver support systems, including in-vehicle, between-vehicle and road-vehicle technologies, help the driver to perform his task safely, preventing errors and violations which may otherwise have resulted in a crash.

The requirements regarding car design are set at an international (UN-ECE) and a European level (EC). However, there is a clear gap between the minimum requirements set by these international bodies and what is potentially possible from a safety perspective. Hence, there are also substantial differences in the safety performances for different cars. Informing the consumers on the safety performance of a car seems to have two consequences. It creates a consumer demand for safer cars and it stimulates car manufacturers to take safety into account as a marketing strategy.

Driver support systems help drivers to drive their vehicle safely, e.g. by warning or intervening when a driver crosses the side line of his driving lane (Lane Departure Warning System), when he approaches too close to the car ahead of him (Adaptive Cruise Control or Collision Avoidance systems), when he exceeds the speed limit in force (Intelligent Speed Assistance), when he or his passengers forget to use a safety belt (Seatbelt Reminders) or when he is about to lose control of the vehicle (Electronic Stability Control). Most of these measures will be made available in new cars by car manufacturers, or as an aftermarket (retrofit) product.

There is a clear relationship between the speed on a particular road and the number and severity of crashes. Reducing speed limit violations will directly affect the safety level. There are various methods to enforce speed limit compliance. Fixed and mobile speed cameras are a well known method of automatic speed enforcement that is applied in many European (and non-European) countries. Another more recent method is section control, currently used in The Netherlands, Austria and the Czech Republic. With section control the average speed over a particular distance (typically several kilometres) is calculated automatically by identifying a vehicle when it enters the control section and when it leaves it, and recording the travel time between those two points. Whereas most section controls are fixed locations, there are also mobile units in use (e.g. in the UK and Austria) particularly at road works zones.

Road safety data are essential for the development of well founded road safety strategies. What exactly is the problem? What are the causes? The more we know about road safety developments and about the underlying causes of those developments, the better we will be able to design and implement the appropriate solutions. Efficiency analyses for assuring that the limited resources are used optimally also require sufficient data. This means that we need reliable data in a number of areas: crash statistics, exposure data, safety performance indicators and data from in-depth crash analysis. Whether the data are reliable largely depends on the data collection method that would need to ensure that the data are correct and representative. Furthermore, good documentation of the data collection method is important as is the accessibility of the data.

Not all road crashes are registered and stored in a database. Generally, fatal crashes are best registered, but even here the data are not complete. The registration rate of fatalities probably ranges between 85% and 95%. As injury severity decreases, the registration rate decreases further. The registration rates of severe injuries generally do not exceed 60%; of slight injuries, it generally does not exceed 30%. Another general phenomenon is that the registration of crashes that do not involve a motorised vehicle is far less complete than that of crashes that do involve a motorised vehicle. Underreporting of crashes leads to an underestimation of the size of the road safety problem. Underreporting of particular types of crashes can also lead to unjustified decisions about road safety measures.

For a good understanding of road safety developments and road safety problems, exposure data are indispensable. Exposure data provide information about how, where and how far people travel and who these people are. Together with crash information, this information allows for calculating the relative risk of travelling in general, or for particular transport modes, particular types of road or particular groups of people.

All over Europe, the number of road crashes has decreased in the last couple of decades (Figure 1), despite the huge increase in mobility. This means that the risk of getting involved in a road crash, e.g. per kilometre travelled, has declined substantially. But this decline is neither equally distributed over transport modes, nor over road types or road user types. If the risk of some types of travel stays behind, it might be needed to take specific measures to catch up or to prevent that the number of crashes will increase if a risky type of travel is likely to increase in the future. To assess differences in risk and risk developments, it is necessary to monitor exposure on a regular basis. A huge decrease can be seen in Figure 2 concerning the road fatalities in the EU during the given time interval, as well.

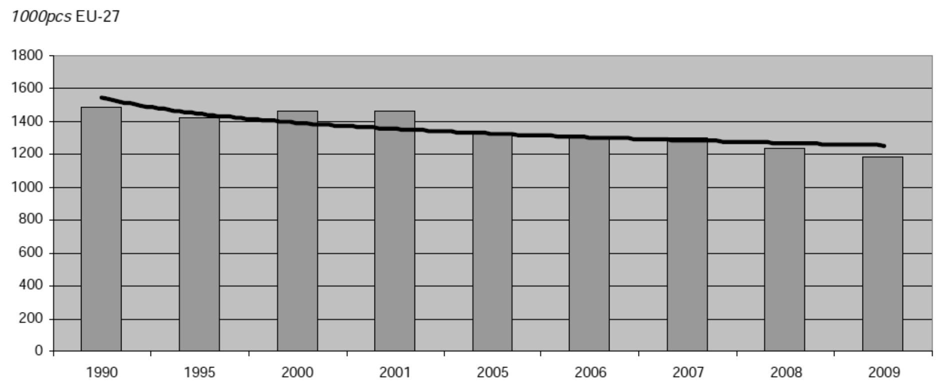


Figure 1. Number of road traffic accidents (1990-2009)

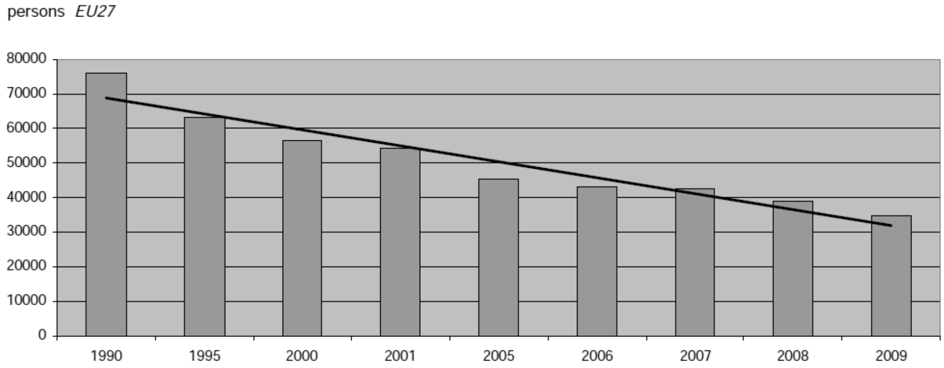


Figure 2. Road fatalities in the EU (1990-2009)

The number of road traffic victims and the severity of the injuries are the most direct measure of road safety. However, it is also useful to monitor road user behaviour or characteristics of the road that have been proven to relate to the road safety level, e.g. driving speeds, the prevalence of drunk driving, seat belt wearing rates, or the presence of forgiving road sides. These types of measures are called safety performance indicators. They provide an indication of the road safety level of a country, and can be used to assess the effects of particular road safety measures. It is important to define safety performance indicators that can be measured reliably and have a causal relationship to the number of crashes or to the injury consequences of a crash.

In-depth crash studies aim to get more detailed information about the causes and the outcome of crashes than available from police records. In in-depth studies, crashes are reconstructed retrospectively by investigations on-the-spot, by interviewing participants and witnesses, by inspecting the damage to the vehicles involved, and by information about the sustained injury. Normally, in-depth studies focus on specific crash types. The extra information is used to detect shortcomings and potential improvements in, for example, vehicle design, road design, road user training, and medical care. In-depth studies are rather common in other transport modes, but less common for road traffic. One of the reasons may be that it is a rather costly type of study. Nevertheless, there is an increasing amount of experience with this type of crash analysis, for example in France, Germany and the United Kingdom and in the framework of the European projects PENDANT and SafetyNET [5].

3. Accident prevention systems

Event Data Recorders (EDR) or black boxes monitor a number of variables related to driving behaviour, such as speed, acceleration and deceleration forces, use of lights, gears, seat belts, etc. There are two main EDR types. The crash data recorder collects data for a limited period just before and after a crash and the journey data recorder collects all data during driving. The crash data recorder is generally used to reconstruct the occurrence of a road crash. The journey data recorder is generally used to provide feedback to the drivers about driving style from an environmental viewpoint, a safety viewpoint or both, often in combination with a reward programme. EDR are most often used in trucks, vans and company cars, but increasingly also in private cars. Insurance premium reductions are the most common reward for private car drivers. EDRs for trucks, vans and company cars are generally introduced by the enterprises and firms or lease companies, for example as a part of a "Safety Culture" programme. The use of EDR in private cars can be stimulated by insurance companies. It appears that EDR have a preventive effect. It has been calculated that EDR in trucks and vans result in an average reduction of 20% crashes and damages, 5.5% fatalities and 3.5% severe injuries. According to another study24 the benefit-cost ratio for companies is 20 for the journey data recorder and 6 for the crash data recorder. A fleet owner can expect a return of investment within a year.

Correction for underreporting of road traffic fatalities in the Netherlands: in order to calculate the real number of traffic fatalities, the Dutch Central Bureau for Statistics (CBS) compares three data sources:

- Crash registration by the police;
- Court files on unnatural deaths;
- Files on causes of death from municipal population records.

These three data sources are compared by linking date of birth, date of death, type of unnatural death (suicide, traffic crash, etc.), municipality of death, and gender. The data are stored and can be obtained at CBS. Data can be disaggregated to age group, gender, region, modality, day of the week and month. The aggregated data are also available via the SWOV (Institute for Road Safety Research) website. CBS is responsible for overall data management and for collecting and linking the court and municipality data. The Transport Research Centre of the Ministry of Transport (AVV) is responsible for collecting the police records. CBS and AVV work together to arrive at the final database. The reporting rate of the real number of traffic fatalities, based on the combined three data sources, is very high: 99.4% for 2004. The individual reporting rates were 90% (police records), 88% (court data) and 95% (municipality records). The costs are not exactly known, but assumed to be rather low (a few person months a year), because existing databases can be used.

In-depth analysis of heavy truck crashes in the Netherlands concerns a pilot research project, aiming to explore the possibilities for primary and secondary safety improvements of heavy trucks. In-depth data are collected from inspections at the crash sites, from police and hospital information, and from the road users that were involved. This way the crash can be reconstructed and analysed. During the pilot, data of 30 crashes were collected. In addition, 30 control group locations were investigated to control for the effect of exposure. The police notified the researchers when a relevant crash had happened. Within 24 hours, the crash location was inspected and questionnaires were sent out to involved parties and witnesses. Vehicles were inspected later. The police collected the data according to their own procedures and submitted this information for the in-depth analysis. The data were collected by the TNO Research Organisation and Dutch Crash Investigation Police departments. TNO is responsible for data coding, data analysis and maintenance of the database. The small number of crashes (30 in all) does not lend itself to reliable analyses, even though interesting indications about the problem of heavy truck crashes have already become visible. It is estimated that a sample of 1,000 crashes is needed to find statistically significant results. The costs are 3,000 Euro per crash and 1,000 Euro per control group location [5].

4. Peculiarities in Hungary regarding the accident statistics

Purely seeing the statistics the same conclusions can be drawn as the leading accident cause is the human factor (more than 90%). If we make a comparison between the years to be analysed the following tendency can be seen (Figure 3) [1]. Regarding the different vehicle types (motorcycle, car, lorry) except in the bus traffic an unambiguous decrease can be realised.

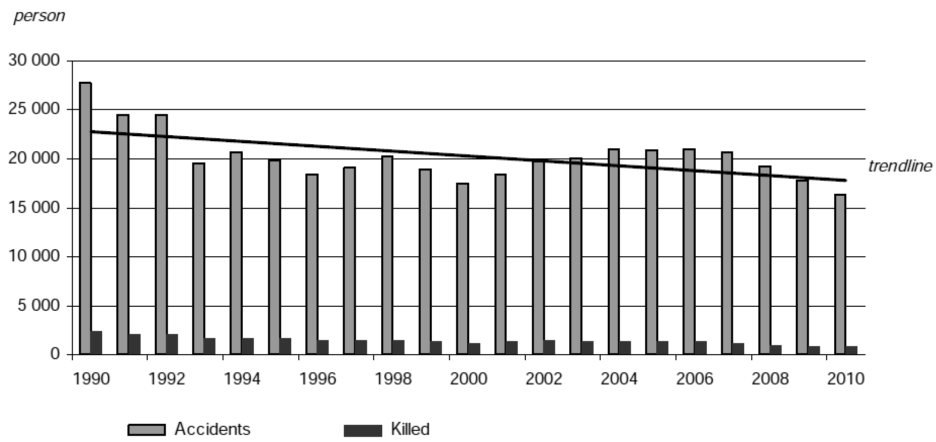
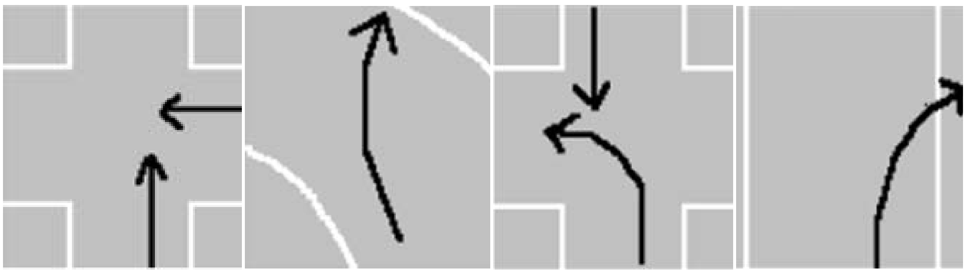


Figure 3. Accidents involving personal injury and the number of persons killed

Concerning the buses almost 20% decrease could be noticed between 2006 and 2007, but it increased almost reaching the data derived from 2006 in 2008. All these data were introduced from the aspect of the drivers' fault [2, 3, 4].



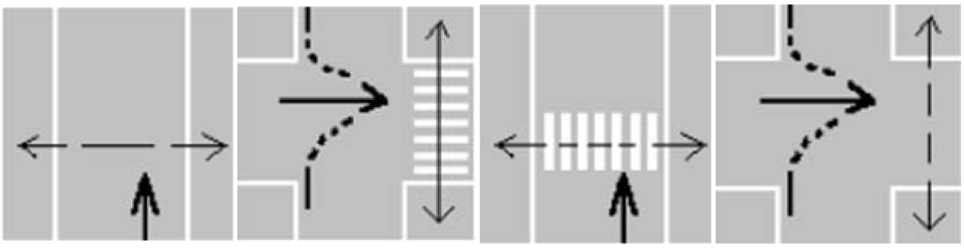
a) Accidents between moving vehicles at interchanges (2134 accidents in 2010)	*b) Single vehicle accidents, vehicle is leaving the line on the right side in curve (680 accidents in 2010)*	*c) Accidents between moving vehicles at interchanges one is turning left (740 accidents in 2010)*	*d) Single vehicle accidents, vehicle is leaving the line on the right side (758 accidents in 2010)*

Figure 4. The most frequent types of vehicle accidents involving personal injury (1)

Regarding the circumstances (Figure 4) of the accidents the leading causes (20-20%) are still:

- inappropriate speed (vast majority to the road condition);
- denied priority (vast majority despite of road sign);
- non observance of traffic regulations (about 30% denied follow distance, 20% left turning vehicle denied priority of vehicles going ahead or turning right)

About the half of the cases happened in road sections and about the one-third in intersections. Looking at the Hungarian experience the accident types give the following view. 60% of the accidents occurred because of the collision of vehicles in motion. About 10-10% of the accidents happened by collision with parking vehicle or obstructions or skidding, capsizing, leaving line or accident between vehicles and pedestrians (Figure 5) [1].



a) Pedestrian accidents outside pedestrian crossings excluding junctions (500 accidents in 2010)	*b) Pedestrian accidents at pedestrian crossings at junctions (423 accidents in 2010)*	*c) Pedestrian accidents at pedestrian crossings excluding junctions (303 accidents in 2010)*	*d) Pedestrian accidents at junctions outside pedestrian crossings (256 accidents in 2010)*

Figure 5. The most frequent types of pedestrian accidents involving personal injury

5. Conclusions

The investigation aims to perform an analysis that examines the operation of the safety systems of vehicles used in real traffic. A robust remote diagnostic reference system is planned to be created that can transfer the data of various vehicle safety systems to a central database analysing them from statistical and telemetric aspects. The analysis would primarily focus on the type of interventions and their suspected causes. The data collected from the remote diagnostics system would be integrated with current databases and the correlation analyses of these statistical properties may help forecast accident risk locations and times. The investigation can help to define the directions of legislation and technical research more accurately. The remote diagnostics system and the methodology may support to test the developed vehicle and traffic safety systems.

References

[1] *Traffic Accidents 2010*, Hungarian Central Statistical Office, (2011).
[2] *Traffic Accidents 2008,* Hungarian Central Statistical Office, (2009).
[3] *Traffic Accidents 2007*, Hungarian Central Statistical Office, (2008).
[4] *Traffic Accidents 2006,* Hungarian Central Statistical Office, (2007).
[5] *Best practices in road safety.* Handbook for measures at the country level, (2007).

The Public Transport Services to Measure the Quality of Standard Bases

P. Fáskerty, G. Horváth, A. Rixer, J. Turi

Széchenyi István University Department of Transport
Phone: (96)503-400, fax:(96) 613-561
e-mail: faskerty@sze.hu
gabhor@sze.hu
rixer@sze.hu

MÁV Zrt. Directorate of Strategy Strategy Planning Department
Phone: (1)511-4938, fax: (1)511-7786
e-mail: turij@mav.hu

Abstract The public passenger transport services are the relevant section of social common goods by forming the standard of living. Therefore it is a general social- political expectation against the national public transport companies to provide their services on an adequate level of quality. Its basic condition is the development and continuous improvement of the appropriate quality-criterion system and quality assurance system monitoring and auditing the client-satisfaction. The general thematic standards compiled with the basis of the so-called best practice could be a good ground for that. It was proved on the ground of the exploration of the relating standard background that the appropriate requirement, recommendation, guidance, general, administration and traffic standards are available for the formation of the appropriate public transportation quality assurance concept by the national public transport companies.

Keywords: public transportation, public services, quality criterion, quality assurance

Introduction

The public transportation services[1], are the relevant section of social common goods by forming the standard of living and therefore it is a general social-political expectation to provide these services on an adequate level of quality. Its basis and condition is the appropriate planning, operating and continuous development of the quality management system and particularly the quality assurance system of the public transportation

[1] In summary, public transport, non-profit, and public transport providers and the public (service person) rather than delivery of key terms (Reason: [1], 238-239. Page)

companies. For reaching this aim, parallel with the consideration of the legal frameworks[2], the so-called best practice standards could serve as a good basis.

Regarding the public transportation services, like the common goods in general, the public transport companies have two groups of clients, contrary to the business undertakings:

- On the one hand, the general so-called end users, so the passengers who require the public transport services.
- On the other hand, the so-called responsible for public issues (regarding the local public transport services the local governments in general, regarding the point-to-point public transportation the central government) who order public transport obligations (for service compliance, -quality, -tariff, etc.) according to the relating legal regulations, within the frame of the so-called public service contracts; however only with the burden of financing obligation as offset of the overflow.

The related legislation - traffic law abiding enterprise practice- development process of a major milestone that we have become EU member. In the framework of EU harmonization- which has since continuous follow up - EU laws (regulations, directives etc) must be integrated into the domestic legal system, ensuring that the relevant domestic laws with EU legislation compliance. The transport services in the field of quality management practices domestic than in the less developed in EU, law has its proper development.

The new MSZ EN ISO 9000 so-called quality management family of standards, which was published in 2000-2001, gave significant impetus and general regulation framework for the continuous and spontaneous improvement in the field of quality management on the standards' side. Beside these general – industry- and sector-neutral – standard requirements the industrial relevant standards have a significant role in public transport services, just as the relevant specific transport's standards have in the case of service companies.

It is obvious that the construction and operation of the domestic public transport companies' quality management systems must be, or should be achieved in accordance with the relevant laws' mandatory requirements and with the general and specific quality standards' requirements and recommendations.

This article's goal is to prove that the proper requirements, recommendations and instruction general and transport standards are already available to establish an appropriate public transport's quality measurement conception for the domestic public transport companies.

[2] Primarily in [2] and [3] I refer to the literature sources

1. Standard background for measuring quality

1.1 General solutions

The measurement of quality and its underlying quality management systems in terms of view, fundamental to the following standards:

- MSZ ISO 9001: 2008 Quality management systems. Requirements (measurement, analysis, development of quality management subsystem)
- MSZ EN ISO 10012:2003 Measurement management systems. Requirements for measurement processes and measuring equipment (the metrological function, strengthen the metrology and measurement process for the design and implementation)
- MSZ ISO/TR 10017:2004 Guidance on statistical techniques for ISO 9001: 2000 (the sampling and measurement methodology for the analysis)
- MSZ ISO/IEC 9126:2000 Information technology. Software product evaluation. Quality characteristics and guidelines for their use.
- MSZ EN 13816:2002 Transportation. Logistic and services. Public passenger transport. Service quality definition, targeting and measurement. (the quality of public service delivery system design criteria and performance criteria for quality and satisfaction measurement methodology)
- MSZ EN 15140:2006 Public passenger transport. Basic requirements and recommendations for systems that measure delivered service quality. (Quality criteria for measurement system design and implementation of measurement)

In the following, for space reasons only the ISO 9001, 13816 and 15140 standards relevant aspects are detailed.

1.2 Quality measurement and analysis requirements of the standard MSZ ISO 9001:2008

The standard MSZ EN ISO 9001:2008 [4] determines general minimal requirements for quality management systems, which can be used by organizations for internal applying, certificating or contracts. They also encourage progress-oriented development of quality management. Essentially these standards' requirements are completely and directly applicable for planning, developing, operating, maintaining and improving the quality management systems of the domestic public transport companies. (See details in: [2], [11]).

- Management responsibility
- Resource management
- Product realization
- Measurement, analysis and improvement

These are the subject of the last subsystem, measurement, analysis, development is important, within which the standard chapter 8, the following minimum requirements states:

- Monitoring and measurement (8.2)
    - Customer satisfaction (8.2.1)
    - Monitoring and measurement of processes (8.2.3)

- Monitoring and measurement of product (8.2.4)
- Analysis of data (8.4)

The basic requirement within the standard includes the following specific requirements:

- The organization shall monitor information relating to customer perception as to whether the organization has met customer requirements (8.2.1).
- The organization shall apply suitable methods for monitoring and measurement of the quality management system processes (8.2.3).
- The organization shall monitor and measure the characteristics of the product to verify that product requirements have been met (8.2.4).
- The organization shall determine, collect and analyse appropriate data to demonstrate the suitability and effectiveness of the quality management systems. The analysis of data shall provide information relating to:
  a. The customer satisfaction (8.2.1),
  b. Conformity to product requirements (8.2.4)
  c. Characteristic and trends of processes and products, including opportunities for preventive action (8.2.3 and 8.2.4).

Perceptible that these requirements are generally interpreted therefore, the quality standards are particularly important for public transport service companies in the transport sector..

1.3 Public transport services' performance and customer satisfaction measurement methodological requirements and recommendations of the standard MSZ EN 13816:2002

The standard MSZ EN 13816:2002 has an importance of transport sector and public transport quality history [9], which contains requirements (marked with bold letters in the following list) and recommendations (marked with bold, italic letters in the following list), and fully applicable in the area of public transport services and service quality management for the public transport services' different processes, such as:

- determining its principals (*Annex B* of the Standard)
- creating and specifying its quality criteria system (*Annex A* of the Standard),
- Methodology of its services' performance and customer satisfaction measurement
  (*Annex C* of the Standard),
- creating its quality management system and identifying its function, and
- contents of the contract of public transport services

(See details in: [12]).

In the following we will specifying the third relation (methodology of services' performance and customer satisfaction measurement) based on the standard, which fits into this topic.

Based on the standard the partners (responsible staff's agents, public transport service companies and/or others), who are involved in the production of public transport services, have to make a contract with each other. In this contract they share the partners' competence, and they determine to build up a quality management system – including a quality measurement system – which can provides the following:

- selecting criteria based on the quality criteria list (taking account of involved passengers' number),
- determining the targeted performance level for each criteria (taking account of involved passengers' rates), which also includes the inadequacy threshold,
- performance measurement, which includes particularly the next:
  - selecting measurement methods,
  - deciding about measuring frequency,
  - decision about result's evaluation method and the proper validation (about validation/approval),
  - documentation of results.

The standard determines quality criteria system of public transport services, which have eight numbered categories 1. availability, 2. accessibility 3. information 4. temporal aspects 5. customer caring 6. comfort 7. safety 8. environmental effects (The first two categories describe the quality of public transport services' supplement using general expressions, but the others serve the detailed description of services' quality. The last category describes environmental effects in terms of the whole society.)

Based on the standard determining/presenting the quality of the offered service(s), the public transport services company have to apply the level-three quality criteria list of the standard's Ann*ex A* for specifying the selected public transport system's service quality, where level 1st is represented by eight quality categories symbolized with a single digit, level 2nd contains quality criteria indicated with double-digits (total of 29), and level 3rd contains quality criteria indicated with code numbers of three-digits (total of 99). The quality system can be built up on the 1st-3rd levels, so criteria can be selected from level 1st to level 3rd, but the system's progressive establishment is also possible in accordance with the continuous improving principals of quality improvement.

These notes aim to provide guidance on the main performance and satisfaction measurement methods in common use in public passenger transport; these include particulary:

- For satisfaction measurement: Customer Satisfaction Surveys (CSS)
- For performance measurements: Mystery shopping Surveys (MSS)
- "Direct Performance" Measures (DPM)

The standard Annex C to performance measurement guide, which

- describes the measurement of performance and satisfaction measures are important aspects (This is followed in C3 to C6 by more detailed guidance on performance)
- contains general comments on quality measurement methods
- comments for the three methods of measurement performance and satisfaction essence, purpose and application characteristics

- some examples of Performance and satisfaction Measures Used in Public Passenger Transport.
- specific examples are then explained more fully in Table C2.

The standard three-methods connection with the following description:

- Customer Satisfaction Surveys (CSS):
  - is a tool to evaluate customer satisfaction,
  - is designed to assess the levels of satisfaction with the service provided and should not be considered a precise measure,
  - by measuring satisfaction, comparisons can be made against the service quality sought by the customer,
  - customer satisfaction is measured against a scale where the customer is judging the extent to which the service provided meets his or her requirements,
  - customers should be surveyed independently based on the most important aspects of their journey, as predetermined by market research,
  - it is recommended to first identify criteria which appear to be the most important for the customer and to evaluate in priority these criteria. (only after this first step should other criteria taken into consideration)
  - surveys conducted should be in accordance with normal market research practice, ensuring that appropriate sampling is undertaken of all users, from all origin points on the network.
  - surveys can take place at various points on a customer's journey, or subsequently, but consideration should be given to the time available and the avoidance of any bias,
  - it is important that surveys are conducted and reported on a regular and timely basis. In addition, it is important that continuous assessment is made of the survey's suitability to meet the needs of service providers and the priorities of the customer. (this requires research into the effect of different quality improvements on customer satisfaction)
  - it should be noted that customer attitudes can be influenced by external factors, such as the performance of another service provider, and other products and services generally.
- Mystery Shopping Surveys (MSS)
  - also measure quality of service, but are based as far as possible on objective observation carried out independently by trained survey teams, rather than interviews to asses customer attitudes,
  - they make detailed observations of the service provided against specific criteria, whilst acting as is they were genuine customers traveling on the system
  - it is important that consistent ranking systems, using calibrated checklist, exist in order to minimize the risk of variation between assessors.
  - MSS should also be carried out and reported on a regular and timely basis to allow the identification of any trends in performance
  - MSS enables monitoring of specific elements of the service that focus on the features that are of greatest importance to the customer, though it cannot itself reveal these. When compared to CSS, which normally take place

during or immediately after a customer's journey and are, therefore, limited by time, MSS facilities monitoring to a grater level of detail. MSS also helps overcome the fact that customer perceptions may not reflect solely the service being measured, or performance on a specific journey.

- Direct Performance Measures (DPM)
  - Monitor the actual performance of the service - either continuously from operation records, or by using sample observation taken on a representative basis
  - Direct Performance Measures allow performance to be monitored and targeted against defined scales
  - Appropriate measurement systems need to be in place to collect the data, and balance needs to be struck between full data provision and sampling approach
  - It is important that measures are relevant, not simply those that are easy to produce, and focus on the impact of performance as seen by the customer.
  - Direct Performance Measures should reflect overall organisational objectives at all levels, so that service providers and staff can see how they can contribute to improved performance.

1.4 The MSZ EN 15140:2006 public passenger transport. Basic requirements and recommendations for systems that measure delivered service quality

This document provides basic requirements and recommendations for systems that measure delivered service quality of public passenger transport to be applied in the framework of EN 13816. The requirements and recommendations specified in this document apply both to third party measurements and measurements conducted by the service provider.

EN 13816:2002, Transportation. Logistics and services. Public passenger transport. Service quality definition, targeting and measurement.

Terms and definitions:

- Continuous measurement: collection of data takes place all year round
- Grid: table used for collecting data and evaluating the various items composing a quality criterion
- Indicator: quantitative expression of a quality criterion resulting from a measurement process
- Item: measured component of complex quality criterion
- Quality criterion: representative of the customer view of the service, as stated in EN 13816:2002 subclause 3.2
- Surveyor: person collecting data.

The referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document applies.

1.4.1 Requirements applying to all measurement system

Design of the measurement system

- Each quality criterion to be measured shall refer to the list of eight categories given in EN 13816.
- The design of the measurement system shall balance the customers viewpoint and use of the measurement as a management tool for reaching targeted quality
- Some quality criteria may need to described more precisely in a grid that lists a number of items (in case, the items in the grid and their weights shall be designed in accordance with the previous requirement)
- When it is not possible to control/measure what customers perceive, evidence shall be given that, as far as the customer is concerned, specified procedures have been followed
- For each measured quality criterion, there shall be a precise definition of what is "in conformity"/"not in conformity".
- The delivered quality measured shall be recorded either as "in conformity", or "not in conformity"
- As stated in EN 13816:2002 subclause 4.2, the level of achievement shall be expressed, where appropriate, as a ratio of passengers affected.

1.4.2 Conduct of measurement

- The measurement of the service quality delivered shall be done during operating hours
- Updated measurement of the chosen quality criteria shall be consolidated and reported at least once a year,
- The organisational arrangements for measurement shall be documented and provisions shall be made for inspection and audit
- Changes in the methods and reasons for the changes shall be documented,
- The data collection and data processing shall be transparent, traceable and verifialble
- The item measured shall be recorded as first observed even if immediate corrective action takes place

1.4.3 Specific requirements according to the type of measurement

- Measurements can be made by surveys or by technical means. They can be continuous or by sample
- The profile selection and training of the surveyors shall be specified, Their briefing process and on- site management shall be specified.
- Data collected automatically shall be compared for consistency purposes, at least when the system of data collection is created or modified, with data from other sources of measurement relevant to the same quality criterion
- It shall be verified that the measure takes place without interruption that would affect the reliability of the results
- The size, choice and frequency of he sampling shall consider statistical rules and shall be documented, it shall be verified that the survey scheme is representative of the type of service in question.

2. The quality criteria for measurement system design concept and application examples

2.1 The quality criteria for measurement system design concept

Each example is described using the same structure, which can be used as a guideline in a conception of measurement processes and indicators:

- Name of the measured quality criterion;
- Category of the criterion (referring to EN 13816:2002, 3.2)
- Design
    - Determination of customer viewpoint: describe how the customer viewpoint is assessed;
    - Management viewpoint: explain how consistency with operational process is ensured;
    - Definition of "in conformity"/not in conformity": insert grid if existing;
    - Ratio of customers benefiting from the service: explain how the indicator is calculated or estimated;
    - Service standard and level of achievement: give a brief statement.
- Conduct:
    - Organisational arrangements;
    - Performance data collection: describe how data collection is performed and, if existing, mention detection of unacceptable performance;
    - Evaluation of the number of customers: describe how the number of customers is calculated or estimated
    - Data processing: describe how data processing is performed and, if existing, mention detection of unaccepted performance
    - Inspections and audits.

2. 2 Examples of public transport service quality measurement system design and criteria for measuring implementation

Different types of measurements may be, according to which the tools used and how the frequency of sampling. The Table 1 gives samples, classified according to the types of measurement. (MSZ EN 13816)

Table 1. Example

	Continuous	Sample
Surveyors	Availability of buses on the route	Cleanliness in train Bus cleanliness
Technical means	Phone waiting time at the Customer Contact Center Punctuality of train services	Punctuality of bus services

The standard measurements for the three application samples presented. The basic steps are the follows:

- organizational measures
- collection of data
- inspections and audits.

The measures are conducted by employees of the company, hired especially for this task:

- To obtain qualified and independent personnel, the following steps apply:
- After two selection interviews, they are trained in four steps
- Two in- house, (presentation of the company and explanation of why measures are necessary, description of the measurement grids)
- And two on- field (measures in a real situation with a teacher, debriefing)
- During the first month, each surveyor is accompanied at least twice,
- Every day, the surveyors are briefed and debriefed.

The data collection techniques and functions of the third article and chapter 4 includes the following steps:

- Definition of "in conformity"/"not in conformity"
- Collection of data.

The standard presents three application samples for measurements by technical devices.
The used technical devices are:

- In the measuring the telephone waiting time: with the telephone customer connection center's automatic call receiver, delay measuring and registering system (it's a generally used, common Call Center system),
- In the measuring of railway services' accuracy: with an automatic data collector system installed on so-called checkpoints of central railway stations and major stopping points or alongside the railway tracks,
- In the measuring of bus services' accuracy: with the on-board ticket issuing and validation devices..

(We must note that in the last two cases this question is already solved and generally used based on GPS techniques both in the practice of MÁV-Start and Kisalföld Volán, too.)

The standard presents three application samples for continuous measurement. The definition of continuous measurement can be found in this article's Point 1.4.

The standard presents three application samples for sampling measurement. The methodology of sampling have a very rich literary (for example [13] page 103-147., [14]) and standard (for example [6], [7]) background, so the standard does not includes such references.

On the following we will present the contents of application samples' unified structure elements with the sample of "Cleanness on trains" quality criteria, which is also a sample for a sampling measurement made by trial customers with quality inspection and evaluation table technique.

3. The professional content of the unified structure of application samples presented in the standard, on the example of the sampling measurement made with the tabular quality analysis and evaluation technique by the surveyors

- Example of measurement by sampling using surveyors
- Name of the measured quality criterion:
  - cleanliness in trains;
  - category of the criterion (referring to EN 13816:2002, 3.2)
  - comfort
- Design
- Determination of customer viewpoint
  - Customers expectation surveys are conducted in order to determine which are the relevant items and to give weight to each one. This is done by means of a survey, which uses open questions asking customers to rank the cleanliness items in order of importance
  - Management viewpoint
    This criterion includes brightness aspects but not maintenance aspects because they belong to two different management processes. The items mentioned as "important" by the customer and measured are clearly identified by the staff. The evaluation of each item is based on the evaluation of the different aspects of non- cleanliness and linked to the different tasks of cleaning
  - Definition of "in conformity"/"not in conformity"

Table 2. Determination of conformity treshold

Aspect/Item ↓	Graffiti	Rubbish	Strisckers	Stain	Dust	Weight	V_i avarage along aspects	Results
	m_{ij}					α_i (%)	$V_i=(\Sigma_j m_{ij})/n_i$	$\alpha_i V_i$
Floors	2	3	2	3	2	*25*	***2,4***	**0,60**
Seats	3	3	3	2	2	*20*	***2,6***	**0,52**
Doors	3	X	3	2	2	*15*	***2,5***	**0,375**
Handrails	X	X	3	3	2	*10*	***2,67***	**0,267**
Windows	3	X	3	3	2	*8*	***2,75***	**0,22**
Exterior	3	X	3	3	3	*5*	***3***	**0,15**
Ceiling	2	X	2	2	X	*5*	***2***	**0,1**
Walls	3	X	3	2	2	*5*	***2,5***	**0,125**
TV sreens	3	X	3	2	3	*5*	***2,75***	**0,1375**
Driver's cab	2	X	2	2	X	*2*	***2***	**0,04**
Total Value: $M = \Sigma_i \alpha_i V_i$:								**1,4145**
Conformity threshold:								**2,53**
X: non applicable.								

According to the amount of graffiti, rubbish (cigarette ends, papers, chewing-gum), stickers, stain, and dust a mark m_{ij} will be given for each item and aspects (if applicable), between 0 and 3; 0= very bad, 1= bad, 2= good, 3= very good. The determination of this level of conformity is based on both the management viewpoint (former results and challenged improvement) and the customer viewpoint (expected marks for each item and weight). The measured train is in conformity when the resulting mark M of its inspection is equal or more than 2.53 and is not in conformity when the mark is less.

- Ratio of customers benefiting from the service
  For every "in conformity inspection", the "customers in conformity" are the passengers of the day and line of the train inspected.
  For every "not in conformity inspection", the " customers not in conformity" are the passengers of the day and line of the train inspected
- Service standard and level of achievement
  More than 95% of the passengers find trains in conditions of cleanliness that are equal to or higher than the conformity threshold.
- Conduct
  - Organisational arrangements
    The measurement is made by a subcontractor. The subcontractor is provided the rules for sampling and planning inspections during the month. All the days of the week and full range of operating hours are sampled successively. The subcontractor's surveyors are also provided the detailed guideline for evaluating the train cleanliness (pictures, descriptions, etc.)
  - Performance data collection
    In each inspection, a surveyors walks through two cars randomly chosen in the train and looks at each item (floor, seats, doors, etc) to evaluate it on a scale of 0 to 3 aspects (if applicable). He reports his evaluations and observations on the grid and then enters both types of data in a database.
- Evaluation of the number of customers
  A software simulating transit in stations and trains gives the number of passengers using each station and line for each type of day (working day, Saturday and holiday)
- Data processing
  When the company receives the collected data, it calculates the indicator using a simple spreadsheet.
- Inspections and audits
  During the audits of the quality management system, auditors verify that the measurement process is reliable and suitable. The quality department verifies the coherence of the collected data.

4. Main statements and conclusions for quality measurement of public transport services, based on the comparative analysis of the application samples

It's determinable by the comparative analysis of the standard measurement methodology and systematic comparative application samples (such as the accuracy and cleanness of trains and buses) that in spite of some formal and content similarities there are significant methodological and systematical content differences in the otherwise identical road and rail service quality criteria. Because of this in our opinion it's not possible to create a unified transport company neither unified transport sector quality measurement system nor methodology, so requiring a unified responsibility/regulatory requirements is also impossible. We will prove our statement with the following comparative analysis.

The presented sample of train cleanness compared with the bus cleanness sample the main measurement methodology and systematic differences are obvious in respect of the following:

- in the structure and evaluation of the quality testing and evaluation (Table 2 and 3) are different
  - the "cleanness/non-cleanness" elements and their
    - score values,
    - weightings,
  - the evaluation method of the "cleanness/non-cleanness", i.e. the determination of "adequate/inadequate"
- the determination method of the rate of the passengers who are concerned by inadequate performance
- the level of the service requirements and the performance level,
- the mode of data collection
- the evaluation methodology of determining the rates of the recipients and the passengers who are concerned by inadequate performance.
- the method and system of data processing
- the method of inspections and audits.

On the following we will specify only the different planning and constructing relations of the "Cleanness on Buses" quality criteria quality measuring application sample as the reason of these differences. (Of course we assume the content comparison of the following "Cleanness on Buses" and the already presented "Cleanness on Trains" quality criteria's relevant structure elements.)

- Definition of "in conformity"/"not in conformity"
  Surveyors are provided with a grid. The grid is made up of 27 items of non-cleanliness, grouped in 5 aspects. The items, their value, and the weights of the aspects are based on customers' expectations shown by the enquiries and management viewpoint, thus defining the targeted cleanliness. If an item is found, a negative value in points is attributed. (see Table 3.) The sum of the points of aspects is between 100 (no items found) and 0 (all items found). The score of each aspect is multiplied by its weight. The total score is between 0 and 100. If it is equal to or higher than 80, the bus cleanliness is in conformity. If the score is under 80, the bus cleanliness is not in conformity.
- Ratio of customers benefiting from the service
  If c_i is the number of buses in conformity counted on day i of the measure, n_i the number of buses measured by the surveyors this same day, t_i the total number of passengers of the day of the measure and d the number of days measured, then the monthly ratio p of customers benefiting from the service is:
  $$p = \sum_{i=1}^{d} \left(\frac{c_i \times t_i}{n_i}\right) \div \sum_{i=1}^{d} t_i \times 100$$
- Service standard and level of achievement
  80% of passengers can expected to find a clean and neat bus, with no unpleasant smells.

Table 3. The cleanliness of buses

Item	Value	Weight	Example
Aspect: Smell	100	0.2	100
Organic smells (vomit, urinem faeces, sweat)	33		
Smell of tobacco	19		–19
Smell of tear gas	20		
Smell of gasoil	10		–10
Stuffy or musty smell	18		
Result			0.2×71 = 14.2
Aspects: Internal cleanliness	100	0.1	100
Dirty body, advertising panels, lateral line panels	13		
Traces of diesel leak near stopper	37		–37
Outside of windows dirty	19		
Traces of diesel fumes or soot	31		
Result			0.1×63 = 6.3
Aspects: Internal cleanliness	100	0.4	100
Presence of garbage on the floor	15		
Presence of vomit	18		
Greasy, slippery or sticky floor	17		
Driver's protection window dirty, greasy or frosted	4		–4
Inside of windows dirty, greasy but not scrachted	9		
Inside panels spoiled, tagged, torn	5		
Dirty handrail or handles	11		
Dirty or dusty driver' s cab	4		
Dirty seats or rotunda	17		
Result			0.4×96 = 38.4
Aspects: External visual aspects	100	0.1	100
Damaged parts of body or lighting out of order	26		
Torn doors or vestibule joints	37		
Outside door opening command out of order	37		
Result			01×100 = 10
Aspect: Internal visual aspect	100	0.2	100
Undulating floor, deteriorated step	32		
Handrail, guardrail or handles broken, lacking or unusable	13		
Damaged or ruined vestibule	16		
Difficult door opening	16		–16
Passengers seats torn to shreds, burnt, or damaged	16		
Inside of windows or protection windows scratched	7		
Result			0.2×84= 16.8
Total score			85.7

- Performance data collection
  The measures are taken by surveyors during a journey. To optimise costs, the surveyors measure other aspects of quality that the customers find on his way from one point to another (e.g information). A minimum of 8 journeys per route is made each month. The job is planned so that all the days of the week and full range of operating hours are sampled successively.
- Evaluation of the number of customers
  The daily number of customers is obtained by automated passenger counting systems
- Data processing
  A separate department of the company is in charge of the data processing. A calculation is performed each month for the work. An unacceptable performance is detected if:
  - A surveyors notes that a bus has graffiti, and the situation was reported by a driver more than 3 days prior;
  - A surveyors notes an unclean or smelly bus, and the bus was kept running after a passage at the end of the route.

The results are published monthly, between the 6th and the 15th day of the following month.

- Inspections and audits
  The surveyors are monitored regularly by their managers, at least twice in three months. Verification measures are conducted, without informing surveyors. Regular interviews with the surveyors help to verify their level of understanding of the task. If necessary, further training is organized. The measures of each surveyors are checked during the computer processing (coherence and plausibility of items noted) The measurement system is audited regularly by external auditors.

Conclusions

Summarize it all, it can be stated that there are standards on the one hand international, of EU- or domestic level, in the other hand in sector/industrial level, which have generally and concrete regulations, requirements, instructions in connection with the public transport services' general management and with the services' qualities, quality measurements, quality managements. These standards are really useable in the management, quality- and measurement management of public transport products, service (production) systems and service (production) processes.

We conclude that within the meaning of benchmarking (level comparison) and creative thinking analogies' principles, the so-called best legal and standard practices of the transport sector/industry and also other industries (for example [2] 74-78. and 84-85. p., [7], [8]) can provide guidance for creating public transport services' quality management systems and high quality service-products.

Of course the relevant legal and standard backgrounds are continually changing and expanding – it's especially true for general and quality management of public transport services – so we expressly attract the involved public transport service companies' agents' and responsible staff's agents' attention to follow the possible changes on the adequate websites in order to apply and get up-to-date information.

References

[1] Rixer, A.: *The concept of quality public transport service background* Hetesi, E. – Majó, Z. – Lukovics, M 2009: *The world of services*, JATE-Press, Szeged, SZTE Economics Faculty announcement, (2009), pp. 235-249.

[2] Dr. Rixer Attila – Dr. Veres Zoltán: *Quality assurance of Services* Universi-tas-Győr Ltd. Győr, (2009). ISBN: 978-963-9819-39-9

[3] Dr. Rixer Attila: *A Public transport services in the concept of quality management standards and law background*. Economy and Society, "Past – Present – Future" ISBN 978-963-9696-72-3 és ISBN 978-963-9696-73-0 MTA VEAB, Veszprém, (2009).

[4] MSZ EN ISO 9001: *Quality management systems. Requirements,* (2008).

[5] MSZ EN ISO 10012: *Measurement management systems.* The measurement processes and measuring equipment requirements, (2003).

[6] MSZ ISO/TR 10017: *Guide* ISO 9001:2000 Statistical methods, (2004).

[7] MSZ EN 13549: *Cleaning services*. Basic requirements and recommendations for quality measuring systems, (2001).

[8] MSZ ISO/IEC 9126: *Information. Evaluation of Software Products.* Quality characteristics and guidelines for their use, (2000).

[9] EN 13816: *Transportation Services. Public Service of passengers.* Basic concepts, performance targets and service quality measurement, (2002).

[10] MSZ EN 15140: *Public transport.* Basic requirements and recommendations for service quality measurement systems, (2006).

[11] Dr. Rixer Attila: *Quality assurance of services.* Quality assurance and management standards. Educational resource material. SZE. Győr, (2003).

[12] Dr. Rixer Attila: *Transport systems for quality management.* Educational resource material. SZE Győr, (2004).

[13] Köves Pál, Párniczky Gábor: *General statistics II*. Economics and Law Publisher. Budapest, (1981).

[14] Dr. Rixer Attila: *Customer relations management.* Transport Customer Satisfaction analysis methodology for rail passenger services as an example. Educational resource material. SZE. Győr, (2003).

Milestones in the History of the Hungarian Railways' Ticket Sales

L. Szabó, K. Galambos

SZE Közlekedési Tanszék, MÁV-START ZRt. Informatikai Szervezet
Phone: 96/503 494, 1/511-2345, Fax: 96/613 561, 1/511-1324
e-mail: szala@sze.hu, galambos.krisztian@mav-start.hu

Abstact: This article includes the practice of the Hungarian Railways' ticket sales since the appearance of the first ticket dispensers to the present day. Different ticket sales methods and the linking of ticketing systems to other computer systems will be presented. This study shows the deficiencies of today's ticket sales system, and the main directions of future development.

Keywords: ticket dispenser, international trains' reservation, reservationss via telephone, Mobile Ticketing System, ticket-printing machines, complex distribution system, on-board ticket sales

Introduction

The necessity of implementing an integrated computerized IT system was already included in the MÁV 2000 concept of the year 1991. To raise passenger transport services' quality, this concept aimed to introduce a customer-friendly travelling, information and trading system. The system's economic benefits was seen especially in effective sales support, which results in revenue growth, the market-oriented optimization of capabilities and in cost reduction.

Developing a passenger-friendly distribution system greatly contributes to increase attractiveness of rail passenger services. The ability of multi-channel service selling is expected from a modern distribution system. Nowadays significant proportion of sales still happens through station channels. Shifting these rates to sales by ticket machines or online is desirable. The introduction of the bar-coded ticket system and the chip card system are also parts of the future plans. The integrated development of domestic and international distribution systems can enhances the passenger-friendly nature of distribution systems. The ticket sales system must to provide services without manual involvement even in corporal accounting and administration processes. The third important factor – which must be handle with priority in the development of ticket sales systems – is the connection with other distribution and non-distribution systems (for example management control systems) and scheduling databases.

1. Generally about the passenger information systems

Regardless of transport sub-sectors, the existing and efficient information system, which helps the passengers travels, are important elements of the passenger transport services' attractiveness. An ability to increase the complexity of passenger services is the global interconnection and interoperability of each sub-sectors' systems. This globalization often comes with the involvement of hotel and restaurant distribution services.

1.1. Application areas of the passenger transport IT systems

Based on traveling and regardless of subsector breakdowns the IT systems' services are concentrated in two main areas:

- auxiliary processes like operations before and after traveling
- main process, which can be related to the actual traveling.

In terms of passenger transport technologies the auxiliary processes includes preparation and finishing operations. The complex passenger transport information systems cover these operations in the form of different IT services. The most important auxiliary processes are providing scheduling and pricing informations and selling electronic seat-reservation vouchers and railway tickets. Other services also include hire of vehicles, reservations from other systems and extracting different subsequent travel informations.

The main process' goal is to generate informations which could serve traffic control and the accounting of different performances, not only informing passengers and expectants. The time values and the current location of the vehicle can be shown to the traveling public during the journey.

1.2. The distribution system of seat-reservation vouchers and tickets

Selling tickets is one of the most important auxiliary processes of passenger transport, which includes selling seat-reservation vouchers and railway tickets. They are commonly known as distribution system. The most important primary data groups are:

- infrastructure (stationary and moving equipment)
- schedule
- tariff
- other (for example job-IDs, statistical codes, tax IDs, etc.).

The infrastructure primary data group contains the data which are necessary for describe clearly the transport routes (reservation sections) and properties of the vehicles for generating reservation offers. Important to specify the train IDs among scheduling data. The other groups' data are needed to generate a lot of information and certificate.

The most important output groups are:

- producing seat-reservation vouchers and railway tickets
- passenger (reservation) lists
- different trading statistics
- supporting traffic control

- supporting schedule planning.

Producing and ordering seat-reservation vouchers and railway tickets can be made not only by transport companies, but in a lot of different access points with network availabilities. [1]

In the following we will review the development of the domestic distribution system of seat-reservation vouchers and railway tickets.

1.3. Specifics of railway distribution

Obviously these systems must also be complied with expectations described in section 1.2., however we need to mention some specifics which are characterized in rail transport. A railway company's ticket distribution system has to provide other services beyond directly related services to passenger transport. They have to make those services available which are provided by other railway companies and partner agencies. These partner agencies can be transport companies, major hotel chains or even airlines. The railway company's ticket distribution system is definitely connected to a management control system, which provides important data for the leading information system which supports decisions about passenger transport. The large-scale scheme of the railway company's ticketing system and its environment is shown in Figure 1.

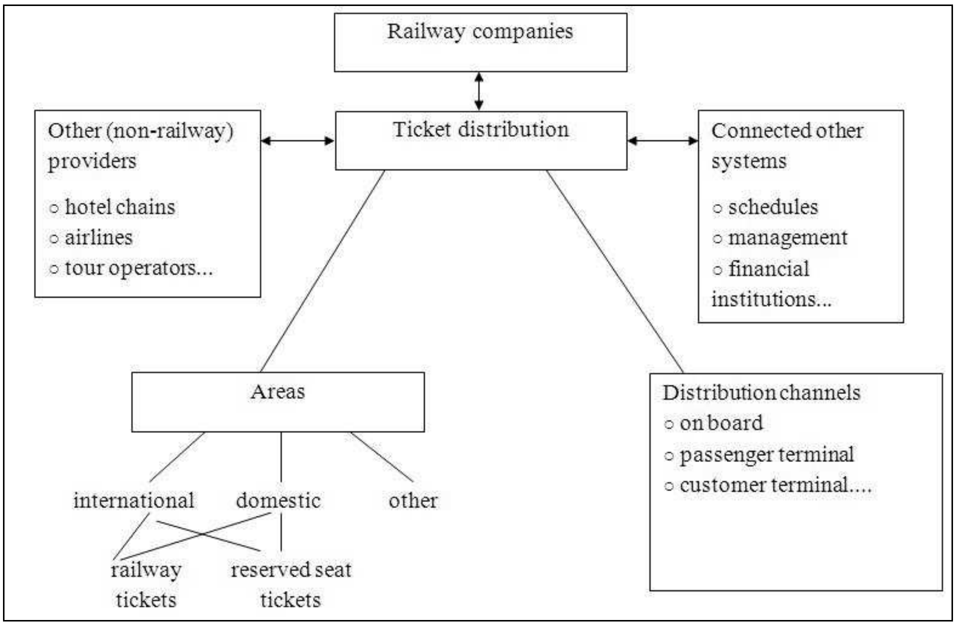


Figure 1: Large-scale scheme of the railway company's ticketing system and its environment (Source: made by the author, Lajos Szabó)

2. Chapters from the history of the hungarian railway ticket distribution

The chronological presentation of the MÁV's distribution systems from the 90's is also the illustration of the current distribution systems, as there haven't been any comprehensive replacement of the entire distribution system in the past few years.

2.1. The past

The first electromechanical ticket-printing machines in Hungary were installed in 1958 at the Budapest-Keleti Pályaudvar, developed by Allgemeine Elektrizitats-Gesellscaft (A.E.G.). This ticket printing-machine, which had landscaped control panel, could generate 630 different types of tickets, and could be operated electrically or manually. With these machines the cashier press the ticket at the passenger ticket windows during the ticket change process, and the machine counts the issued tickets at the same time. These two machines functioned until the end of the sixties. [2]

In 1793 fifteen Italian SASIB ticket-printing machine were purchased. Two types of these electrical ticket machines came to Hungary. They had electrical control panel. The bigger one, which could print 1000 different types of tickets, were operated at the MÁV Public Relations Office, and the smaller ones, programmed to 500 different tickets, were operated at different locations; 10 at the Budapest-Déli Pályaudvar, 2-2 at the Budapest-Keleti Pályaudvar, and at the railway station of Debrecen. On these machines the cashier had to find the appropriate ticket type in a crosshair, and had to print the ready ticket onto a separately inserted carton sheet. They used brown cartons for second-class tickets and green ones for the first-class tickets. The red lines onto the express trains' cartons were printed previously. When the VAT were simplified in 1980, temporay solutions were used at the machine's reinstallation because of the scarce currency, but along with it they were operated until 31th December 1998, after that they were replaced to Hungarian-made MAEF machines. [2]

The first electronic ticket issuing machine in Hungary was made by the Dutch Simmonds Precisions Company. The thought of ticketing's extensive mechanization were raised for the first time at the end of the 70s at MÁV. Chief Executive Officer Zoltán Szűcs, who otherwise was highly efficient, recognized the importance of the issue, and he also would have canceled the procurement of an electric locomotive in order to appropriate mechanization. Several companies offered to develop the electrical cash register, including the Swedish ALMEX, the Swiss BILEXA and the Dutch Simmonds Precision. The MÁV's ideas were elaborated by Dr. Sándor Szabó, István Nagy, Imre Perger and György Horváth, under the leadership of Deputy Head of Department Miklós Süle. Based on the prepared descriptions, tables and block diagrams the Dutch company made a simple, easy-to-handle machine, what didn't slowed down the process of ticketing noticeably, but simplified accounting and statistical recording significantly. The machine produced tickets based on the seven-digit code numbers, which had already proven in statistical recording. The base ticket was the passenger train's second-class ticket. The different reduced price tickets could be producted based on this, so for a passenger, who traveled in second-class, the cashier only had to type in the charging zone and press the eject button. The prototype was operated at the MÁV Public Relations Office until the ticket's currency conversion to forint in 1978-80. The two devices, which were made after the tariff system changes, worked at the Budapest-Déli Pályaudvar from 1982 to the tariff increase in 1989. Additional purchase was failed due to chronic scarce currency. The devices which cannot be used any more due to tariff changes were scrapped in 1996. [2]

The IT systems appearance in the field of distribution is illustrated well in Figure 2.

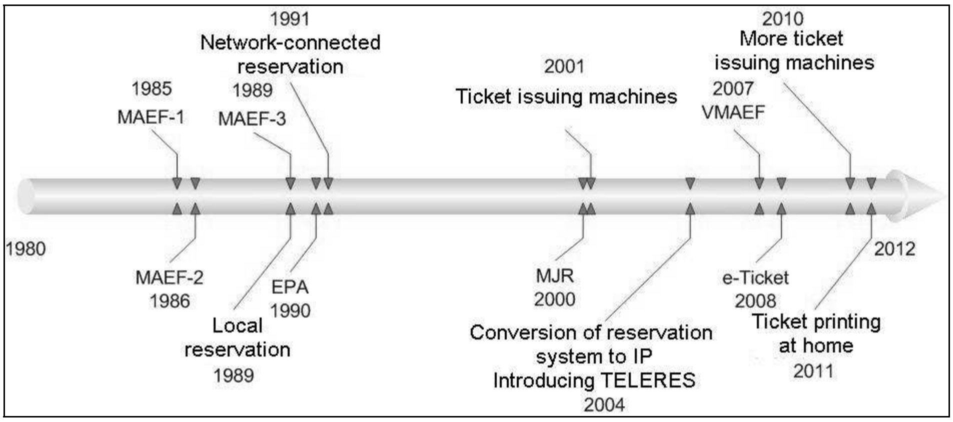


Figure 2: Timeline of the distribution systems' introduction

In order to reservation in international trains, the MÁV joined to the DB's automated location center in Frankfurt am Main, where the five founding member railways – DB, ÖBB, DSB, SNCB, CFL – stored all of their place-maintained train services' places. Electro-mechanical ticket printers – aka. Walther terminals – were installed to the location center of Budapest and to the Public Relations Office in the Andrássy út for printing seat-reservation vouchers. The requirements of those service areas which didn't have an EPA machine were received in the location center of Budapest via telex, fax and telephone. At the beginning the ÖBB railway company also maintained the MÁV trains' informations. After that in 1990 10 PC-based EPA terminals were installed to railway stations, travel agencies, ticket offices in Budapest, and to the location center of Budapest. Our trains' basic data are supplied on ZBR terminals by MÁV in its own discretion. At present MÁV-START have 69 terminals in checkouts, which cause a significant decrease in the amount of location transmissions. [3]

2.1.1. Installing the MAEF ticket issuing machines (1985)

The first Hungarian electronic ticket issuing machine is the MAEF. The need for domestic development came to the front due to the impossible purchasing of Simmonds Precision's devices. The young engineers of the TBKF (Távközlési és Biztosítóberendezési Központi Főnökség) – Dénes Büky, Tibor Kovács and Tamás Laczkó – using the principles of the Dutch machine, developed a simple electric device as an innovation, which was produced by the Zöld Mező TSZ at the beginning, and later the Data-Press. The first 10 MAEF-1 ticket issuing machines were installed in 1985 at the Nyugati Pályaudvar's ticket offices. 26 MAEF-2 second-generation devices were commissioned in the end of 1986 at the Keleti and the Nyugati Pályaudvar. The Trade Service formulated new requirements in 1989. The mechanization of domestic reservation of seats became an urgent task, which brought along with the ticket issuing machines' modernization. The machines had to make suitable for working in the network. This led to the development of the MAEF-3 machines. The construction of the X-25 network started in 1990 as an experiment by MÁV, and the MÁV's domestic placeholder network were installed onto it. At first the three main railway stations were connected, and after comes the other provincial bigger and smaller stations continuously.

The general proliferation of the MAEF ticket issuing system took place only in the mid-nineties. Functionally "needle-matrix" tickets replaced the tradicional (crusted, labeled and reform) tickets, which were hegemonic before.

The ticket-issuing machines had two main parts: a central unit – which included a printer unit, and a keyboard for data input – and a connectable monitor (normally monochrome, CRT). The "application software" enabled to issue kilometer-zone tickets, so the railway tickets contained the distance in kilometers instead of starting place and destination. The paper tapes, which were used at the beginning, were replaced to thermal paper, which is still in use. [4]

Figure 3: Cash register at Széchenyi-hegy station [4]

The ticket issuing machines, which were developed by the TBKF's engineers, were made, developed and operated by Data-Press and its predecessors. From 2007 they provide system support as Data-Press Informatikai Szolgáltató Kft.

In 2004 every MAEF-3 ticket issuing machines' CRT monitors were replaced to LCD monitors, because the ticket's masks were burned into their kinescope's phosphor layers. The matrix printers were modernized by replacing them with STAR TSP 700 thermal printers, which are functioning reliably so far.

The matrix printers' knocking noise disappeared from ticket offices, the cashiers welcomed the faster and quieter printing. The operating costs are significantly reduced, too.

The MÁV-START Személyszállító Zrt. was founded in 1st of July 2007. At the same time they introduced ticketing levels, which were an expectation of the owner (the Hungarian state). This method isn't based on kilometer zones. The starting place and the destination are on the tickets as contexts. For this the MAEF devices had to be reprogrammed and expanded. This meant connecting keyboards (which were indispensable for entering station names), increasing the processors' performances, and memory upgrading. In addition these machines became capable of performing many new functions, such as issuing IC tickets ordered by phone. [6]

2.1.2. Installing the Domestic Reservation System (RES)

The MÁV's manual reservation system could not meet the increasing traffic demands nor quantitatively or qualitatively, so it was the time to mechanize domestic reservation using modern computer technology. The DATA-PRESS's employees created a software for commercially available computers, which is suitable for storing and dealing out domestic trains' places, and can operate the reservation services smoothly.

In 1989 new personal computers (PCs) had been installed at the Keleti, the Nyugati and the Déli Pályaudvar in Budapest. All operating MAEF-3 cash registers were connected to these PCs via local networks. From that time cashiers can give railway tickets and seat-reservation vouchers directly from cash registers. Travel-back tickets (express trains' reservations from other railway stations) was still asked and issued by telephone.

The next step was the network connection among PCs (1990-1991). Every scheduled stop-off point was connected into the network. The reservation database was created decentralized with collecting devices, which were situated in starting railway stations. The current logical infrastructure follows this method, 16 contingent storage devices record the main data of the trains which are traveling with reservation.

The RES programme also creates passenger transport reports about tickets sold by cash registers, generates monthly statistics about MAEF-3 devices, which are connected on local networks, and manages reservations and issuing.

In 2004 telephone reservations were centralized and modernized with a new callcenter with AVAYA technology. The new customer support did not only have to give informations about schedule and pricing, but they had to record IC reservations, too. For this a new application called TELERES was developed, which can store reservation data, and ensures to take orders at stations with ticket issuing machines.

2.1.3. The introduction of the Mobile Ticketing System (MJR)

It was one of the goals of the Passanger Transport Management of MÁV Rt that the registration of their products and services' distribution will be realized in a networked, IT-supported system. To achieve this goal the Info*Sys Kft. created the Mobile Ticketing System (hereinafter referred to MJR), supplemented the previous development efforts. The MJR fits into the MÁV Rt.'s passenger transport distribution system, and ensures ticketing with mobile ticket issuing devices which are compatible with other systems. The MJR's hardware devices on system startup are:

- PSION WorkAbout (hereinafter referred to mobile ticket issuing device) – British-made mini-computer designed for hand-held use
- HuniPrint matrix printer – purposefully planned Hungarian-made mobile printer with rechargeable built-in nickel-cadmium battery
- Pentium II. PC with SVGA monitor 14”
- Peripherals:
  - Epson LX 300 printer
  - docking station for data transmission
  - external modem.

Figure 4: Mobile ticket issuing device

Two softwares provide the system’s operation. One of them is the application on the mobile ticket issuing device, and the other is the PC-side MÁVSYS accounting system.

The Huniprint matrix printers, which were used at the beginning, were replaced to Citizen CMP10 thermal printers. This step eliminated the rudimentary operational difficulties caused by these printers’ operations. Currently 1750 PSION WorkAbout devices ensure the network coverage. These devices are not assigned to person but passenger trains’ scheduled rounds. The conductors can account in 52 stations with this device. [7]

2.1.4. Ticket-printing machines

In 2001 the MÁV Rt.’s management amied to deploy ticket-printing machines in order to serve passengers in a faster and more modern way without queuing. There was an important aspect that deploying these machines didn’t require a new application of human resources. The development was ready to September 2001, made by Data-Press. After that 12 devices were deployed, at first at the area of Budapest (Nyugati

Pályaudvar: 6, Keleti Pályaudvar: 3, Déli Pályaudvar: 3 devices), then in 2010 two other, more modern devices at the railway stations of Pestszentlőric and Ferihegy.

Ticket-printing machines are suitable for credit card transaction via OTP besides cash payment, and they sell the tickets based on the ticketing levels.

2.1.5. Online sales

In ticket sales the next great step forward was the introduction of the online sales system, the E-TICKET. With the upgrading of the application, it can be used in international traffic for limited types of tickets from 2010. The system's operational core is the online version of the MÁV Zrt.'s scheduling software (commonly known as ELVIRA). The system could be introduced so fast, because it was built on the existing scheduling and pricing system. In the E-TICKET system every ticket (with selected route, time, discounts, seat, class and other conditions) can be placed onto the customer's carts. Seat-reservation vouchers and spare tickets are available for the selected ticket, which also placed onto the cart. These tickets, which can belong to different passengers or travels, can be paid simultaneously via a totally safe, online banking payment system using credit card. The system issues paper based or electronic bill about the transaction.

In the beginning the tickets' receiving was ensured by 58 KIOSKs (ticket issuing devices with touchscreen), which were placed onto 40 busy stations. Home ticket printing made the online sales more widely reachable, because it means that the tickets' receiving was no longer bound to selected stations. These tickets include a QR code, which consists of the necessary data for verifying the purchased tickets. Currently the conductors check this QR code with an application installed onto an Android-based Motorola Defy cellular phone. They can do it in online or offline mode, depending on network conditions.

The innovation of internet sales continues, and the MÁV-Start Zrt. enabled payment via mobile balance from May 2012 in cooperation with the following mobile network operators: Magyar Telekom, Telenor Magyarország and Vodafone Magyarország. Recently online sales became possible by e-Ticket system with appropriate credit cards, but with using this new payment method in purchasing process the whole transaction is just as easy, and we can finish it by using our cellular phone only. During the purchasing process, the system send a confirmation message for the customer, and then the total amount appears on the mobile balance.

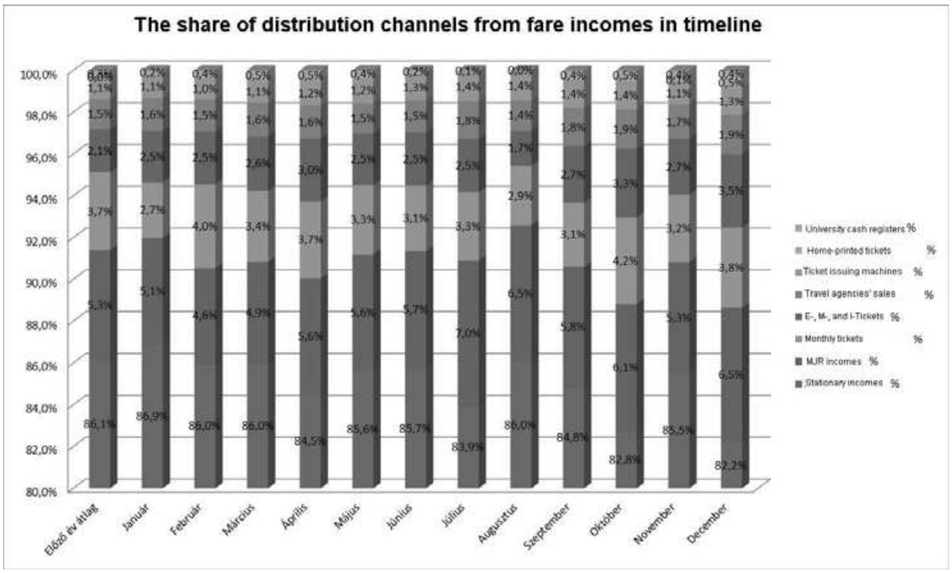
2.1.6. Development of complex distribution

The MÁV already decided in 1995 to establish a modern complex distribution system, which worked under the name of MHR (Menetjegyeladási, Helyfoglalási és Utastájékoztatási Információs Rendszer) within the company. This project started by IBM (International Business Machines Corporation) as prime contractor and by TLC (Transport-, Informatik- und Logistik Consulting GmbH) as subcontractor. In 2000 the MÁV refused the presented program after its first test. In 2001 the IBM, the TLC and the MÁV conducted negotiations about continuing the project MHR with the agreed terms. They signed the modified contract of the MHR in December 2001. TLC became prime contractor. It's task was creating a new program for the MÁV until 2004, which will be based on the German KURS 90' system. But this project was suspended by the former management in 2006 on nearly 50% of readiness.

2.2. The present

In additon with the development of distribution systems we described above, the continuous automatization of different techniques can be observed, however these systems are still working evidently side by side. From terminols which remained at tradicional cash registers to online sales, the MÁV-START Zrt.'s ticketing system is made up of system elements which are showing different technological improvements. This technological backwardness is established due to the lack of comprehensive development in the past decade, which became more and more necessary.

The MÁV-START's service distribution is realized through the channels of Figure 5.



5: The share of distribution channels from fare incomes
(Source: MÁV-START Zrt. controlling compilation)

The international distribution is realized via Internet by using tradicional ticketing, 69 EPA terminals and limited tickets.

The current equipment:

- VMAEF ticket issuing machines 391
- MJR conductor devices 1750
- Automatic printing machines 14
- E-TICKET kiosks 58
- EPAs 69.

2.2.1. The weaknesses of the distribution system

- Our existing distribution system doesn't have APEH authorization, and there is no possibility for giving bill via VMAEF machines. The credit card payment is limited due to the lack of connection between the POS terminals and the ticket issuing machines.
  - The 40% of cash registers perform a significant amount of tradicional ticketing.
  - Currently the MÁV-START doesn't have a fund system for international ticketing.
  - The PSION WorkAbout mobile computer is a construction from 1997, and it's maintenance become more and more expensive. The ticket issuing machines are not capable for online connection, so exchange of data is possible with docking only.
  - The automatic ticket dispensers are capable for limited suburban ticket issuing only, and there aren't enough dispensers.
  - Internal and international reservation systems are not interoperable yet, so other country's place contingents are not reachable directly from internal fund systems. In addition there is no possible way to book tickets for the domestic trains of MÁV-START Zrt. from abroad.

2.3. Vision of the future

A global complex distribution system's development will be reasonable in the future because of the lack of the distribution system's development, the lack of connections between different systems, and the different software solutions among systems.

It was the MÁV's main goal with the project MHR, and also it's the MÁV-START ZRt's primary target with the project JÉ. This is one of the key projects of the MÁV-START, and it was started to renewing ticket sales.

Expectations of Project JÉ:

- Implementing a centralized, server-sided distributing and accounting system with the approval of the NAV (Nemzeti Adó- és Vámhivatal, previously called APEH), instead of the current ticket issuing machines.
- Accounting and administration processes without manual involvement.
- Establishing a ticketing system with barcodes, and an online checking system without manual processes in all distribution channels.
- Establishing a chip card system for expensive, season ticket-like products (Adjusting with the national unified traffic card system's development and it's standard solutions and recommendations).
- Integrated development of domestic and international distribution.

The base of the development concept was the pursuit of the complex distribution system's uniformity and simplicity (Figure 6). Unified services can be ensured in different distribution channels if they are using a common database, and the methods of routing, princing and other functions are the same. So a new centralized (server-sided) search logic will serve out the requests of cash registers, issuing machines and the requests from on-board and internet sources. Server-sided and non-local installed applications need stable online connection, but their maintenances, upgrades, updates and operation are safer, faster and easier. [8]

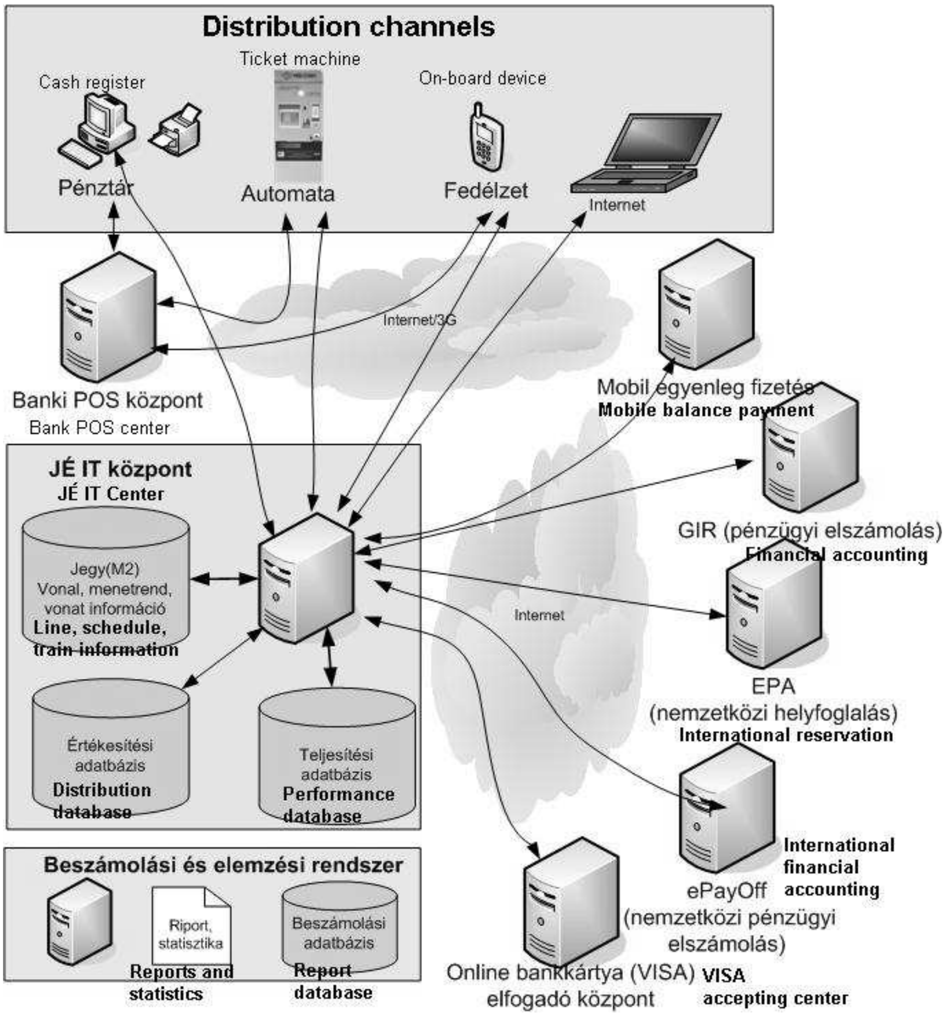


Figure 6: Architecture of the planned system
(Source: Ticket distribution renewing concept)

Besides Project JÉ, 48 ticketing machines' public procurement process is on queue. This machines will be installed to the 100 (40 machines: Budapest Nyugati – Szolnok) and the 120A (8 machines: Rákoshegy, Rákoskert, Ecser, Pusztaszentistván, Tápiószentmárton, Zagyvarékas) lines in next year. These are fully functional machines, which can do more than limited ticket issuing.

2.4. Connections with other systems

Figure 7 shows the current distribution systems and their connection points.

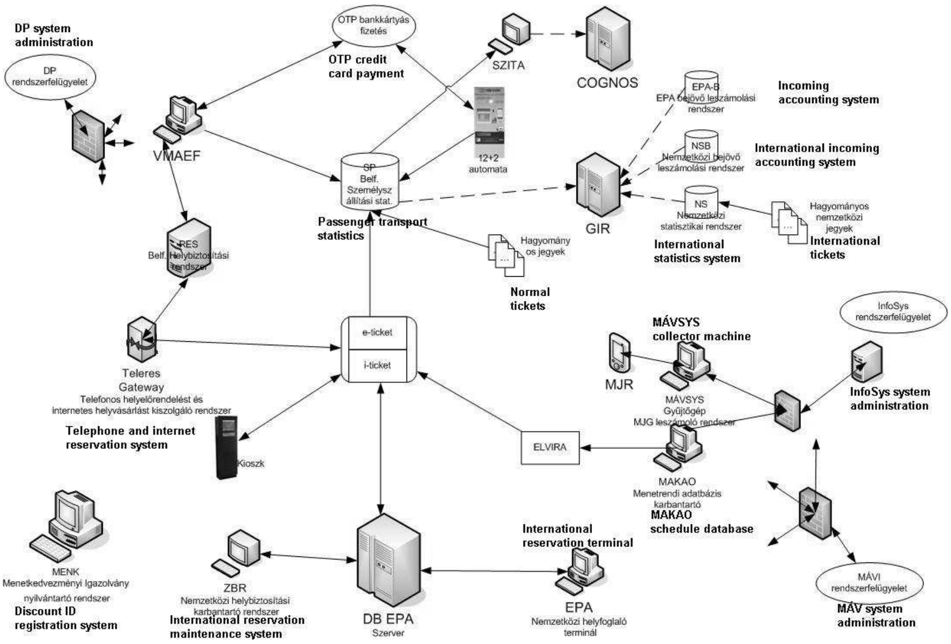


Figure 7: Connections of distribution systems
(Made by Krisztián Galambos)

Every internal distribution system reports to the SP (internal passenger transport statistic system), and it's results are being accounted to the company's management control system, the GIR. The processed results about international ticketing and incoming accounts will be stored here, too.

The RES domestic reservation system grouping the ticket issuing machines, ensuring the distribution of domestic seat-reservation vourchers, furthermore it collects and forwards the ticket issuing machines' monthly accounting data. Online sales reservations are also get information via the RES, while scheduling and pricing basic data is being generated via the scheduling database registry software (MAKAO). The MAKAO also generates sceduling data for international data exchange and ticket issuing devices.

Conclusion

In the past few years there was not any comprehensive development in the area of Hungarian railway ticket distribution, which could make the global distribution system renewed. But there was some improvements, which were counted as milestones. In 1974 the MÁV joined to the international reservation system centered in Frankfurt am

Main, and then started the introduction of mechanized ticket issuing at busy ticket offices in the eighties. The distribution of mechanized seat-reservation vouchers started at bigger railway stations of Budapest in 1989, which was progressively expanded to every reservation-obliged railway stations. For helping the suburban transport in Budapest, ticket issuing machines were installed in the capital city's railway stations in 2001. In 2004 the telephone reservations were centralized. The MÁV-START Zrt. was founded in the 1st of July 2007. At the same time they introduced ticketing levels, which were a great step forward in domestic conditions. There is traditional ticketing in the 40% of ticket offices, and the MÁV-START does not have a fund system for international ticket issuing. Internal and international reservation systems are not interoperable. The absence of connections and different software solutions between systems is typical due to the above-mentioned lack of global developments. That is why is so important to develop a simple and unified complex distribution system.

References

[1] Dr. Zvikli Sándor et al.: *Közlekedésinformatika,* Universitas-Győr Nonprofit Kft, (2008).

[2] MÁV Rt.: *Vasúti Nagylexikon 1,* Budapest, (2005).

[3] Baritsa Csaba: *Személyszállítási Informatikai Rendszerek MÁV-START Zrt*., Budapest, (2002).

[4] http://iho.hu/hir/maef

[5] http://www.gyermekvasut.hu/chrw_news.php?extend.351

[6] MÁV-START Zrt: *VMAEF jegykiadó gép felhasználói kézikönyv P. 5. sz. Utasítás Állandó jellegű pénztári rendelet,e* Budapest, (2008).

[7] MÁV-START Zrt: *MJR-2 MJG felhasználói kézikönyv* 1/2009

[8] *Jegyértékesítés megújítása koncepció (Előterjesztés a MÁV-START Zrt. FEB részére),* Budapest, (2009).

Shipping as Public Transportation in Budapest from Earliest Times to the Present Days

G. Zsigmond

Budapest Transport Company, Urban Public Transport Museum, 2000, Szentendre, Dózsa György út 3.
Phone: 1/461 6500
e-mail: zsigmondg@bkv.hu

Abstract: Local shipping in the history of public transportation of Budapest is the oldest story and I believe, the overview of this story can help us to analyse the role of shipping in the public transport system and establish recent and future challenges in this field. When proper laws, finance and shipyard capacity were present, local shipping was a rather integrated part of the public transport system of the Hungarian capital. Nevertheless, many other acts (e.g. building the inner-city, development of road traffic, local problems in intermodality) cause difficulties to organise the local shipping system. Although, the first Danubian steamship was operated in Budapest (then Pest and Buda) in 1820, the local shipping lost its importance in the transportation within this approximately 200 years. These months there is a significant improvement in progress in the local shipping system in Budapest supported by the European Union.

Keywords: Carolina, DDSG, BKV, EU support

1. Introduction

In this article I try to summarize local shipping in Budapest, on the one hand, and I point out those past-rooted problems which caused and might cause difficulties in this system on the other hand. It is widely known that the Danube as an option to transport and shipping plays a key role in the interregional connections and in the local transportation in the Danubian cities and it offers a relevant alternative to green demands in the bustling big cities connected by international trends. In addition, Budapest has a particular geographical location, with the words by John Lukacs, the famous American-Hungarian historian "It is the only large city on the Danube through which that majestic river flows in the middle. Five-sixths of Vienna are to the south of it (the same is true of Belgrade); you can spend months in Vienna without being aware of the great stream. Budapest is almost evenly divided by it. (…) As in the case of Venice or New York, in 1900 the best and also the cheapest way to arrive in Budapest was by boat. (…) It is as if the Danube had been invented for the esthetic purposes of the city, which, of course, is not the case."[1] Moreover, the river flows through the historical and UNESCO heritage inner-city, so it connects imposing landscapes, sights and some old districts. Although, the Danube counts as an excellent facility of Budapest, it has barely any role in public transportation. We believe that history can help find the causes of this as some journalists made complaints about the poor traffic on the river as early as over 100 years ago.[2]

The suburbs of Budapest consist of approximately 80 towns and villages and make up 2,538 square kilometres. Almost one quarter of Hungary's total population live in this region which means 2,451,000 inhabitants.[3] Despite this factual data, shipping does not offer alternative public transport service either to inhabitants of Budapest or to residents who live in the suburbs. When the chances of potential investments are examined, it is not unnecessary to overview historical aspects and past-rooted problems of local shipping in the region and show relevant statistical data.

2. Local shipping in Budapest from earliest times to the establishment of BKV

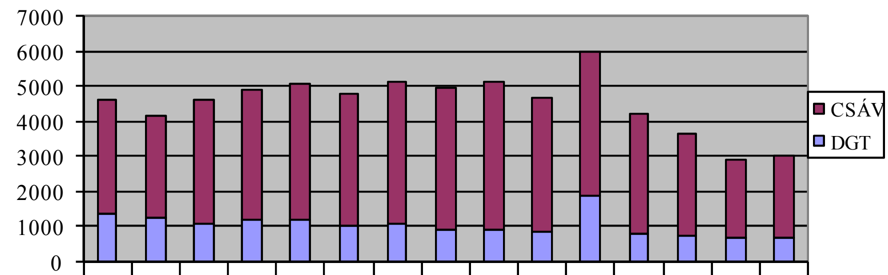
During the 400 years of Budapest's Roman history there existed local shipping in the region of Aquincum and Contra Aquincum.[4] Although the further flourishing of the Roman city was hindered by barbarian invaders, the area was not uninhabited. In addition, in the Middle Ages, after the Mongol invasion of 1241-1242 in particular, the city started to develop during the reign of Árpáds. The importance of local ferrymen proves they privileged guilds from 1268.[5] In the life of the developing capital crossing the Danube counted as the oldest transport challenge. It is by no accident that the first modern vehicle appeared in the field of river crossing, well ahead the appearance of omnibus in 1832 in Pest.

It is widely known that Robert Fulton built the first commercial steamboat in the USA in 1807. Later, he offered his invention to European countries as well and similar inventions were encouraged in Austria which owned the significant part of the Danube. The latter encouragement was discovered by a Hungarian born inventor Antal Bernhard who built his own steamship only 10 years after Fulton's ship. He built the first European tugboat named Carolina after the empress consort. The steamship was launched in 1817 and was operated in 1820 as the first modern public transport vehicle in Budapest (then Pest and Buda) but she was in service only until November 20.[5] A company who operated a pontoon bridge in the city reached with authorities that the passenger of Carolina had to pay not only the fare of ship but tan amount for he possibility of river crossing also. Both charges were too expensive for passengers thus Carolina did not operate further in the city. [6]

A new steamship appeared in the city only 20 years later when János Girczy, a Hungarian entrepreneur, operated the Hoffnung in 1844. At the same time the rich, Habsburg privileged Austrian company, Erste Donau Dampfschiffarts Gesellschaft (DDSG, First Danube Steam Navigation Company) discovered the possible benefits of the lines, so DDSG established its local shipping in the Hungarian capital. This company owned Óbuda shipyard, the biggest Hungarian factory at that time where, among other ships, the company built some special ships for its local shipping service.[8] Only within a few years DDSG carried almost 500,000 passengers yearly, while approximately 150,000 people lived in Pest, Buda and Óbuda.[7] In 1849 the new competitor appeared, the first permanent bridge across the Danube between Pest and Buda. Beyond the Chain Bridge other bridges were opened in the following decades and coaches, horse-drawn trams and pedestrians appeared on them.

In the meantime, in 1872 Hungarian entrepreneurs and engineers established a new company under the name of Budapesti Csavargőzös Átkelési és Hajózási Rt. (Budapest Propeller Steamship Co.) The company, the name of which was abbreviated as CSÁV, operated relatively small, economically operable ships, which carried 1.8 million passengers in its first fiscal year and in the second year, this number reached 3.6 million. The Hungarian company seemed much more successful as compared to DDSG. With the unification of west bank Buda and Óbuda with east bank Pest in 1873, Budapest became a new big European capital, which developed immensely and spectacularly. The population tripled between 1873 and 1900 and the need to travel soared. First in Europe, a tram network was built in Budapest in the inner-city and more than 67 million passengers travelled on the trams in 1900, while DDSG and CSÁV carried together only 4.4 million people that year.[9] It was a huge and sudden change because the first tram appeared barely a decade (in 1887) earlier in the city. During the development of the city the connection with the river deteriorated due to the construction of imposing buildings near the bank of the Danube.[2] It is fairly interesting that on the location of today's Nagykörút (Grand Boulevard) a canal for local shipping was planned but plans were dismissed because of the rapid development of the tram network.

Table 1. Number of Passengers Carried between 1886-1900 (1,000 passengers)

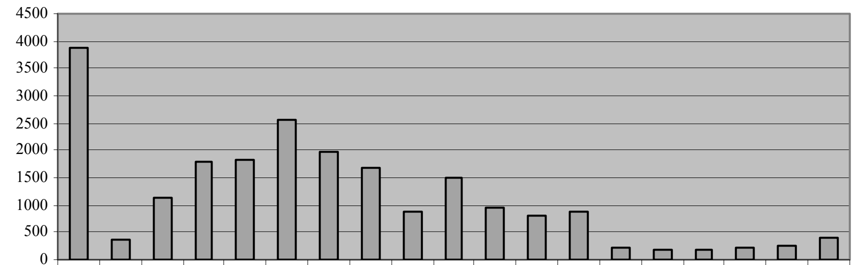


	1886	1887	1888	1889	1890	1891	1892	1893	1894	1895	1896	1897	1898	1899	1900
CSÁV	3280	2936	3523	3734	3924	3762	4060	4102	4252	3857	4119	3447	2949	2253	2352
DGT	1333	1237	1079	1164	1169	1011	1092	884	903	835	1876	795	700	663	686

During World War I Austrian DDSG as well as Hungarian CSÁV gave up local shipping service in Budapest. DDSG operated its ships in the city for over 70 years, while CSÁV stopped its almost 50-year service and sold ships to a Hungarian company established in 1894, Magyar Folyam- és Tengerhajózási Rt. (Hungarian River and See Shipping Co.) in 1917.[10] Despite subsidy by the government the company was not able to upgrade the local shipping fleet and infrastructure due to the hardships after the lost war. The company had to pass almos half of its ships to the winners and the subventions were of no value due to inflation, so MFTR gave up local shipping in 1925. The Ministry of Commerce urged to restart the service because of the importance of tourism, but the city was not able to offer its part of the necessary subsidy. In addition, in the 1920s bus transport reached a significant role in the public transport of Budapest with more than 2 million passengers in 1929 and also taxis became more popular than eariler.[9]

In 1928 motor vessels appeared in Budapest as watertaxis, however, it seems this service was a secret attempt to develop the Hungarian Danube navy. It is certain that approximately 300,000 passengers travelled on ships in Budapest, while only on the marvellous Zsófia yacht alone more than 130,000 people travelled, mainly tourists.[11] The figures show that local shipping started to turn towards tourism instead of public transport. Upcoming changes were predictable even before WWI, when the busiest stops were in the inner-city, next to the baths and on the Margaret Island.[12] Between the WWI and WWII, city-planners planned a Norht-South high-speed rail and highways on both banks of the river instead of further developing the shipping service.[14]

Table 2. Number of Passengers Carried between 1918-1936 (1,000 passengers)



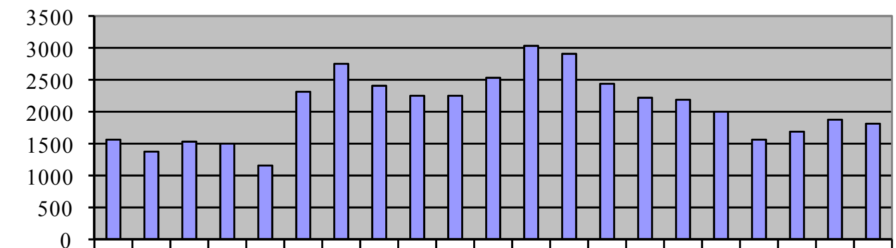
	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935	1936
utasszám	3889	378	1142	1783	1822	2564	1969	1688	889	1506	943	797	893	205	199	200	214	238	398

After the siege of Budapest in 1944-1945, not surprisingly because of the exploded bridges, the significance of ships suddenly rose.[14] Some years later, in 1949, the operation of MFTR was stopped and the time of nationalizaton and Soviet models in Hungary began. That year an act was accepted about the expansion of the borders of Budapest and in 1950 some formerly independent suburban territory, with a lot of residents was attached to the capital. After that new measures were taken to organise public transportation. In 1957 the Fővárosi Kishajózási Vállalat (FKV, Shipping Company of the Capital) was established under the control of city administration. In the 1960s similar statistics could be seen in the number of passengers as before 1914 due to the tremendous subsidy. The number of carried passengers reached 2 million yearly.[9] The FKV owned 26 ships and 3 ferries.[15] To modernize the fleet the company ordered 9 new ships in 1958 and 1959. These ships later became popular elements in the marketing of local shipping with their names coming from famous fairy tales (Hansel, Gretel, Little Red Riding Hood, the names of the seven dwarfs, etc.) In 1959 an old ship, built in 1895, by the name of Margitsziget (Margaret Island) was renovated, renewed, and renamed to Hófehérke (Snow White). In the 1960s seven new ships and three waterbuses were purchased from the shipyard in Vác in order to modernize the service.

3. Shipping service of BKV till the present days

Four company – including FKV – were merged on 1st January, 1968 under the name of Budapesti Közlekedési Vállalat (Budapest Transport Company, BKV). At that time 23 ships, including 21 motor vessels and two ferries were under BKV flag.[15] In the first fiscal year the number of passengers carried reached almost 1.6 million.[9] The company operated 9 ferry lines and scheduled ship services in the city from 1st May to 30th September.[9] Between 1973 and 1983, over a decade, the annual number of passengers carried always exceeded 2.0 million (in 1979 even exceeded 3.0 million) and in 1984 reached almost 2.0 million. The BKV placed its ships next to Jászai Mari Square in the summer and in the Újpest bay in the winter. BKV had a little workshop in Népsziget, with a floating dock, and a filling station in Garam Street. Some articles emphasize the importance of tourism, instead of public transportation at that time in local shipping. Future plans counted on tunnels and bridges across the Danube.[16] To rationalize the shipping service, BKV introduced new organisation models in 1972, when 130 people worked for shipping services.[17] In the same year the metro line (M2) was finished under the Danube and connected Pest and Buda. It seemed a new competitor for shipping, however, only the Kossuth tér to Batthyány tér ferry service was closed. The local shipping service made up 0.1% of the total number of passengers and this number did not change after introducing the new metro line.[18] Although surprisingly, instead of the supposed role in public transportation, the popularity of tourism-related lines to Margaret Island increased partly due to the ban of cars on the island. The weekly number of passengers was basically realised at weekends.[17] While BKV operated 29 stops in 1981, there were only 24 stops by 1987. Many experts emphasized the importance of coordination between BKV, PKJV (Pest Megyei Kishajózási Válllat, Ferry Company of Pest County) and MAHART (Magyar Hajózási Rt., Hungarian Shipping Co. Ltd.) in favour of shipping as a means of public transportation in the city and in the suburbs.[19] In 1981 fares were doubled and in 1985 and subsequently in 1987 prices went up again. As a peculiar form of rising fares, using BKV bus and tram tickets on ships was banned, thus shipping as public transportation lost its former importance, which can clearly be seen in the statistics.

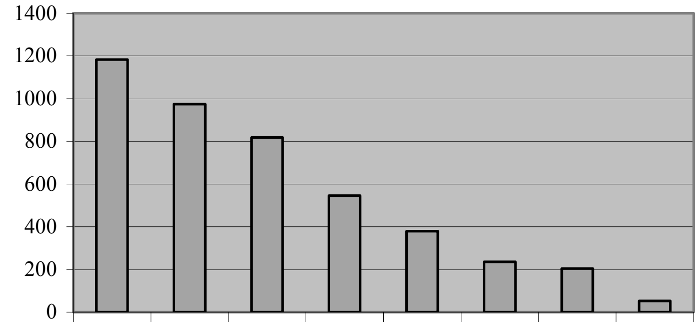
Table 3. Number of Passengers Carried between 1968-1988 (1,000 passengers)



	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
utasszám	1567	1378	1518	1496	1144	2324	2751	2427	2255	2258	2525	3047	2911	2440	2233	2199	1999	1577	1680	1872	1825

It is characteristic to the regression of the passenger km performance indices that while statistics indicated 10,722 thousand passenger kms in 1988, this number amounted to a mere 138 thousand in 1996. The place km performance was 18,489 thousand place kms in 1988 while it decreased to 1,074 by 1996.[20] In 1988 BKV had 19 ships and two ferries.[17] In 1996 BKV had 15 ships, one ferry, 15 stops and 12 captains. Around that time BKV established BKV Hajózási Szolgáltató Kft (BKV Ship Ltd.). In the following years, besides the necessary repairs, mainly refurbishing and the improvement of catering facilities, as well as building a new promenade deck seemed important on ships in favour of fulfilling the new role, namely tourism.

Table 4. Number of Passengers Carried between 1989-1996 (1,000 passengers)



	1989	1990	1991	1992	1993	1994	1995	1996
utasszám	1183	975	819	546	379	235	204	53

In 2004 BKV initiated the dissolution of BKV Ship Ltd.[21] In the following years BKV started to develop the ship service, including daily operated ships and they also increased the number and length of services at weekends. Last year (2011) ships were operated with predictable and dependable time tables; services run with labels V1, V2 and V3. V1 and V2 operated daily from 30 April to 29 August, V3 only at weekends. The connections to ships from other BKV services appeared in the passenger information of BKV, for instance on tram No. 4/6.

The oldest ships in the current fleet are the waterbuses, which were built in Vác shipyard in 1966 and 1967. The floating dock was launched in Újpest, in the MAHART shipyard. The great majority of ships were built in Balatonfüred, among the last products of the shipyard near the bank of the Lake Balaton, after 1980. Firstly the H-01 types carrying 100 people arrived in Budapest in 1982, and in 1987 larger ships (H-06 carrying 150 people). A valuable part of the fleet is the above mentioned Hófehérke (ex Margitsziget), which was launched as a steamship in Újpest shipyard in 1895. However, she was rebuilt; her original hull is a remarkable heritage of Hungarian shipping and shipbuilding. Besides these, there is a 16-ton ferry and a shuttle boat, which was built in Horány in 1978.

The significance of ferries and shuttle services has been dramatically decreasing for decades. These services were operated by MAHART in Hungary and by PKJV in

County Pest and by BKV in Budapest. Shuttle service is still operating between some towns and villages in the suburbs of Budapest, but PKJV, which coordinated the services outside Budapest in the county, was closed in 1993.[22] Nowadays, shipping services between the capital and suburbs are a common issue in the Hungarian media. In Budapest, there were some shuttle services as well, but only one service operates by now. Some services were closed due to the closing of significant factories, such as Csepel Művek, which supported a shuttle service to help its workers' transportation to the factory.[10] After 1989 the number of cars and car owners dramatically increased in Budapest and simultaneously the subsidies to shipping services dramatically decreased. Some years ago, in 2008 and in 2009 the importance of the shuttle service was easily observed, when the Northern Railway Bridge, which was also used for pedestrian crossing, was closed due to restoration. A BKV water shuttle stop was deployed barely 500 m from Gyöngyösi utca metro station. Nowadays, only one BKV ferry operates from Soroksár to Csepel every day from 6 am to 21 pm, considering the connection to bus No. 148. Many kinds of tickets and passes are available and lorries of more than 3.5 tons can use this service.

The local shipping service of BKV is upgraded by EU support. This year 3 new stops are built (Újpest, Árpád híd, Millenniumi Városközpont) and 5 stops are renewed (Meder utca, Jászai Mari tér, Batthyány tér, Petőfi tér, Boráros tér). According to the plans, ships will operate between Újpest and Millenniumi Városközpont (Millennium City Centre) every 20 minutes in the rush hour. The whole 11.2 km route will take 45 or 60 minutes depending on the direction. The whole investment cost 493 million forint, which includes 90% EU support and consists of other developments apart from the stops, e.g. partial accessibility, bicycle transportation, WIFI. One of the most important item of the project is that the passenger information will be connected to the BKV new traffic control and passenger information system (FUTÁR project). Unfortunately, the investment will not affect the ships.[23]

4. Conclusion

Modern local shipping service in Budapest started only approximately 10 years after the invention of the steamship. The first European tugboat operated as public transportation in Pest in 1820, well ahead of the appearance of other modern public transport vehicles. During dualism (between 1867 and 1918) a fascinating city-planning swept through Budapest with huge constructions, even though these imposing constructions closed the Danube from the city and better transport connections seemed none too important. Later, financial opportunities and the decrease of significant shipyard capacity caused difficulties in local shipping in Budapest. Particularly, though not singularly, due to these changes local shipping lost its importance before WWI. In the 1960s and 1970s the annual number of passengers carried was above 2 million again, thanks to the heavy government subsidy.

The remodelling of local shipping as a means of public transport can affect a vast number of areas, such as legislative and financial background, shipyard capacity, new workplaces, tourism, ecotourism, EUROVELO international bicycle lane or green projects. As a matter of course, there is an abundance of challenges as well, such as intermodality, modern ships, accessibility or e-tickets. To manage all these issues, close co-ordination is needed in the state, local, regional, economic, corporate and civil sector as well. Demands come from the same sectors and form international transport and city-planning trends. Currently there is an important development ongoing in Budapest in local shipping thanks to EU support. Hopefully, other new investments will be implemented in the near future.

References

[1] Lukacs, J.: *Budapest 1900*, Budapest, (2004).
[2] Pálóczi, A.: *Budapest helyi személyforgalma a Dunán*, Budapest, (1902).
[3] Bakos, N., Brinszkyné Hidas, Zs., Pásztor L.: *Közlemények a budapesti agglomerációról 14. – Társadalmi, gazdasági jellemzők*, KSH, Budapest, (2007), pp. 5-6.
[4] Zsidi, P.: *Az aquincumi polgárváros – vezető az Aquincumi Múzeum romkertjében*, Budapest
[5] Nagy, E., Szabó D.: *Budapest közlekedése tegnap, ma, holnap*, Budapest, (1977), pp. 26-28.
[6] Jankó, B.: *A gőzhajózás kezdete a Dunán, „Carolina", az első gőzhajó*, Budapest, (1967), pp. 5-18.
[7] Bíró, J.: *A fővárosi helyi hajózás*. Városi Közlekedés, Vol. 15. No. 5, (1975), pp. 425.
[8] Kaiser, A., Varró, J.: *Volt egyszer egy hajógyár*, III. kerület, Budapest, pp. 44.
[9] Koroknai, Á., Sudár K. et al.: *A főváros tömegközlekedésének másfél évszázada I*, Budapest, pp. 205-373.
[10] K. Juhász, E.: *Százhetvenöt év után a fővárosi kishajózásról*, Városi Közlekedés, Vol. 36. No. 4, (1996), pp. 239-241.
[11] Csillag, M.: *A budapesti helyi- és átkelési hajójáratok multja, jelene és jövője*, Budapest, (1930). pp. 24.
[12] Magyar Országos Levéltár (MOL) Z 1139, 1CS, 19 t, Gazdasági levéltár, MFTR-Hajózási főosztály, 7021/917
[13] MOL Z 1139, 1CS, 19 t, Gazdasági levéltár, MFTR- Hajózási főosztály, 338/1928
[14] MOL Z 1139, 1CS, 19 t, Gazdasági levéltár, MFTR- Hajózási főosztály
[15] *A Budapesti Közlekedési Részvénytársaság évkönyve 1968-1998*, Budapest, pp. 25-74.
[16] Kiss, L.: *A fővárosi hajózás jelene és jövője*, Városi Közlekedés, Vol. VIII. No. 3, (1968), pp. 171-173.
[17] Tanulmány a hajózási üzemegység munka és üzemszervezési feladatainak kialakítására, (1972).
[18] Mányi Szabó, I.: *Egy évtized az utasokért*. BKV, Budapest, 1968-1978.
[19] Marcsa, I.: *Budapest és környéke vízi közlekedésének jövője*, Városi Közlekedés, Vol. 25, No. 6, (1985), pp. 304-307.
[20] BKV évkönyvek 1968-1996.
[21] Heti világgazdaság, 2004. október 23. pp. 12
[22] Zsigmond, G.: *A Budapest környéki hajóközlekedés az 1970-es években*, Városi Közlekedés, Vol. 51, No. 3-4, (2011), pp. 235-239.
[23] http://www.bkv.hu/hu/kozlemenyek//2

Environmental Risk Management of Air-Transport and Airport Development

J. Bera*, L. Pokorádi✈

***Middle-Danube-Valley Inspectorate for Environmental Protection, Nature Conservation and Water Management**
Phone: 30/303 9959, fax: 1/478 4520
e-mail: bera@kdvktvf.kvvm.hu
✈University of Debrecen
Phone: 30/919 4929, fax: 52/418 643
e-mail: pokoradi.laszlo@prosysmod.hu

Abstract: The aviation has environmental risk as well as other forms of transportation. The risk factors shown by data and limiting values represent a danger to environment. These ones de-emphasize considerations that are needful for development of aviation and its complete estimation from point of view of environmental protection. Therefore the Authors would like to review the played down questions mentioned above applying their experiences of environmental protection investigations and risk management.

Keywords: aviation; environmental protection; risk; uncertainty

1. Introduction

Nowadays people opine negatively the aviation from environmental protection point of view albeit that air-transport fulfils global requirements.

Firstly an important fact should be cleared: most people are not there, where they want to be, so people are traveling, more and more distance is wanted to bridge the shortest time, which is no possible without the flight.

The aviation has many advantages compared to other transport sectors. Few of them are: extent of land reservation, the environmental impact of airports covered by their neighborhood, soil loads affect only the area of airport.

Many examples show that the problems of environmental protection can be solved by a series of possible compromises. The problem solving requires a compromise position, and later to maintain a series of decisions, which in itself carries any uncertainty and risk. Its essence has been expressed: How to effectively reduce the uncertainty and risk is inherent in environmental impact assessment?

These questions can arise in case of earlier initiated or long time activities. Therefore, the existing air traffic and airport related development also raises the question of properly environmental impacts management. The over- or underestimated environmental effects can generate several consequences that are taken up as a mistake. Therefore, the uncertainty and risk management are increasingly linked to environmental protection questions related to the airport and aircraft operation and development processes.

This relationship has other importance. The environment protection should become a requirement system that saves the natural and built environment. This can be realized by the proper management of environmental risks, that requires continuous inspection of risk factors.

The main aims of this paper are to summarize their former environmental protection [1]; [2]; [3] and risk management studies [9]; [10] of the Authors, and to determine their future investigation connected to them in the aviation.

The paper will be organized as follows: Section 2 shows environmental judgment of the aviation. Section 3 presents risk factors of airport development and connection between aviation and its environment. Section 4 words methods of uncertainty analysis in the risk management. Conclusions and future work are provided in the last section.

2. Environmental judgment of the aviation

In our days the enforcement of environmental interests can be approached by two ways. Therefore there are two levels: the *human judgment* and the *natural environment based assessment levels*.

The environmental protection based assessment is important as a decisive factor in the environmental judgment of the aviation-related activities. The term of environmental assessment level has more importance because of the environmental impact of human activities in a modern society form a coherent system. The aviation is an important part of transportation and economy. The Authors have investigated this question in reference [4] in case of noise protection.

The environmental impact assessment is dependent on how the neighborhood affected by flight. The expected reaction of the environment can be used to estimate the frequency of the noise depends on different areas. An example is shown by Figure 1. in which a passenger aircraft noise levels can be seen in cases of a noisy city and quiet residential area background.

Approaching from environmental point of view, the human activity can be investigated as: waste, soil, surface and ground water, air, noise and vibration, nature conservation and built environment protection. There are links between the fields mentioned above, but the environmental impacts are classified separately, by different standards of compliance.

To assess the environmental effects of aviation, the following conclusions can be depicted:

- environmental impact of aviation and its assessment can not be independent of the levels of the environmental assessment;

- the environmental impacts should be rated by only consistent comparison requirements of the different areas of expertise;
- for environmental judgment of aviation the levels of evaluation based analysis that discovers the flight activity and environmental relations can bring good results.

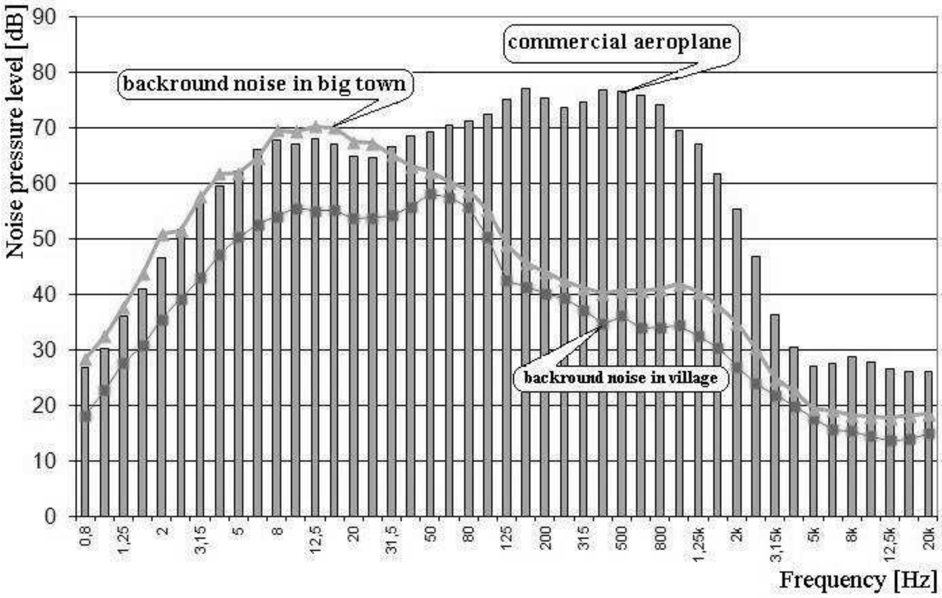


Figure 1. Comparison of aircraft noise and different background values

The key aspect of the environmental assessment should be to collect the important data sets and their application with sufficient accuracy. It is a fundamental base to estimate which will be the real situation?

It is very easy to say that human activities, as the aviation, have significant environmental impact. The environmental impact is a complex and time-varying definitions, which have many factors and these ones should be considered individually and collectively necessary.

If the importance of different environmental effects is examined, the following result can be got:

- in aviation, waste management, soil conservation, surface and ground water protection issues can be treated mean, here we meet with the least conflict;
- protection of nature and the built environment forms a complex problem area because of the uncertainties of the system, the system boundaries and the current neighborhood.

Delineation of the environmental aspects as described above will influence the estimation of effects and the possible outcomes of various events. From point of view mentioned above It is should be investigated, that system excitations and excitations from neighborhood how generate the environmental loads. Features arise from excitation process, and can affect environmental risk levels are shown by Figure 2.

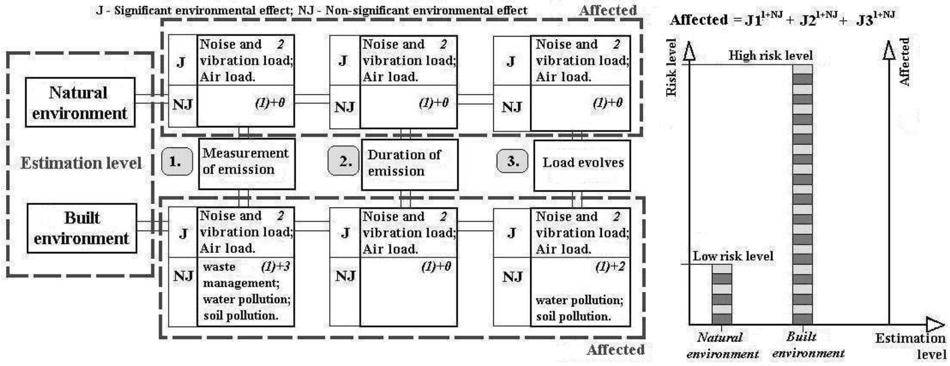


Figure 2. Estimation of risk level depend on affects

3. Risk factors of airport development

The air transport should be renewed from social and economical demands. This regeneration means the development of air traffic and airports. This change is not always the increases of air traffic and the environment load. The modernization can mean upgrading traffic conditions, renewed fleet and technologies.

To understand the environmental impacts – to determine influences from airport development exactly –, various model and mathematical modeling procedures should be applied. For this modeling, measured data, empirical information and exact conclusions should be used.

The mathematical model is the mathematical equation or system of equations which describes the internal principles of the process occurring on the system from the point of view of the given investigation [11]. On the one hand the real systems are precise, but complex. Additionally the large-scale systems consist of large number of inter-related subsystems. On the other hand, the mathematical model should be simple therefore may be imprecise. Mathematical modeling and simulation of complex technical systems, such as the aviation, must include the nondeterministic features of the modeled system and its environment or human interaction with the system [8]. These nondeterministic features mean that the response of the system cannot be predicted precisely because of the existence of uncertainty in the system or the environment [7].

The air traffic and airport create a complex system which can be determined with relative accuracy. The uncertainty arises when the system boundaries are changing due to environmental effects. What does the uncertainty resulting from the system boundary mean? The answers to these lists are given in a summary way:

- Appropriate and sufficient accurate data should be used to determine the boundaries of the system. Their absence results distorted system boundaries.
- It has to be determined what aspects are used to depict environmental requirements.

- The prescribed threshold values where and what times must be met? Without them depiction of system boundary is impossible.
- Local or larger effects are investigated?
- How much and what kind of change are in environmental conditions?

For example, evaluation and estimation process of flying noise shows the uncertainty arising from the system and environment relationship. This is a time-varying environmental load, which increases the number of risk factors. The value of noise load depends on the flight parameters such as system characteristics, and also excitation from the environment. The aircraft noise load can be determined by the equation:

$$L_{AM,re} = 10 \cdot \lg \frac{\tau_{ref}}{T_M} \cdot M \cdot 10^{0,1 \cdot L'_{AX}} \left[dB\right] \qquad (1)$$

where: $L_{AM,re}$ – equivalent A-weighted sound pressure from flying [dB]; T_M – reference time; τ_{ref} – 1 s; M – number of flying operations; L_{AX} – average sound pressure[4].

From equation (1) numerous important statements can be formulated. For example, the reference time T_M is 16 hours in the day-time, and 8 hours at night-time.

4. Investigation of uncertainty

One of the most widely recognized distinctions in uncertainty types is between aleatory and epistemic ones [6].

Uncertainties are characterized as epistemic or model, if the modeler sees a possibility to reduce the model by gathering more data or by refining models. Epistemic uncertainty derives from some level of ignorance of the physical process, the system or the environment. Experts use the term epistemic uncertainty to describe any lack of knowledge or information in any phase of the modeling and model application. During modeling of a large-scale or a system of systems, the complexity can be a significant problem. Complexity involves the number of degrees of freedom in a system and how the parameters that express the degrees of freedom interact. When systems become too complex to deal with all parameters directly, simplification of one or more parameters is necessary. The result is a simplified model, a simply abstraction of the studied system, which has epistemic uncertainty.

The epistemic uncertainty may be comprised of substantial amounts of both objectivity and subjectivity. Some of types of epistemic uncertainty sources that can occur in technical systems simulation include:

- false knowledge of system or its environment;
- incorrect application of scientific laws;
- selecting the appropriate model formulation;
- model generalization;
- model reduction;
- linearization.

Aleatory or parameter uncertainty pertains to random chance and may only be quantified statistically. Also referred to as irreducible uncertainty, this type cannot be reduced by the addition of more knowledge. The natural variability of the physical properties of the system or its environment typifies sources of aleatory uncertainty. In engineering, this type of uncertainty is usually represented by a random variable or a probability distribution.

Aleatory uncertainty is primarily associated with objectivity. Its possible „engineering“ sources:

- incorrect measuring;
- measuring noises;
- discretization;
- strong statistical information;
- sparse statistical information;

From practical engineering point of view, probabilistic uncertainty investigation set two problems. Firstly, the parameters of probability distributions of independent variables can be determined by any statistical method, therefore they have so-called second-order uncertainties. Secondly, from mathematical point of view, the domain of variability of probability distributions is basically infinity.

In the Fig. 3. there are two possible paths are shown as right and left downward arrows.

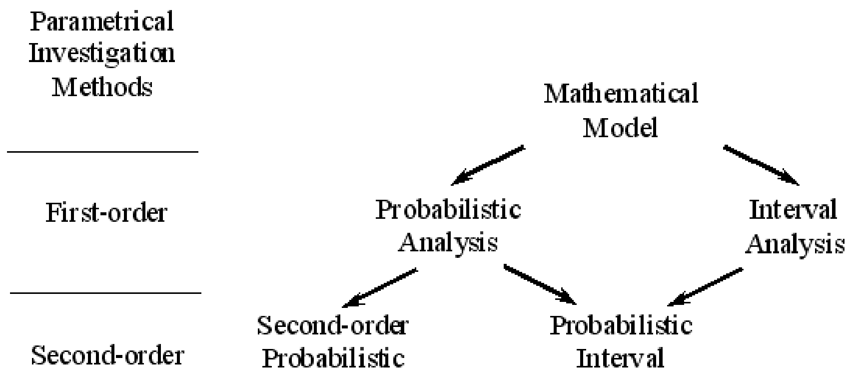


Figure 3. Relationships among Different Uncertainty Investigation Methods

To answer the first question mentioned above, the left one shows a probabilistic uncertainty analysis of a probabilistic calculation. The resulting analysis would be a second-order probabilistic assessment.

Another derived method applies bounding arguments to the probabilistic calculation and arrive at interval versions of probability distributions. The second problem mentioned above can be answered by this method. Therefore the infinity of variability of probability distributions is impossible in engineering practice. Ferson and Tucker call such calculations PBA [5]. This approach represents the uncertainty about a probability distribution by the set of cumulative distribution functions. PBA is an uncertainty analysis of a probabilistic calculation because it defines neighbourhoods of probability distributions.

One of the most well-known probabilistic uncertainty investigation methods is the Monte Carlo simulation. The “classical” Monte Carlo simulation is used as an uncertainty analysis of a deterministic calculation because it yields a distribution describing the probability of alternative possible values about the nominal (designed) point.

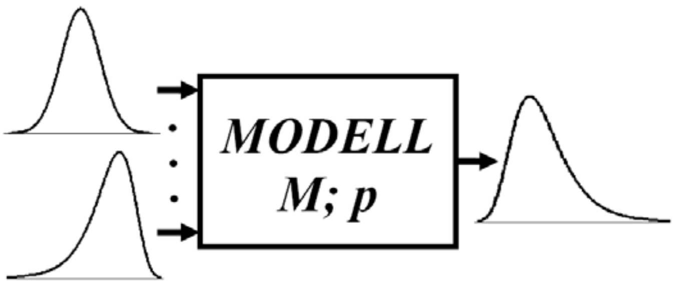


Figure 4. Monte-Carlo Simulation

5. Conclusions, future works

The environmental impacts of air traffic are many sources of conflicts. The flight parameters uncertainties create uncertainties of environmental impact assessment automatically. This is a risk factor during the investigation of airport operations and development. Risk factors of airport development closely associated with the system and system-environment relationship that is risk and uncertainty too. Therefore, the airport development process can be controlled by tools of risk assessment methodology

Authors plan the future scientific investigation based on their earlier work and results of other related scientific activities. Their aims are to develop risk and uncertainty analysis methods and procedures, which greatly assist environmental experts and decision makers. For example accomplishment a Monte-Carlo Simulation-based method to estimate impacts of changing the flight parameters and neighborhood characteristics to noise loads of a heliport.

References

[1] Bera J.: *Repülési zaj értékelése*, Műszaki Tudomány az Észak Alföldi Régióban (2007), pp. 5-14. http://store1.digitalcity.eu.com/store/clients/release/musz_fuz_jo_04.pdf

[2] Bera J.: *Repülőtér létesítés és környezeti zajvédelem*, Repüléstudományi Közlemények Különszám, , Szolnok, (2009). http://www.szrfk.hu/rtk/kulonszamok/2009_cikkek/Bera_Jozsef.pdf

[3] Bera J.: *Ipari helikopteres repülés környezeti hatása*, Műszaki Tudomány az Észak Alföldi Régióban, (2010), pp. 89-94., www.mfk.unideb.hu/mszb/muszfuz.

[4] Bera J., Pokorádi L: *Helikopterzaj elmélete és gyakorlata*, Campus Kiadó, (2010).

[5] Ferson S., Tucker W. T.: *Sensitivity analysis using probability bounding*, Reliability Engineering and System Safety 91 (2006) pp. 1435-1442.

[6] Möller B., Beer M.: *Engineering Computation under Uncertainty – Capabilities of Non-traditional Models*, Computers & Structures. Vol. 86, Issue 10, (2008), pp. 1024-1041.

[7] Oberkampf W.: *Error and Uncertainty in Modeling and Simulation*. Reliability Engineering & System Safety Vol. 75. (2002) pp. 333-357.

[8] Perincherry V.: *Uncertainties in the Analysis of Large-Scale Systems, Uncertainty Modeling and Analysis*, Proceedings Second International Symposium (1993), pp. 216-222.

[9] Pokorádi L., Madarász L.: *Kockázati tényezők és kockázatkezelési példák a katonai repülésben*, Új Honvédségi Szemle, Budapest, 1999/12, pp. 7-16.

[10] Pokorádi L.: *A repülőterek körüli madárveszély vizsgálata*, Haditechnika, Budapest, 2005/4, pp. 16-20.

[11] Pokorádi L.: *Rendszerek és folyamatok modellezése*, Campus Kiadó, Debrecen, (2008).

Cost Calculation in Transport Companies

Z. Bokor

BME, 1111 Budapest, Műegyetem, rkp. 3.
Phone: +36 1 463 1051, fax: +36 1 463 3267
e-mail: zbokor@kgazd.bme.hu

Abstract: Transport costs are often analysed by various macro- and micro economic models but detailed cost calculations within transport companies are hardly reported although this information is essential to control transport operations. Traditional as well as improved costing approaches can be implemented in transport management. If the examined transport company operates with considerable indirect costs it is worth applying the improved calculation methods. This paper aims at adapting the principles of multi-level full cost allocation to the specific characteristics of transport. The adaptation is performed through conducting a full-scale illustrative example. Based on the research results the advantages and the constraints of possible implementations are also considered.

Keywords: cost calculation, cost allocation, transport

1. Introduction

Calculating and analysing costs in transport companies is one of the most important tools of supporting decision making procedures [9]. Accurate cost data are the basis of setting prices, allocating resources or outsourcing various activities, etc. That is why special attention shall be paid to the methodology of cost calculations. Distortions in costing information may lead to inappropriate decisions which mitigate the operational efficiency of transport companies.

Transport costs are relatively often discussed in the literature. There can be found macroeconomic as well as microeconomic approaches dealing with this topic or its relating issues. From macroeconomic point of view the main research task is to determine the social costs of transport. So called transport accounts have been set up and studied to give estimations on transport related internal and external costs and revenues in aggregate levels (countries). The main challenge of this approach is to overcome the problems of lacking input data through using second best appraisal methods. Another task is to harmonise the definitions of cots categories so that consistent data bases can be built [14]. Another macroeconomic example is the evaluation of transport network expansion through elaborating and applying explicit econometric cost functions [12].

The microeconomic approaches analyse the cost structure of transport companies and branches or use transport costs for optimisations. For example rail costs are determined on the basis of generally used cost drivers and compared to the charges applied in pricing systems [7]. Empirical research has been done in the field of bus transit operation costs. It has shown that physical and geographical characteristics are plausible explanatory cost factors of such transport services [8]. Cost data are often used for optimising the operation of various transport systems. For instance a freight distribution system has been improved by using a vehicle routing model minimising the transport costs [11]. Transport planning also uses cost data. An interesting research result in this field is that collaborative planning of transport tasks yields lower operating costs and cost savings shall be allocated to the participants in a transparent and fair way [10].

Although transport related researches frequently consider costs in the level of national economies or business companies, the detailed cost data within transport companies, i.e. the costs of elementary services or performance generators, are rarely investigated. Activity-based costing (ABC), as a well known calculation scheme, is used in some cases to give an insight into the mechanism of cost allocation in transport companies. For example a complete calculation of road freight transport service packages has been carried out by exploring the main cost drivers of relevant activities causing the indirect costs. This ABC application has showed that the cause-effect based allocation of indirect costs leads to more reliable cost data as compared to the outcomes of the traditional costing regimes [1]. Truck transport has been evaluated by other ABC models too [15]. Sophisticated numerical ABC examples of other transport modes could not be found in the literature reviewed. There are, however, some ABC applications in the field of logistics, like the analysis of logistics costs in a manufacturing company, etc. [13].

Beside ABC the multi-level full cost allocation (MFCA) technique can also be adapted to transport when there is a need of allocating indirect costs in an exact way. The basic principle of MFCA is similar to the one of ABC: indirect costs are allocated on the basis of measured performance relations or consumptions. The advantage of MFCA is that its models can depict the complex hierarchical operation structures and the intern service relations within them in a transparent way so that the cost efficiency within the company can be evaluated more effectively.

The aim of the further analysis is to give a guideline on how to apply MFCA in case of transport companies. The general model of transport costing has already been elaborated and serves here as a starting point [4, 5, 6]. Another input of the calculation is the sample costing model of a bus transport company [5]. The calculation is performed by making use of the experiences and formulas of other related pilot projects aimed to support decision making in rail transport and logistics [2, 3].

2. The calculation model

Figure 1 illustrates the sample cost calculation model set up for the case of a bus transport company. Bus services, as profit objects, are produced by the cost objects of drivers, vehicle types (#1…3) and sales. They contribute to the realisation of the profit objects by providing performances measured by the indicators of working time, vehicle km and transaction, respectively. The cost objects of drivers and vehicle types are controlled through dispositions of the operative commanding unit. Vehicle types are served by the vehicle maintenance unit too. Here operation time drives the cost allocation. The performances of IT (information technology) and management cost objects are measured by data volumes and the number of orders respectively. They both serve the cost objects of sales, operative commanding and vehicle maintenance [5].

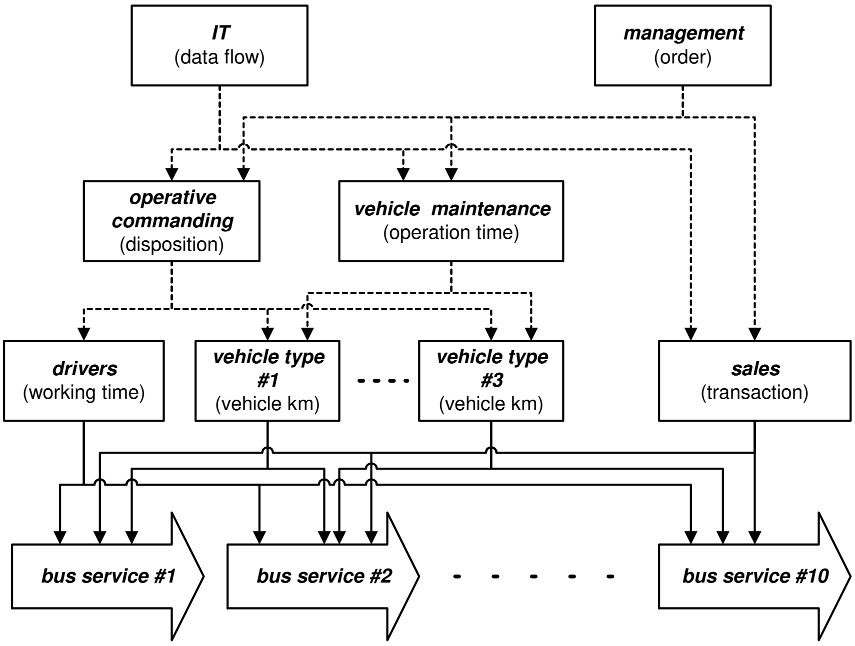


Figure 1. The calculation model

Equation (1) explains how to calculate the total cost of a cost object. The total cost of a cost object consists of the primary cost and the sum of the allocated intern service costs. Primary cost, representing a certain part of the total indirect costs in the company, is assigned to the cost object directly. The costs of the intern services are allocated to the cost object by using the ratios of relative performance consumptions. These are the so called performance intensities.

$$C_k^{co} = C_k^{pr} + \sum_{i=1}^{9} C_i^{sco} p_{ki}^{co} \ , k = 1 \ldots 9 \tag{1}$$

where:

C_k^{co} : total cost of cost object k

C_k^{pr} : primary cost of cost object k

C_i^{sco} : total cost of service cost object i

p_{ki}^{co} : performance intensity, i.e. relative performance consumption, of cost object *k* at service cost object *i*

Equation (2) shows how to calculate the total cost of a profit object. The total cost of a profit object consists of the direct cost and the sum of the allocated intern service costs. The allocated intern service costs constitute the indirect cost of the profit object. Direct cost is assigned to the profit object directly. The costs of the intern services are allocated to the profit object by using the corresponding performance intensities.

$$C_j^{po} = C_j^d + \sum_{i=1}^{9} C_i^{sco} p_{ji}^{po} \quad , j = 1\ldots10 \tag{2}$$

where:

C_j^{po} : total cost of profit object *j*

C_j^d : direct cost of profit object *j*

p_{ji}^{po} : performance intensity, i.e. relative performance consumption, of profit object *j* at service cost object *i*

It shall be noted that:

$$\sum_{k=1}^{9} p_{ki}^{co} + \sum_{j=1}^{10} p_{ji}^{po} = 1, \text{ for all } i = 1\ldots9 \tag{3}$$

Equation (4) is the formula of calculating the average cost of a cost object: the total cost is to be divided by the total performance. This, as the intern price of performance generation, can be used as the indicator of cost efficiency. So the cost efficiency of resource utilisation (e.g. human resource or vehicles) or of operating organisational units (e.g. sales, maintenance, etc.) can be determined exactly.

$$c_k^{co} = \frac{C_k^{co}}{P_k^{co}}, \ k = 1\ldots9 \tag{4}$$

where:

c_k^{co} : average cost of cost object *k*

P_k^{co} : total performance of cost object *k*

Through subtracting the total cost from the revenue the margin of a profit object (bus service) can also be determined according to Equation (5). The margin can be regarded as the indicator of profitability.

$$M_j^{po} = R_j^{po} - C_j^{po} \quad , j = 1\ldots10 \tag{5}$$

where:

M_j^{po} : margin of profit object *j*

R_j^{po} : revenue of profit object *j*

3. Numerical example

The operation of the proposed cost calculation model can be illustrated by a numerical example. The input data, however, are estimated and assumed as real data could not be obtained yet. Nevertheless, the pilot calculation delivers enough information to form an opinion of the usefulness of the model.

The estimated performance intensities are summarised in Table 1. The rows represent the cost or profit objects receiving intern services while the service cost objects are listed in the columns.

Table 1. Performance intensities

r./s.	*IT*	*man.*	*opc.*	*v.m.*	*sal.*	*driv.*	*veh.1*	*veh.2*	*veh.3*
IT									
man.									
opc.	0.46	0.60							
v.m.	0.18	0.11							
sal.	0.36	0.29							
driv.			0.40						
veh.1			0.20	0.20					
veh.2			0.31	0.35					
veh.3			0.09	0.45					
ser.1					0.03	0.05	0.20		
ser.2					0.08	0.09	0.07	0.04	0.23
ser.3					0.13	0.07		0.18	
ser.4					0.21	0.17	0.13		0.21
ser.5					0.06	0.11		0.15	0.08
ser.6					0.12	0.08	0.14		0.11
ser.7					0.08	0.09	0.17		0.16
ser.8					0.06	0.15		0.43	
ser.9					0.13	0.12	0.29		0.13
ser.10					0.10	0.07		0.20	0.08

The estimated input data, like primary costs and performances, and the calculated data, like total costs and average costs, of cost objects are listed in Table 2. Equations (1) and (4) have been used for the calculations. The cost data are measured in thousand monetary units (th. MU) while the dimensions of performance and average cost data are indicated in the table. Looking at the average cost data the cost efficiency of various performance generations can be evaluated. This data can be compared to the similar data of previous years or to the similar data of other transport companies having the same operational structure. Even outsourcing decisions can be supported as average cost data, as the prices of intern services, can be compared to the prices offered by extern service providers. So, for example, vehicle maintenance may be outsourced if the company has a price offer lower than 215.58 MU/hour, etc.

Table 2. Input and calculated data of cost objects

data	**pr. cost**	**total cost**	**performance**		**average cost**	
cost obj.	(th. MU)	(th. MU)	value	dimens.	value	dimens.
IT	50	*50.00*	3000	GB	*16.67*	MU/GB
man.	30	*30.00*	1500	no. ord.	*20.00*	MU/ord.
opc.	40	*81.00*	8800	no. disp.	*9.20*	MU/disp.
v.m.	850	*862.30*	4000	op. hours	*215.58*	MU/hour
sal.	330	*356.70*	54000	no. trans.	*6.61*	MU/trans.
driv.	1100	*1132.40*	23300	w. hours	*48.60*	MU/hour
veh.1	230	*418.66*	600000	veh. km	*0.70*	MU/vkm
veh.2	360	*686.92*	890000	veh. km	*0.77*	MU/vkm
veh.3	190	*585.33*	1200300	veh. km	*0.49*	MU/vkm

The estimated input data, like direct costs and revenues, and the calculated data, like total costs and margins, of profit objects are showed by Table 3. Equations (2) and (5) have been used for the calculations. All data in this table are measured in thousand monetary units (th. MU). The indirect costs within the total costs of profit objects are allocated on a cause-effect basis so they can be regarded as reliable. The margin data give a support for decision making on which bus services should be preferred and which ones should be rationalised or re-priced. The causes why certain operations are efficient or not and whether given services are profitable or not can be assessed exactly through analysing the performance generation chains in the model.

Table 3. Input and calculated data of profit objects

data ***profit obj.***	**direct cost** (th. MU)	**total cost** (th. MU)	**revenue** (th. MU)	**margin** (th. MU)
ser.1	100	*251.05*	260	*8.95*
ser.2	120	*441.86*	470	*28.14*
ser.3	90	*339.28*	310	*–29.28*
ser.4	150	*594.76*	550	*–44.76*
ser.5	180	*475.83*	500	*24.17*
ser.6	220	*476.39*	450	*–26.39*
ser.7	140	*435.28*	490	*54.72*
ser.8	120	*606.64*	570	*–36.64*
ser.9	110	*489.76*	440	*–49.76*
ser.10	80	*379.15*	460	*80.85*

To have an evidence of the correctness of the proposed model, it is worth comparing the results of MFCA with the results of the traditional cost calculation: see Table 4. In the traditional cost allocation scheme indirect costs are allocated to profit objects on the basis of direct cost ratios. The calculated data of Table 4 highlight that there are significant differences between the results of the two different approaches. Note that the corresponding ABC applications have reported similar deviations [1].

The difference is caused by the fact that the traditional method ignores the heterogeneity of the transport service structure and assumes that the indirect operational costs are proportional to the direct costs. This is generally not true in complex transport companies running different services so the application of MFCA is proposed for their cost calculations. Of course, in smaller transport companies or in companies with a homogenous transport service structure traditional costing methods may also deliver satisfactory results. Nevertheless, in this case managers do not have the possibility to analyse the cause-effect chains of costs and performances.

Table 4. Results of traditional calculation

data ***profit obj.***	**total cost** (th. MU)	**difference** (th. MU)	**margin** (th. MU)
ser.1	*342.75*	*91.70*	*–82.75*
ser.2	*411.30*	*–30.56*	*58.70*
ser.3	*308.47*	*–30.81*	*1.53*
ser.4	*514.12*	*–80.64*	*35.88*
ser.5	*616.95*	*141.12*	*–116.95*
ser.6	*754.05*	*277.65*	*–304.05*
ser.7	*479.85*	*44.57*	*10.15*
ser.8	*411.30*	*–195.34*	*158.70*
ser.9	*377.02*	*–112.74*	*62.98*
ser.10	*274.20*	*–104.95*	*185.80*

4. Applicability

The MFCA transport costing model is able to support cost and performance management tasks by delivering more reliable information on the profits and costs of elementary transport services and on the cost efficiency of various operational units or resources. Another advantage of it is the transparent presentation of performance generating chains within the company. This model can mainly be utilised as an ex post analysing tool.

The model, however, is able to support even ex ante operational planning in transport management. Here the input data shall be forecast on the basis of former experiences and expected business or technology factors. The planned data can be compared to the fact data regularly and the interventions aiming at improving the transport operations can be made in time by analysing the causes of the deviations.

Another application area is the impact assessment of business process or technology reengineering. Introducing the effects of the improvements into the model makes it possible to investigate how they affect cost efficiency or profitability. Let us see an ex ante pilot impact analysis by using the model developed. Let us imagine that the IT modules of operative commanding, maintenance and sales are improved. It affects these units unequally: the IT subsystem of maintenance is moderately improved while the other two subsystems are significantly developed. The improvement leads to higher IT costs and performances while the primary costs of operative commanding, maintenance and sales decrease due to saved workforce. The assumed changes in the data are the following:

- the primary cost of IT increases by 100% while its performance increases by 50%;
- the primary cost of operative commanding, vehicle maintenance and sales decreases by 25%, 5% and 25%, respectively;
- the performance intensities between IT and operative commanding, vehicle maintenance and sales change to 0.53, 0.06 and 0.41, respectively.

Running the model with the slightly modified data has given the results presented in Table 5. Accepting the assumed effects it can be concluded that the improvement of IT yields cost savings of bus transport services. The total cost of producing the services has decreased by 1.89%. So it is possible to estimate the cost savings of the IT improvement in a more exact way. Of course the reliability of the assumptions limits the applicability. Conducting similar sensitivity analyses enables more accurate operational cost or cost saving data needed for cost-benefit analyses of investments.

Table 5. Impact assessment of IT development

data ***profit obj.***	**total cost** (th. MU)	**cost saving** (%)	**margin** (th. MU)
ser.1	*248.65*	*0.96*	*11.35*
ser.2	*432.78*	*2.06*	*37.22*
ser.3	*330.36*	*2.63*	*–20.36*
ser.4	*579.04*	*2.64*	*–29.04*
ser.5	*470.19*	*1.19*	*29.81*
ser.6	*467.13*	*1.95*	*–17.13*
ser.7	*427.38*	*1.81*	*62.62*
ser.8	*600.08*	*1.08*	*–30.08*
ser.9	*479.08*	*2.18*	*–39.08*
ser.10	*370.32*	*2.33*	*89.68*

Despite its advantages the practical implementation of the MFCA model may have several constraints. The main barrier of introducing MFCA in transport is the lack of high quality input data, which may require additional estimations. Another problem is that the operational structure of the real-world transport companies can not be depicted perfectly in the model and generally simplifications are needed. It makes the model applicable but at the same time the correctness of the results declines. Nevertheless, if the operation or the service structure of the transport company is complex or heterogeneous and there is an intention to make the management information system more accurate, it is worth considering the introduction of MFCA.

5. Conclusions

The adaptation of MFCA to the specific features of transport companies and the implementation of related costing models deliver real advantages for decision makers.

One of the advantages is the more accurate and detailed cost, cost efficiency and profitability information of operational units or services in transport companies. The output data base of MFCA contains much smaller distortions due to the cause-effect based indirect cost allocations.

Another advantage of the new costing regime is the ability to carry out more sophisticated analyses, i.e. exploring the causing factors of profits or losses, determining the efficiency of operations or the viability of transport services, investigating the impacts of business or technology improvements, etc. Even the management related procedures of transport planning can be supported when both plan and fact data are fed into the model and the plan-fact deviations and their influencing factors are then evaluated carefully. This function of MFCA enables the decision makers to control transport management procedures effectively and in a transparent way.

Considering the constraints of MFCA it can be concluded that the operation of transport companies can not be modelled perfectly in practice. Some simplifications have to be included when depicting the organisational and service structures, which may make the calculation results less accurate. These results, however, are in general still more correct than the outputs of traditional costing approaches. It shall also be taken into account that MFCA calculations require more and high quality input data than the other cost management tools do, which may need more efforts from the users and maintainers of management information systems.

Comparing the advantages and disadvantages of MFCA it can be stated that this kind of cost calculation is worth implementing in case of transport companies operating with complex organisational structures causing considerable indirect costs and/or their service structures are extensive and not homogeneous.

Acknowledgement

This work is connected to the scientific program of the "Development of quality oriented and harmonized R+D+I strategy and functional model at BME" project supported by the New Széchenyi Development Plan (project ID: TÁMOP-4.2.1/B-09/1/KMR-2010-0002). Furthermore, this paper is prepared with the support of the project "Modelling and multi-objective optimization based control of road traffic flow considering social and economical aspects" of OTKA (project ID: CNK 78168).

References

[1] Baykasoglu, A., Kaplanoglu, V.: *Application of activity-based costing to a land transportation company: a case study*, International Journal of Production Economics, Vol. 116, No. 2, (2008), pp. 308-324, doi:10.1016/j.ijpe.2008.08.049.

[2] Bokor, Z.: *Integrating logistics cost calculation into production costing*, Acta Polytechnica Hungarica, article in press.

[3] Bokor, Z.: *Cost calculation models for rail transport*, Horizons of Railway Transport, Vol. 2, No. 1, (2011), pp. 5-19.

[4] Bokor, Z.: *Improving transport costing by using operation modeling*, Transport, Vol. 26, No. 2, (2011), pp. 128-132, doi:10.3846/16484142.2011.586111.

[5] Bokor, Z.: *Transport costing based on the modelling of technology processes*, Acta Technica Jaurinensis ser. Transitus, Vol. 4, No. 2, (2011), pp. 259-266.

[6] Bokor, Z.: *Calculation model for transport costing*, Periodica Polytechnica ser. Transportation Engineering, Vol. 39, No. 1, (2011), pp. 43-47, doi:10.3311/pp.tr. 2011-1.08.

[7] Calvo, F., De Ona, J.: *Are rail charges connected to costs?*, Journal of Transport Geography, Vol. 22, (2012), pp. 28-33, doi:10.1016/j.jtrangeo.2011.11.004.

[8] Cubukcu, K. M.: *Examining the cost structure of urban bus transit industry: does urban geography help?*, Journal of Transport Geography, Vol. 16, No. 4, (2008), pp. 278-291, doi:10.1016/j.jtrangeo.2007.09.001

[9] Duleba, Sz., Shimazaki, Y., Mishina, T.: *A dynamic analysis on public bus transport's supply quality by using AHP*, Transport, Vol. 27, No. 3, (2012), article in press

[10] Frisk, M., Gothe-Lundgren, M., Jornsten, K., Ronnqvist, M.: *Cost allocation in collaborative forest transportation*, European Journal of Operational Research, Vol. 205, No. 2, (2010), pp. 448-458, doi:10.1016/j.ejor.2010.01.015

[11] Gonzalez-Feliu, J.: *Cost optimisation in freight distribution with cross-docking: n-echelon location routing problem*, Promet Traffic&Transportation, Vol. 24, No. 2, (2012), pp. 143-149, doi:10.7307/ptt.v24i2.286

[12] Jara-Diaz, S. R., Basso, L. J.: *Transport cost functions, network expansion and economies of scope*, Transportation Research Part E, Vol. 39, No. 4, (2003), pp. 271-288, doi:10.1016/S1366-5545(03)00002-4

[13] Krajnc, J., Logozar, K., Korosec, B.: *Activity-based management of logistic costs in a manufacturing company: a case of increased visibility of logistic costs in a Slovenian paper manufacturing company*, Promet Traffic&Transportation, Vol. 24, No. 1, (2012), pp. 15-24, doi:10.7307/ptt.v24i1.265

[14] Link, H.: *Transport accounts – methodological concepts and empirical results*, Journal of Transport Geography, Vol. 13, No 1, (2005), pp. 41-57, doi:10.1016/j.jtrangeo.2004.11.004

[15] Nurminen, T., Korpunen, H., Uusitalo, J.: *Applying the activity-based costing to cut-to-length timber harvesting and trucking*, Silva Fennica, Vol. 43, No. 5, (2009), pp. 847-870

Galileo in Urban Public Transport

B. Horváth, J. Pfister

SZE, 9026 Győr, Egyetem tér 1.
Phone: +36/96 503 494, fax: +36/96 613 561
pwp- systems GmbH, D65520 Bad Camberg, Otto- Hahn- Str. 20a
Phone: +49/6434 9096630, fax: +49/6434 906735
e-mail: hbalazs@sze.hu, pfister@pwp-systems.de

Abstract: This paper focuses on the FP7 supported project Galileo Signal Priority (GSP). It shows the main problems regarding signal prioritising and vehicle location and monitoring. It discovers the main points towards to develop a new method for signal priority based on robust positioning with Galileo system.
The research leading to these results has received funding from the European Union Framework Programme (FP7/2007-2013) under grant agreement n° [277688-2].

Keywords: Galileo, signal priority, public transport, FP7

1. Introduction

Electromobility and renewable energies play a pivotal role in preparing our society for the future. The best way to cut on carbon emissions in big cities and metropolitan areas is through the positive environmental impact of attractive public transport (PT) services. [4], [6] With the issue of sufficient energy supply already solved, tram systems are the most mature electric vehicles currently on the market. Operation times of more than 16 hours per day and transport capacities of more than 100 passengers per vehicle are proven standards in daily operation all over the world.

Since GPS has reached full operational capability in 1993, the system has been taken up by public transport applications quite slowly compared to automotive navigation devices on the road. The current state-of-the-art in PT shows the deployment of different technologies, which are partly based on GPS, logical methods (e. g. door open signal) in combination with distance travelled or with position fixes through infrastructure based transponder (e. g. infrared or radio beacon). Today GPS can handle PT operations such as calculating the estimated time of arrival for traveller information at tram/bus stops. However, more complex applications like transit signal priority (TSP) or track sharp localisation have higher requirements. For those demanding functions, infrastructure based positioning is still being used in PT. This means that in addition to the GNSS unit in each vehicle, many transponder beacons are installed along the track and every vehicle needs special equipment on-board to read these beacons and initiate corresponding actions (e.g. trigger the traffic light for transit priority). Finally it has to be stated that the effort for calibration and maintenance of infrastructure based systems is rather high and costly.

As a consequence, intermodal traffic control systems (ITCS) apply both technical systems (GPS positioning for traveller information and infrastructure based positioning for TSP). This situation in state-of-the-art ITCS is neither technically reasonable, nor economically affordable and has to be changed.

2. PT-operations with link to positioning

The location and monitoring of the public transport vehicles in Hungary has not got too long tradition. Before the millennium there were only in Budapest such a system, called AVM. It worked and works still today with transponders along the line routes. The operation of this system is based on the cooperative work of the transponders and odometer on the vehicles. It resulted in location along the line route. It works well till there is no change on the line route. In case of a new or modified route there are no possibilities to follow the vehicles. Apart from this system there is only a few years tradition in vehicle location and monitoring in Hungary. [2], [5]

Figure 1. Smart bus stops in the cities Győr and Sopron

It is very important to mention a system started in Pécs and widespread in the last few years countrywide. It is a GPS based location system with several functions customized to the Hungarian market. The problems described before are no problems at such a system because even the signal priority is based on the GPS signals. In consideration of the Hungarian situation there were need to build up the communication system between signalling dispatching centre and vehicles.

There are other benefits of this system because it is able to record the runs of the vehicles and feeds the passenger information system. (Figure 1.)

In general can be say about such a location and monitoring systems the followings:

The general information of the position for each vehicle in real time forms a basic data set, which can be used for different functions within the operational schemes of PT. In the following the best known functions are listed [7]:

- Vehicle disposition of the whole PT fleet.
- Real time passenger information about the estimated arrival time at each stopping point/area.
- Dynamic schedule synchronisation to assure connecting lines at switching stations.
- Transit signal priority (TSP) for PT-vehicles at traffic light controlled junctions.

The complex relation between the technical capabilities and limitations of satellite navigation and the demands for the single application shall be explained in more detail on the example of real time passenger information in contrast to TSP.

Figure 2. Two examples of real time passenger Information Displays at bus/tram stops.

In Figure 2 two examples of real time passenger Information displays for bus or tram stops are depicted. Those installations have reached a wide distribution and are well known to most PT users. Currently there are various initiatives going on, to bring this information on the estimated time of arrival of PT-vehicles onto mobile devices like smartphones. The data-measurements of the necessary input information are generated directly from the PT-vehicles via standard GNSS-modules. The generated GPS position is mapped onto the PT route and from the know distance to the upcoming stops the arrival time can be computed. Since the resolution of the estimated arrival time is 1 minute the requirements on the positioning unit is quite low. Assuming an average speed of 5 m/s for inner city areas, the accuracy can tolerate more than 100 meter on the position error, without any degradation of the service itself. Furthermore an error of announcing a PT vehicle by 1 or 2 minutes early compared to the real arrival does not lead to any inconveniencies of the passengers themselves. Consequently this service shows high user acceptance and is state of the art in modern PT operations.

With respect to the functionality of TSP, these conditions are totally different, because especially for the application of TSP a precise localization, which shall have a track sharp character, is requested for the positioning of PT vehicles. In **Hiba! A hivatkozási forrás nem található.** an example is shown for a traffic junction with two arterial roads (one for inbound traffic and one for outbound traffic), which are crossed by 6 PT-lines. During peak traffic hours (which are in line with peak PT-demand) each line operates at a frequency of 4 times per hour and in both directions. Thus the depicted example needs to process 48 trams per hour, which need to cross the arterial road, which does have high traffic load by private car traffic.

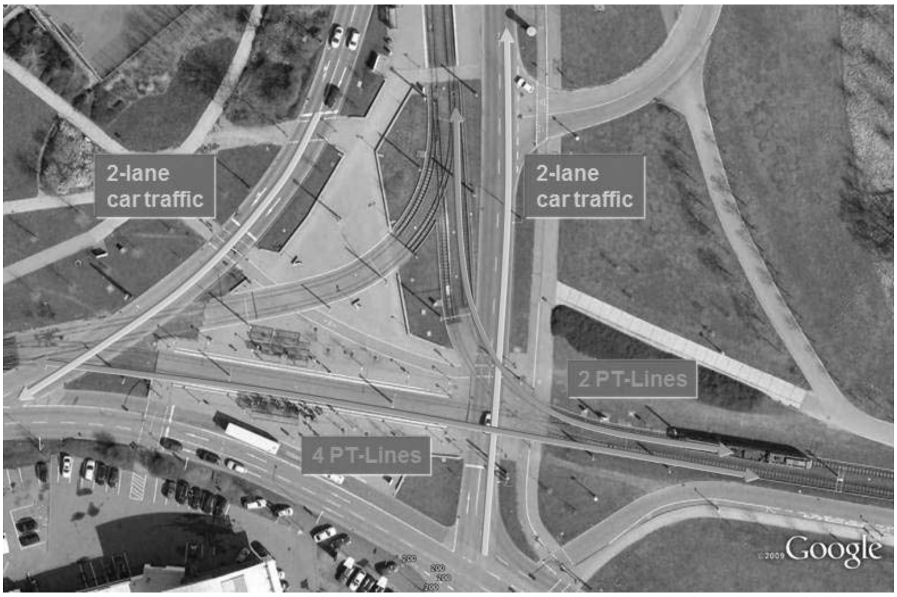


Figure 3. Traffic junction with 2 arterial roads crossed by 6 PT-lines

Furthermore it has to be recognized, that for the signalling program of such an important traffic light system, every second is of relevance. As a rule of thumb, every 2 seconds a complete car can cross the junctions during a green phase of the traffic light. Consequently each extension of 2 seconds for the green phase of private care traffic is contributing towards better traffic flow. With respect to the aim of TSP, it is also understandable, that PT-vehicles shall receive priority, but not under every condition. First analysis have shown, that up to 30% of the trams are not able to use their window of opportunity to cross the junction and have to accept waiting times of more than 1 minute. Thus an improved TSP scheme has the potential to reduce the travel time of the PT-vehicle significantly and enhancing the throughput of private car traffic at the same time [8].

From the conclusions of these two operational examples it becomes obvious, that the focus of GSP has been put on TSP to overcome the last obstacle for a sustainable introduction of GNSS to support and improve all functions of PT. With this step the existing infrastructure based systems (which are less flexible and more cost intensive) shall be dispensable, to save cost on equipment and maintenance and explore the full potential of on-board intelligence. [1]

3. Technical Approach

From the analysis of the PT operational requirements, a new positioning module is needed to serve the application demands of PT. In this context the main objective of the current project is, to develop a prototype for robust positioning exploring EGNOS, EDAS and in the future Galileo as main sensor, in order to satisfying all the requirements in PT. In order to assure sustainability, the second objective is to develop new traffic light control schemes, which can explore the advantages of GNSS based systems in PT and overcome the deficiencies of costly infrastructure based systems.

Figure 4. Typical GPS-measurements with the Galileo-tram in Halle (Saale)

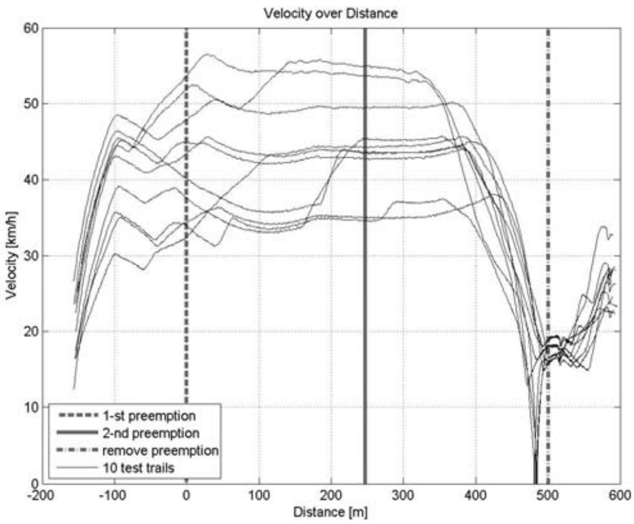


Figure 5. Velocity profile of 10 real life test trials with the Galileo-tram over distance

The term track sharp localization from the application domain is often transferred into the technical domain of navigation by specifying the accuracy requirement with a maximal tolerable position error of 1 meter, which needs to be guaranteed at every time, all over the world and under all conditions. As depicted by Figure 4, these strict requirements cannot be satisfied by ordinary GPS modules. This is the reason why many TSP operations are still triggered by additional infrastructure based systems. As a consequence the GPS module is only used for passenger information and a separate system is used for TSP. In order to explore synergies one positioning giving device or methodology is necessary, which can satisfy all operational schemes in PT, which are position related. The importance of the above mentioned precision can be follow at the Figure 5, where clearly shown the differences in vehicle runs. These small differences can lead to misuse of the time window for public transport if the positioning resolution is not high enough.

4. Assessment of the traffic application

According to the specified objectives the GSP project has its focus on the intelligent interaction between the PT-vehicles and the traffic light systems. To show the potential performance of the new approach, the GNSS based TSP is compared to the traditional infrastructure based TSP. The development of adequate positioning modules to drive GNSS based TSP forms an essential module of the project. In this regard the Galileo testing field in Halle (Saale), which offers special vehicles and equipment from PT applications is subcontracted, to show the benefits on the basis of real life measurements.

For PT applications, robust navigation, with high accuracy, full availability and good integrity, has the potential to enable great improvements within the operation. With respect to the necessary properties of the ‘to be developed’ robust positioning prototype (RPP) for PT, two development domains have to be distinguished. On the one hand side the domain to develop the RPP itself and on the other hand the domain to integrate this RPP into the operation schemes of PT. Both steps are essential elements for a successful market entry plan to bring robust positioning into demanding PT applications.

Through the available instruments inside the Galileo-tram (e.g. high performance reference system based on dual frequency GNSS in conjunction with three axis inertial navigation unit), the assessment of the ‘to be’ developed positioning unit can be executed in a high quality manner. Furthermore the methodology of Virtual Galileo will be applied, where real life test trials of the tram will be augmented with simulated Galileo signals. Therefore the Galileo System Simulation Facility (GSSF) from ESA shall be applied, which has been extended to include a 3D Model of the city buildings in the testing field of Halle (Saale). This way the benefits of Galileo for the specific conditions of PT can be assessed directly through a comparison to the achieved results without Galileo inside. Thus the introduced methodology allows quantifying the potential benefits of Galileo that can be explored in the future for an individual application in its domestic environment.

While new performance levels in positioning are achievable through the use of EGNOS, EDAS and Galileo, the migration of this innovative technology into existing systems of PT has to be solved as well. A concept will be elaborated to enable a smooth transition from state of the art systems, towards new PT schemes on the basis of innovative products. The project objectives support the development of adequate GNSS based products, including necessary steps for their integration into modern ITCS.

Figure 6. Galileo-tram with special equipment installed for development and assessment.

5. Expected benefits for public transport

First feasibility tests on transit signal priority have shown that robust positioning could offer improvements of up to 50% compared to conventional systems, thereby accelerating PT and also allowing for longer green periods for private car traffic. Thus the project work shall bring about the following expected results:

- Development of a robust positioning prototype to suit all requirements in PT by one single solution.
- Shorter travel times for PT through advanced signal priority schemes.
- Enhancing the capacity at traffic nodes for private car traffic by enlarging their green period.
- Achieving significant savings on investment and maintenance cost for the PT operator.
- Assess the potential performance of the future Galileo system (IOC and FOC) and the resulting benefits for PT.

6. Summary

One of the solutions (if not the only) to solve the problems in urban traffic is the prioritise public transport. To perform this task today we need different costly supplementary infrastructure. As a result of the new robust positioning prototype it will be possible to integrate the signal prioritisation into the vehicle monitoring and location system, which will more effective and cost efficient then the systems today. Effect of this development can be that road and public transport can cross a junction faster the today. It can be a win-win cooperation between car traffic and public transport.

The research leading to these results has received funding from the European Union Framework Programme (FP7/2007-2013) under grant agreement n° [277688-2].

References

[1] Pfister, J. et al: *Description of Work FP7*, Galileo Signal Priority (277688-2) (2011).

[2] Horváth, B.: *A tömegközlekedés előnyben részesítésének módszerei a városi közlekedésben* Közlekedéstudományi Szemle 2001/10.

[3] Horváth, B.: *Bevorzugung des öffentlichen Verkehrs und dessen Wirkungsanalyse* Frühlingsakademie „Mobilität und Verkehrssicherheit" München 2000. május 2-7.

[4] Horváth, B.: *A fenntartható városi közlekedés elemei* Európai Mobilitási Hét Mosonmagyaróvár, 2007. szeptember 17.

[5] Prileszky, I., Horváth, B.: *Informatikai alkalmazások jelene és perspektívái a közforgalmú közlekedésben* VIII. HTE Kongresszus, Széchenyi István Egyetem, Győr, 2008. november 28.

[6] Prileszky, I. et al: *A nyugat-dunántúli régió nagyvárosaiban a tömegközlekedés prioritását biztosító intézkedési terv* Nyugat-Dunántúli Regionális Fejlesztési Tanács megbízásából Szerződésszám: NyDRFT23/1999-7 Győr, (2000).

[7] Pfister, J., Kalden, O., Kleint, A.: *Analyse von Galileo- und GPS-Positionierung für ÖPNV-Anwendungen*, DGON-Symposium; POSNAV ITS 2011, Darmstadt Germany, November 2011.

[8] Pfister, J., Kolbert, P., Plank-Wiedenbeck, U.: *Accelerating Public Transportation with Galileo*, EUGIN-Symposium; European Navigation Conference 2010, Braunschweig Germany, October 2010.

Elaboration of a Method's Theory regarding the Establishment and Revision of Bus Lanes

D. Esztergár-Kiss, P. Kaderják, Cs. Csiszár

Budapest University of Technology and Economics,
Faculty of Transportation Engineering and Vehicle Engineering,
Department of Transport Technology,
1111 Budapest, Műegyetem rkp. 3-9.
Phone: 0036-463-1053
e-mail: esztergar@kku.bme.hu, peter.kaderjak@gmail.com, csiszar@kku.bme.hu

Abstract: Bus lanes should be integrated into the transportation network in an efficient way, while the location-specific features and the function of the certain section should be handled, too. The scope of this article is the *elaboration of a method*, which can help to determine, in which cases the establishment or existence of a bus lane is reasonable. With the method the processes can be analyzed in three steps: the arising *transportation demands* are handled, the questions of *feasibility* are reviewed, and the *expected traffic situation* after the establishment is estimated. The reasonable action in the section is calculated by the determination of the total time loss.

Keywords: *bus lane, classification, traffic analysis, time loss calculation, establishment solutions*

1. Actuality of the topic

The enhancement of the public transportation's competitiveness and the shift of the modal-split is an essential issue all over Europe [14]. Bus transportation plays a significant role in the execution of the urban public transportation [3], the quality of the transportation can be increased by its preference. However, these measures should be introduced cautiously in order to avoid their later revocations or modifications. The reasoned decisions [9] concerning the establishment of bus lanes have high importance, because an unconsidered decision may cause disadvantages for the participants of the individual transportation.

Some general aspects and threshold values can be helpful when making a decision. Although there are domestic and foreign guidelines for the establishment of bus lanes, they have plenty of deficiencies. The Transportation Research Board (= TRB) published a framework of aspects [7], which described the usage conditions of bus lanes. This paper reviewed a study called Austroads [1], in which the advantages of bus lanes are discussed in detail, but it contains no guidelines for the evaluation of them.

Taylor [10] provided an answer for this based on the work of Vuchic [13]. He states that the requisite of the establishment is, that at least as many passengers should pass through in the bus lane, as separately in the remaining traffic lanes. This indicator is based only on the passengers' throughput of an arterial section, and does not consider such factors, as the environmental impacts or the expectable changes of the modal-split because of the less time delay. It provides only an approximate estimation concerning the planned facility.

The TRB association published another study [12], which aimed the analysis of bus lanes on arterial sections. The bus routes are classified by the number of stops and the frequency, and then the infrastructural demands are assigned to the categories. However, this is still not a comprehensive solution, because the criteria of the establishment of bus lanes are only determined by the actual traffic situation.

Regarding the surveys found it can be obtained, that they have analyzed the establishment of the bus lanes from many aspects, but there are no such formulas, which can give a prognosis about the expected traffic situation and the advantages and disadvantages of the establishment.

2. The elaborated method

With the application of the method it can be determined, in which cases the establishment of a bus lane is reasonable. The method includes a three-step analysis, which is shown in the Fig. 1.

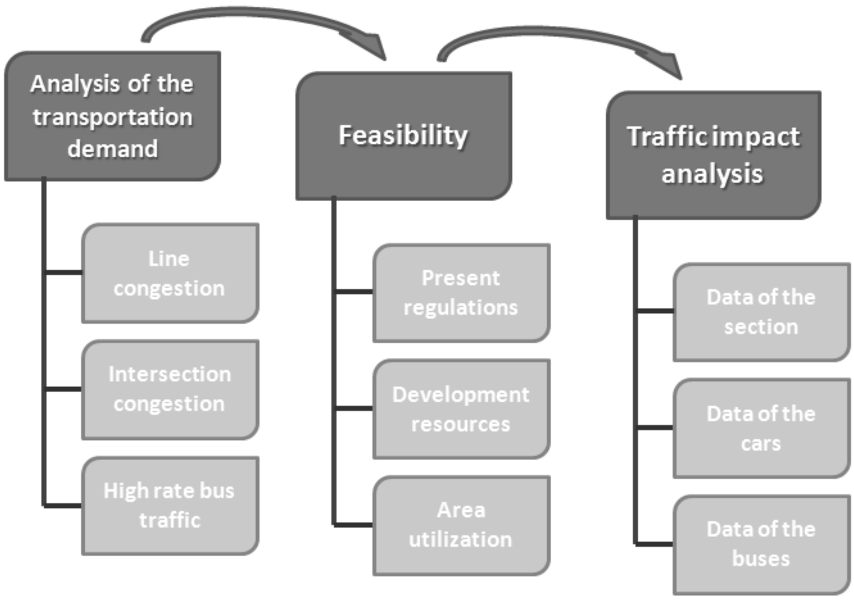


Figure 1: The three-step analysis of the method

As a first step the transportation demands of the public transport are analyzed, and then it is checked whether the conditions are met for the realization or not. At last in some cases the traffic impact analysis is needed to be executed, so that the changes in the time losses of passengers can be calculated on a certain section.

2.1. Analysis of the transportation demands

It is important to determine what is the type and amount of demand of the public transportation. Knowing the actual traffic situation on a certain section, it can be decided, whether the network structure is able to satisfy the expectations or not.

- *Line congestion:* When the public transport vehicles are forced to pass through slowly because of the other vehicles, e.g. congestion at a same level railway crossover, where the bus cannot turn in or reach the bus stop. In this case a separate bus lane could help.
- *Intersection congestion:* In the case of an otherwise undisturbed traffic situation an intense congestion often occurs close to the intersections. A short bus lane can mean time saving for the buses, which can be even a turning lane. An improved version is the intersection check-in system [11].
- *High rate bus traffic:* Independent from the traffic situation the establishment of a bus lane should be considered in case of high traffic sections, where the rate of the passengers travelling by bus is higher than 50% or the common frequency of the buses is under 2 minutes. Also the actual regulation handles this case distinguished [8].

2.2. Feasibility

With the analysis of the feasibility the regulation and financial frames can be determined, and the location-specific questions can be answered. Using these, the repartition of the road surface can be considered.

- *Present regulations:* In order to be able to decide among the versions, the technological parameters of the bus lanes should be known [6]. The Hungarian regulation determines only two threshold values [8], as "a bus lane can be assigned in an existing traffic lane, if at least 10 buses per hour pass through in the peak time, or if less than 10 buses per hour pass through in the peak time is typical, but the capacity in the most narrow point section is not decreasing because of the establishment."
- *Development resources:* The infrastructure developments in the urban public transport in Hungary are realized by the contribution of the municipalities, and subsidies from the European Union are also available. Other support can be obtained from the government as a result of tenders.
- *Area utilization:* Concerning the realization another important aspect is the size and location of the certain network element. If the bus lane is established on the existing road surface, the requirements of the traffic facilities have to be analyzed. These are the sizes and features of the traffic lanes, parking lots, sidewalks and bicycle facilities, all of these are included in the technological road regulations.

2.3. Traffic impact analysis

When a solution without a significant effect for the traffic cannot be realized, the changes in the capacity of the section are needed to be analyzed. The question arises whether the modified performance of the section is sufficient to the rate, which is meant to be assured. For executing the traffic analysis the following data are needed:

data of the section:

- n – number of traffic lanes [piece],
- E – vehicle unit [piece],
- N – incoming number of vehicles [E/h],
- C – duration of peak hours [h],
- α_{jk} – ratio of right-turning vehicles [%] (only in case of an intersection),
- t_c – duration of the cycle time [s] (only in case of an intersection),
- t_p – duration of the red time [s] (only in case of an intersection),
- t_z – duration of the green time [s] (only in case of an intersection),
- L – length of the bus lane [m],

data of the cars:

- l_j – average queue length of the cars [m],
- l_b – average safety distance between the cars [m],
- t_k – average clearance time [s],
- N_{sz}– ratio of the cars in the traffic [%],
- u – average number of passengers [person],

data of the buses:

- k – number of buses per hour [piece],
- B – capacity of the bus [person],
- η – average utilization [%].

In the case of the section we take besides the characteristic traffic volumes (q_i) and the signal time plan (T, t_p, t_z) also the ratio of right-turning vehicles (α_{jk}) into consideration, because these vehicles do not pass through the remaining traffic lane, but they use the bus lane. The duration of peak hours (C) helps to determine the rate of the congested queue in case of heavy traffic.

The features of the vehicles are the queue length data ($_{lj}$, l_b) and their ratio (N_{sz}), which determines how many cars and how many trucks pass through. The average clearance time specifies how fast the vehicles leave the section. The average number of passengers (u) is needed to determine the total time loss of the passengers in these cars.

In the case of the buses from the given data (k, B, η) the total number and the total time loss of the passengers on the buses can be calculated.

3. Results of the traffic analysis

In our survey we estimated and calculated the expected traffic situation in a queue jump lane in an intersection arm, which is a bus lane assigned in an existing lane. With the analysis the loss times concerning the original and established statuses can be determined. After comparing the two values, it can be decided whether the establishment of the bus lane is suggested or not. We used the following assumptions:

- The time loss refers always to an average vehicle, which arrives during the middle of the red time, and waits in the middle of the queue, and arrives in the middle of the peak time.
- The clearance time of the vehicles is 0.5 s.
- The arrival of the vehicles in the intersection section is uniformly distributed.

3.1. Original status

Cars:

In the original status, when the bus lane is not yet realized in the section, the total time loss (eq. 1.) for the cars (T^a) is specified by the red time loss (T_p^a), by the clearance time loss (T_k^a), and by the eventually occurring congestion time loss (T_t^a).

$$T^a = T_p^a + T_k^a + T_t^a \tag{1}$$

- car red time loss:

$$T_p^a = \frac{t_p}{2} * u * N_{sz} * N * \frac{t_p}{t_c} \tag{2}$$

When calculating the red time loss (T_p^a) the car arrives during the middle of the red time (t_p) in the average case. Assuming uniform arrival and multiplying with the average number of passengers (u) the value for one person can be determined, with the N_{sz} ratio the same can be applied for the cars. This time loss (eq. 2) occurs only to those cars, which have to wait because of the red sign.

- car clearance time loss:

$$T_k^a = \left(\frac{\frac{N \cdot t_p}{3600}}{2} * \frac{1}{n} * t_k \right) * u * N_{sz} * N * \frac{t_p}{t_c} \tag{3}$$

In case of the clearance time loss (T_k^a) firstly the number of appearing cars during one red time (t_p) can be determined. The car stands in the middle of the car's queue in the average case. In the case of more traffic lanes (n) the vehicles are distributed among the traffic lanes and leave the section with a predefined clearance time (t_k). The time loss (eq. 3) for one person can be calculated as shown in eq. 2.

- car congestion time loss:

$$T_t^a = \left(\frac{\frac{N \cdot t_c}{3600}}{2} - \frac{t_z}{t_k} * n \right) * t_k * \frac{3600}{t_c} * \frac{C}{2} * u * N_{sz} * N \tag{4}$$

Congestion (eq. 4) happens when the incoming traffic volume in the section is greater, than the maximal throughput of the section during the green time. In case of the congestion time loss (T_t^a) the number of cars have to be measured during the whole cycle time (t_c). We can assume here also an average case. The number of congested vehicles decreases during the green time (t_z) depending on the number of traffic lanes (n) and the clearance time (t_k). This time loss can be multiple increased during an hour depending on the cycle time (t_c). Because we considered an average car, which arrives in the middle of the peak hours (C), it waits only until the half time. The time loss for one person can also be calculated as shown in eq. 2.

Buses:

In the original status the total time loss (T^b) for the buses (eq. 5.) can be calculated very similar to the case of the vehicles (eq. 1.).

$$T^b = T_p^{\,b} + T_k^{\,b} + T_t^{\,b} \tag{5}$$

- bus red time loss:

$$T_p^{\,b} = \frac{t_p}{2} * k * B * \eta * \frac{t_p}{t_c} \tag{6}$$

When calculating the red time loss (T_p^b) in case of the buses, the bus arrives during the middle of the red time (t_p) in the average case. The value for one person can be calculated from the number of buses per hour (k), from the capacity of the bus (B), and from the average utilization (η). The time loss (eq. 6.) also occurs only, when the buses have to wait because of the red sign. The value is independent from the volume of the traffic.

- bus clearance time loss:

$$T_k^{\,b} = \left(\frac{\frac{N \cdot t_p}{3600}}{2} * \frac{1}{n} * t_k \right) * k * B * \eta * \frac{t_p}{t_c} \tag{7}$$

In case of the clearance time loss (T_k^b) the same calculation (eq. 7.) can be proceeded as with the vehicles (eq. 3.). Difference is only shown when calculating the time loss for one person.

- bus congestion time loss:

$$T_t^{\,b} = \left(\frac{\frac{N \cdot t_c}{3600}}{2} - \frac{t_z}{t_k} * n \right) * \frac{3600}{t_c} * \frac{C}{2} * k * B * \eta \tag{8}$$

The same (eq. 8.) can be stated during the calculation (eq. 4.) of the congestion time loss (T_t^b).

3.2. Established status

The traffic situation after the establishment can be defined using the following formulas. With them the amount of the time loss compared to the original status can be determined, as well as the characteristic threshold values. This approach does not take into consideration the negative externalities caused by the congestions, because it assumes the possibility of the modal-split's shift.

Cars:

In case of the established status the total time loss (eq. 9.) for the cars (T'^a) consists of the red time loss ($T'_p{}^a$), of the clearance time loss ($T'_k{}^a$), of the right-turning time loss ($T'_j{}^a$), and of the eventually occurring congestion time loss ($T'_t{}^a$).

$$T'^a = T'_p{}^a + T'_k{}^a + T'_j{}^a + T'_t{}^a \tag{9}$$

- car red time loss:

$$T'_p{}^a = \frac{t_p}{2} * u * N_{sz} * N * \frac{t_p}{t_c} \tag{10}$$

The red time loss ($T'_p{}^a$) is not affected by the establishment of a bus lane, so its value (eq. 10) remains unchanged.

- car clearance time loss:

$$T'_k{}^a = \left(\frac{\dfrac{N \cdot (1-\alpha_{jk}) \cdot t_p}{3600}}{2} * \frac{1}{(n-1)} * t_k \right) * u * N_{sz} * N * \frac{t_p}{t_c} \tag{11}$$

In case of the clearance time loss ($T'_k{}^a$) the formula (eq. 11) is very similar to the original one (eq. 3), but from the number of arriving cars during the red time (t_p) the right-turning vehicles (α_{jk}) have to be subtracted, and one traffic lane less (n–1) is available for the cars.

- right-turning car clearance time loss:

$$T'_j{}^a = \left(\frac{\dfrac{N \cdot \alpha_{jk} \cdot t_p}{3600}}{2} * t_k \right) * u * N_{sz} * N * \frac{t_p}{t_c} \tag{12}$$

The clearance time of the right-turning cars also have to be taken into consideration, because these cars pass through before the bus lane section with the other vehicles together. This formula (eq. 12) differs from the car clearance time loss ($T'_k{}^a$) in the number of appearing cars and the number of traffic lanes is only one.

- car congestion time loss:

$$T'_t{}^a = \left(\frac{\dfrac{N \cdot (1-\alpha_{jk}) \cdot t_c}{3600}}{2} - \frac{t_c}{t_k} * (n-1) \right) * \frac{3600}{t_c} * \frac{C}{2} * u * N_{sz} * N \tag{13}$$

From the congestion time loss (T'^{a}_{t}) the right-turning cars (α_{jk}) also have to be subtracted, and one less traffic lane (n–1) is available for the cars. The other parameters remain unchanged (eq. 13.).

Buses:

In the established status the total time loss (eq. 14) for the buses (T'^{b}) can be calculated as follows: from the red time loss (T'^{b}_{p}), from the clearance time loss (T'^{b}_{k}), and from the eventually occurring congestion time loss (T'^{b}_{t}), where compared to the original status (eq. 5) the overload time loss (T'^{b}_{tt}) appears.

$$T'^{b} = T'^{b}_{p} + T'^{b}_{k} + T'^{b}_{tt} + T'^{b}_{t} \quad (14)$$

- bus red time loss:

$$T'^{b}_{p} = \frac{t_p}{2} * k * B * \eta * \frac{t_p}{t_c} \quad (15)$$

The red time loss (T'^{b}_{p}) is also not affected by the establishment of a bus lane, so its value (eq. 15) remains unchanged.

- bus clearance time loss:

$$T'^{b}_{k} = \left(\frac{\frac{N \cdot \alpha_{jk} \cdot t_p}{3600}}{2} * t_k \right) * k * B * \eta * \frac{t_p}{t_c} \quad (16)$$

We should calculate with the clearance time loss (T'^{b}_{k}) only because of the right-turning vehicles (α_{jk}) in the bus lane, which is negligible in case of an overload, because when the average bus arrives to the end of the section, the vehicles have already left the bus lane. The other parameters (eq. 16) can be handled as in the original status (eq.7).

- bus overload time loss:

$$T'^{b}_{tt} = \left(\frac{\left(\frac{N \cdot (1-\alpha_{jk}) \cdot t_p}{3600} - \frac{L}{(l_j - l_b)} * (n-1) \right) * t_k * k * B * \eta * \frac{t_p}{t_c}}{n * 2} \right) \quad (17)$$

The overload time loss (T'^{b}_{tt}) can be observed, when more vehicles arrive during a red time, than how many can wait in the remaining traffic lanes parallel to the bus lane. Then the bus has to wait before reaching the bus lane. From the total number of vehicles arriving during one red time (t_p) those can be subtracted, which are waiting in the parallel traffic lanes (n–1), and it also can be divided by the number of lanes (n) beyond the bus lane, assuming that the vehicles are equally distributed in the available area. We consider the case of an average bus, which can wait anywhere in the congested queue randomly, that is why the result is divided by 2. The number of vehicles is the ratio of the length of the bus lane (*L*) and the area occupied by the cars ($l_j + l_b$). All this has to be calculated (eq. 17) for one person and only for the red time periods.

- bus congestion time loss:

$$T'^{b}_{t} = \left(\frac{\left(\frac{\frac{N \cdot (1-\alpha_{jk}) \cdot t_c}{3600}}{2} - \frac{t_z}{t_k} * (n-1) \right) * \frac{3600}{t_c} * \frac{C}{2} * k * B * \eta}{n * 2} \right) \quad (18)$$

When calculating the congestion time loss (T'^{b}_{t}) we can use almost the same formula (eq. 18.) as in the original status (eq.8.), because if there is a congestion, the bus has to wait with the other vehicles before reaching the bus lane. The right-turning vehicles (α_{jk}) also have to be subtracted, and there is one less traffic lane (n–1) available.

3.3. Calculating the total time loss

After the definition of the difference of the original (eq. 19) and the established status (eq. 20), the time losses of the passengers in the cars (ΔT^a) and in the buses (ΔT^b) can be determined.

$$\Delta T^a = T^a - T'^a \qquad \Delta T^b = T^b - T'^b \quad (19)$$

Summarizing these (eq. 21.) the total time loss can be specified (*T*).

$$T = \Delta T^a + \Delta T^b \quad (20)$$

- If this value is negative, then the establishment of a bus lane is suggested.
- If this value is slightly positive, then after reconsidering the transportation-political aspects the establishment can be realized disadvantaging the individual, motorized vehicles. Still the possible congestions have to be taken into consideration, as well the shift of the modal-split in the direction of the public transportation.
- If this value is largely positive, then the establishment of a bus lane is not suggested, because in this case both the vehicles, both the buses suffer such a large amount of time loss, which can be not be justified.

4. Possible solutions

Four output opportunities may be expected (Fig. 2.) after the determination of the data stored. During the process we firstly analyze the conditions for the establishment of a new traffic lane. If the conditions are met, the new lane can be established (I. outcome). If it is not possible, then applying the area utilization parameters and the location-specific data the repartition of the road surface is tried to be realized. The result can be the II. outcome or the traffic impact analysis. On the basis of the elaborated formulas and the simulation data the III. or the IV. outcome can be produced.

- *I. Establishment of the bus lane in a new traffic lane:* If the establishment of the new lane is possible, then only land use planning aspects and correspondence with road regulations have to be considered during the planning process.
- *II. Establishment of the bus lane with the repartition of the road surface:* In this case some stored information is needed, which are the regulations and the data about the given section. Depending on the total width of the road surface and its planning class we can designate enough space for the bus lane with the change of the sizes and allocation of the traffic lanes, parking lots, sidewalks and bicycle facilities.

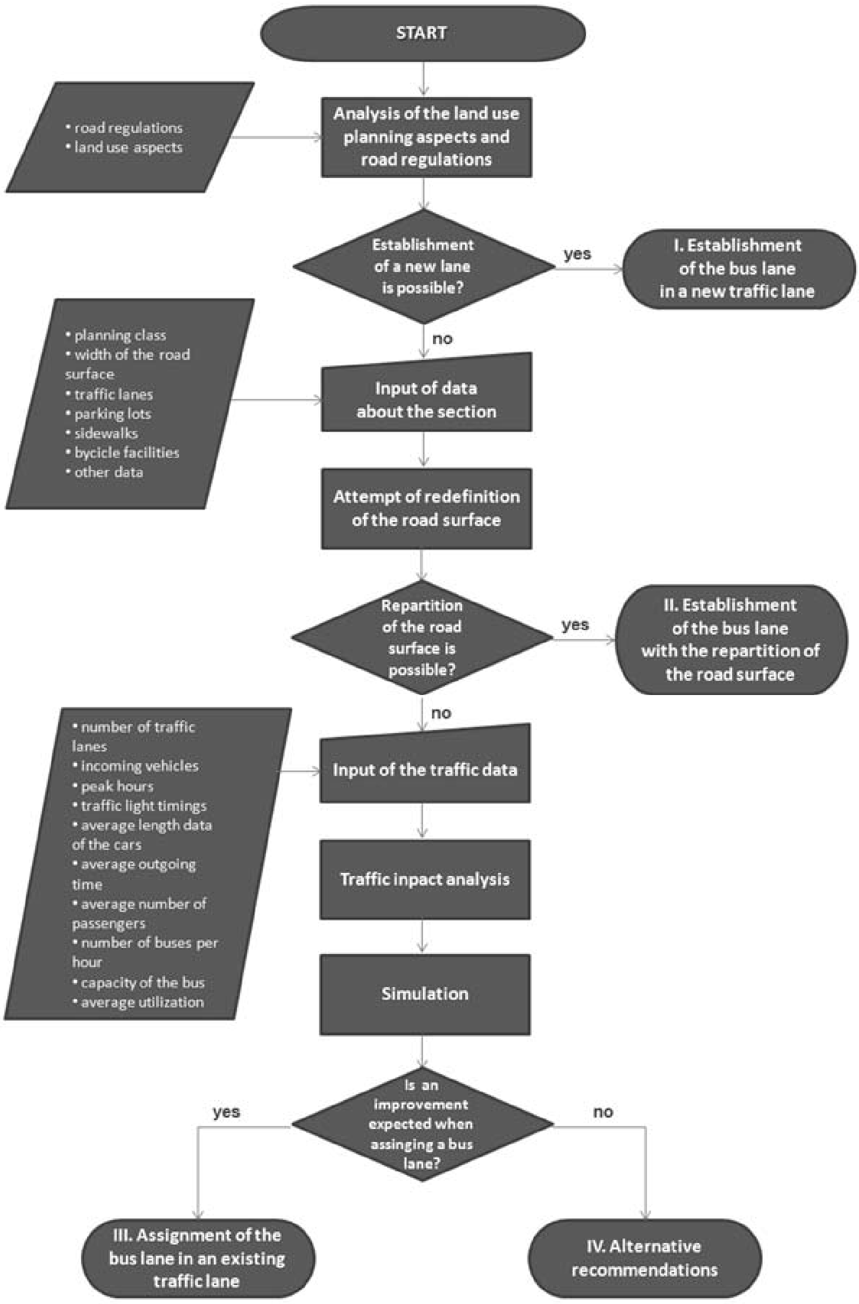


Figure 2: Block scheme of the method for the establishment of bus lanes

- *III. Assignment of the bus lane in an existing traffic lane:* The easiest and mostly used solution is the modification of the function of an existing traffic lane. In this case further data is required, some measurements have to be executed, and data has to be also collected about the vehicles in the traffic flow. Then with simulation techniques the expected traffic conditions can be predicted. The minimization of the time loss on the entire cross-section should be achieved.

- *IV. Alternative recommendations:* These solutions are recommended, when none of the above mentioned solutions is suggested. For example: bus lane on the tramway lane, HOV/HOT lanes [5] , dynamic traffic lanes [2], BRT [4] .

5. Summary

The present guidelines handle the problem with some significant simplifications, and the criteria of the establishment of bus lanes are only determined by the actual situation. We have elaborated a method, which supports the decision regarding the planning and establishing of a bus lane.

We have divided the problem into three steps, and presented four different solutions in case of a certain section. As a first step the transportation demands of the public transport have been analyzed, and then the conditions of the realization have been checked. The result of this step is a decision, which determines how the planned establishment should be realized: establishment of a new bus lane, repartition of the road surface or changing the functions of the existing traffic lanes.

In order to analyze the last case in details a traffic impact analysis is needed to be executed, so that the changes in the number of passengers can be calculated and determined. The aim is to reach the optimal throughput of the section by minimizing the total time loss concerning all the passengers. Knowing these results it can be determined whether the establishment of a bus lane is reasonable, and what kind of alternative solutions are presented.

The elaboration of the method’s practical details and the validation of the formulas with a VISSIM simulation model is the next step of the research, which should prove the correctness of the model.

References

[1] Austroads: *Guide to Traffic Engineering Practice – Part 1: Traffic Flow*, AP-11.1/88, Austroads Publications (1991).

[2] Bede Zs., Szabó G., Péter T.: *Optimalization of road traffic with the applied of reversible direction lanes*, Periodica Polytechnica-Transportation Engineering 38:(1), (2010), pp. 3-8.

[3] BKV ZRt.: *Yearly report* (Éves jelentés), Budapest (2010), in Hungarian.

[4] Diaz R., Hinebaugh D.: *Characteristics of Bus Rapid Transit for Decision-Making*, Federal Transit Administration, USA (2009).

[5] Eichler, M. D., Daganzo C. F.: *Bus lanes with intermittent priority: Screening formula and an evaluation*, Working paper, UC Berkeley Center for Future Urban Transport, (2005), pp. 13-15.

[6] Hungarian Road Association: *The planning of public transport tracks and vehicle traffic facilities* (A közúti közösségi közlekedés (tömegközlekedés) pályáinak,

utas- és járműforgalmi létesítményeinek tervezése (2-1.212:2009)), Budapest (2009), in Hungarian.

[7] Jepson D., Ferreira L.: *Assessing travel time impacts of measures to enhance bus operations*, 1998 Road & Transport Research Journal, 8 (4), 41-54, (1998), pp. 4-6.

[8] Ordinance of the Transportation Ministry: 20/1984. (XII. 21.) *Ordinance about the road traffic regulation and placement of road signs, 9. Special traffic lanes* (KM rendelet az utak forgalomszabályozásáról és a közúti jelzések elhelyezéséről, 9. Különleges forgalmi sávok) (1984), in Hungarian.

[9] Soltész T., Kózel M., Csiszár Cs., Centgráf T., Benyó B.: *Information System for Road Infrastructure Booking*, Periodica Polytechnica, Budapest, Vol.39. No. 2., (2011), pp. 55-62.

[10] Taylor M. A. P.: *Planning and Design for On-Road Public* Transport in Traffic Engineering and Management, Edited by Ogden, K.W. and Taylor, S.Y. Department of Civil Engineering. Clayton, Victoria (1996).

[11] Tettamanti T., Varga I., Kulcsar B., Bokor J.: *Model predictive control in urban traffic network management*, IEEE 16th Mediterranean Conf. on Control and Automation, (2008), pp. 1538-1543.

[12] Transportation Research Board: *Operational Analysis of Bus Lanes on Arterials*, National Academy Press, Washington, D.C. (1997).

[13] Vuchic V. R.: *Urban Public Transportation: Systems and Technology*, Prentice Hall, Englewood Cliffs, N.J., U.S.A.(1981).

[14] White Paper: *Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system*, COM/2011/144 final (2011).

The Opportunities of System Dynamics in the Transport Planning

R. Horváth

SZE, 9026 Győr, Egyetem tér 1.
Phone: +36 96 613561, fax: +36 96 613561
e-mail: richard.horvath@sze.hu

Abstract: One of the tasks of transport planning is to support the development of the sustainable and operable transport system. The deficiency of the data causes a problem because of the change of exterior circumstances during the long term planning. We can supplement it by the system dynamics.

Keywords: system dynamics, transport planning

1. Introduction

One of the tasks of transport planning is to support the development of the sustainable and operable transport system. It is impossible to talk about production because the environment in which the system works changes continuously in sense of economic and transport politics. It is difficult to produce short or long term planes in such an environment due to the change of many external factors. In the past years or decades experts have made several models and model systems. The most often used model is the four-step model. When planning in the long term problems may arise while using the model due to lack of or not enough data. We can supplement it by the system dynamics.

2. The Four-step transport planning model

The Four-step transport model, and its methodology comes from the USA where in the fifties it was necessary to create a uniform planning methodology in order to make plans for the increasing transport demands of big cities. It is usually called Chicago-model originating from the name of one of its big cities.

2.1. Generation

The tasks of this step are to examine and to discover. The result of this step is the incoming and the outgoing traffic volume in each zone (in number of passengers and in number of vehicles). In practice this means the filling in of the sum of the origin-destination matrix rows and columns.

Several models are used in generation step:

- Trend and time line models
- System dynamics models.
- Models based on the attractivity of the zones.

Except for system dynamics model, the models in general do not contain information about the cause-effect interaction or effect each element has on each other. Furthermore they are not able to realise the aims of transport policy.

2.2. Mode-choice

During this step we can calculate what types of transport modes are available and to what extent while travelling:

- Aggregate models
  - Growth-factor models
  - Regression models
  - Category models
- Disaggregate models

On the one hand the advantage of an aggregate model is that it requires less data in order to complete the task. On the other hand the disaggregate model require more and sophisticated date although they make it possible to examine transport policy intervention.

2.3. Distribution

The aim of the traffic distribution model is to fill in “the centre” of the origin-destination matrix in other word we divide the sum of the rows and the columns.

Models used are [1]:

- Analogue models
  - Growth-factor models
- Synthetic models
  - Gravitation models
  - Probability models

2.4. Assignment

This is the last of the four major steps of transport planning process. During the assignment we assign traffic demands which come from the OD matrix to each element of the transport network. As a result we get the traffic volume of the nodes, links and traffic situation of the network. With the use of this data we can calculate other important parameters.

Models used are:

- All or nothing assignment
- Congested assignment
- Dynamic traffic assignment

3. The possibilities of the system dynamics

The models used in the four-step methodology work well in the short term while problems may arise in long term planning. The growth factor model may appear in several steps to which we most assign a growth factor from time to time taking into consideration the actual situation and environment. This environment is none other than the effect these processes have on each other for the examination and representation of which system dynamics is a good tool. You can see the process of the interaction between car and public transport in Figure 1.

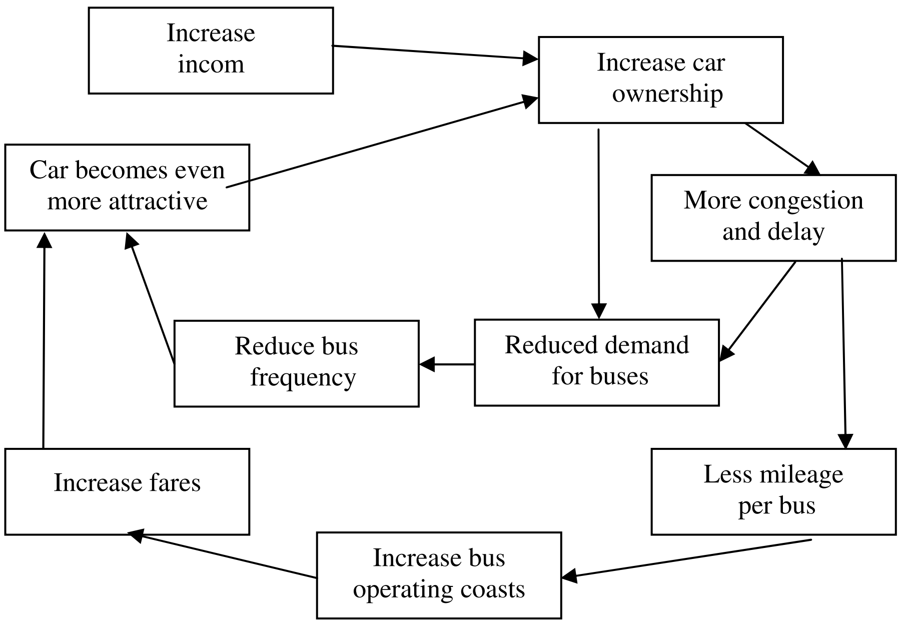


Figure 1. Interaction between car and public transport[2]

A circular process can be seen in Figure 1 which may lead to end of public transport without external intervention. Through system dynamics the process shows a positive confirmatory direction which is usually called "reinforcing loop". The positive reaction destabilizes the system and leads to running away of the system so the system constantly increasing. This does not happen like this in reality because there are restrictive elements for example the level of motorization saturation. The advantage of the system dynamics is that it is rather simple to build this incremental information into the model that result in better models. When planning in the long term accuracy is not the accuracy in a mathematical point of view, because there are lots of distracting factors. So it shows a kind of situation close to reality.

4. System dynamics and the four-step model

We can implement system dynamics possibilities in several steps. For example population, work force can easily be estimated using system dynamics models. It can have a role in mode-choice step of interaction between car and public transport described in Figure 1. The distribution step relates to the economic environment which can be portrayed easily. In the fourth step it is less useable because here we are looking for a short path.

5. Conclusion

Mathematical models can't solve or "reflect" the traffic problems of every day life but they are suitable in the decision making process especially in relation to traffic. Using simplified model we can reduce the necessary amount and detail of the data.

System dynamics studies problems with the help of cause and effect links. It is relatively simple to build models knowing cause and effect links. This has two advantages: on the one hand you can build a working model with even a small amount of data by which you can investigate the effect of individual ideas. On the other hand, investigation of the links of the problem helps to solve the problem. It is often problematic that the link between the cause and its effect is faded by their relative distance in time. It is typical of transportation as well that the result of a decision does not appear immediately but only months, years or decades later. The tools of system dynamics can also be used to investigate such problems by investigating links otherwise which might remain hidden due to time constraints, while building a system dynamics model.

References

[1] de Jong, G., Gunn, H. F.; Walker, W.: *National and international freighttransport models: an overview and ideas for further development*, Transport Reviews, 24(1), (2004), pp.103-124.

[2] Ortúzar, J. de D., Willumsen, L. G.: *Modelling Transport,* Wiley & Sons (1995), England.

The Three-Step Approach Used in Regional Transport Modelling

Zs. Berki

FOMTERV 1024 Budapest, Lovohaz utca 37.
Phone: +36-1-3459745, fax: +36-1-3459501
e-mail: berki@fomterv.hu

Abstract: This paper describes a new approach in modelling transport policy measures in regional context. The most common cordon zone based practice raises some concerns when the planned transport measures are of different nature and their impact area is larger than the typical urbanized region. The paper describes two slightly different approaches which were used in the recent feasibility studies in the practice of FOMTERV Ltd.

Keywords: transport policy measures, urban, regional, feasibility study, transport modelling

1. Background

In the recent years some founds were allocated to regional/city governments in Hungary to involve them into the preparation of transport policy measures, especially transport infrastructure investments on the national backbone network which directly influences their daily transport possibilities.

According to the subsidiary principle these local governments had to prepare a brief description of their ideas and the feasibility context and with this they had to apply for a budget to finance a feasibility study. The funds were offered according to the five different priorities in the Transport Operative Programme of the National Development Agency [1]:

1. Improving the international road accessibility of the country and the regional centres
2. Improving the international railway and waterway accessibility of the country and the regional centres
3. Improving regional accessibility
4. Linking up the modes of transport and improving the intermodality and the transport infrastructure of economic centres
5. Improving urban and suburban public transport

The sharing of planning responsibilities caused that a number of measures planned on the national infrastructure have strong urban context. It means that the traffic on these infrastructure sections is a mixture of regional and urban, and in some case even long distance traffic which have very different attributes and user characteristics.

Additionally the national institutional bodies go ahead with the national transport policy making and planning and set up timelines for the development in both road and rail sectors. The construction of the national infrastructure elements has also direct influence on the regions/cities that had to be included into the feasibility studies.

2. Issues for transport modelling in regional studies

2.1. The special needs of regional planning

Cities are places of the daily life and the majority of transport needs are generated in connection with the city activities.

In the evaluation of transport policy measures that involve a part of the national network as well planner should consider that the local traffic is highly involved as well. It means that in both public and private transport planner should face with the following requirements:

- both the local and regional/long distance transport demand should be properly described,
- the network description should be so detailed to capture all relevant impedance items,
- the mode and route choice models should be able to handle the behaviour of each traffic strata.

Most of the regions have some specialities that are discovered usually by the traffic surveys and counts, like

- presence of long distance traffic,
- asymmetric mode choice (e.g. children transported into the school by car but leaving to home by public transport),
- local distortions in trip purpose (e.g. a shopping mall), or
- quite different cost sensitivities of demand strata (e.g. usually at country borders).

This list just calls the attention that the phenomena can’t be neglected and should be somehow treated in the transport model.

2.2. Challenges in model building

When the transport network is planned in national or European scale cities are usually understood as nodes (in many complex “nodes”) with a very rough description of their transport infrastructure. Usual exceptions are large cities (generally those that have more than hundred thousand inhabitants) and the capital.

It raised a number of issues in the practice since it is very difficult to allocate proper impedances on the transport infrastructures elements of these nodes. If it is too high the traffic on the bypasses are too large if too low then the travel times are quite misleading.

The normal way of handling this issue is to make a bit more detailed network description in urban areas and use "preloaded" network elements. It was sufficient in a number of cases.

When the planned national infrastructure element had a role in urban movements the usual way was to extend the national model to incorporate a broad city model. However this practice led to a number of compromises in transport planning:

- the network description in the city was not quite detailed,
- the impedances of nodes were just a proxy,
- the traffic on these roads were not real loads and
- the route choice was fitted to the long distance/regional traffic.

The other common practice is to extend the city model to capture the bypass movements but in this case different issues come up, like:

- the impact of national or even wider transport policy measures usually not taken by the model,
- the external users' behaviour is hard to manage since only a part of their real trip is included in the model,
- the outer model area is not able to capture all relevant impedances therefore the real inner impedances cause detours in route choice.

There were some workarounds but they were not able to fully catch the interaction between the short and long transport. This caused a number of problems in the first feasibility studies since the traffic time estimation was quite draft which generated discussions especially seeing the results of cost-benefit-analyses (CBAs).

3. Theoretical background of the three-stage approach

The threes stage approach in fact is a common term and it is referenced in a number of papers, like at PTV as macro-, mezzo- and micro models. However the planning practice is usually dealing only with two of them at once.

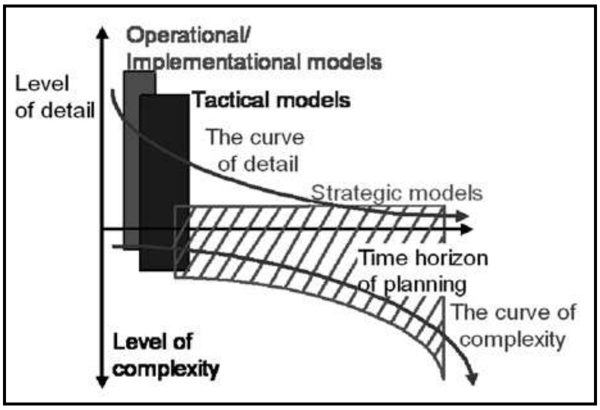


Figure 1. The workflow between mezzo and micro model[1]

According to MOTOS (Transport Modelling: Towards Operational Standards in Europe) [1]: "*Figure 1 illustrates the relationship between level of detail, level of complexity, and time horizon. The expected level of detail decreases significantly with time, while the complexity of the model forecast increases. Some interactions between the infrastructure, regional or urban development, and environment may be so complex that it is debatable whether it can be modelled at all.*"

In the recent feasibility studies made by FOMTERV we developed such models that establish connections among all these stages and the transport policy measures were evaluated by using interaction loops among models.

The first stage in both examples are macro-models, the second is a mezzo model which is in fact the closest to the common model in practice while the third one is a micro-simulation model.

The difference among the examples described below is that one is ranging from a national model to a junction simulation whilst the other one is scaled from a Europe wide model (TRANSTOOLS [3]) to a timetable simulation public transport model.

In the first case the model inputs and outputs are connected while in the second both the elasticities and volumes are handed over.

In both cases the description of the measures are quite broad and the method is in the focus.

4. Modell building scheme of Kecskemet

Kecskemet, a county capital of Hungary, issued two calls in 2010 to order feasibility studies in two separate topics

- The improvement of regional accessibility of Kecskemet
- The intermodal passenger railway terminal and supporting measures

FOMTERV was contracted to prepare feasibility studies for traffic infrastructure developments dedicated to the development of regional accessibilities but it was involved in the planning and traffic modelling of the intermodal interchange as well.[4].

4.1. Measures investigated

The plans of the city referred to (see. Figure 2 as well)

- a city bypassing road dedicated to the non-city bundled traffic;
- a number of road capacity measures on the national roads within the city including lane addition, traffic engineering brush up, new alignments;
- ITS (intelligent transport system) measures capturing a city-wide traffic management centre and signal control;
- new, intermodal public transport interchange and supporting measures like rearranging service layout, acquisition of new vehicle fleet, providing passenger information and establishing P+R facilities.

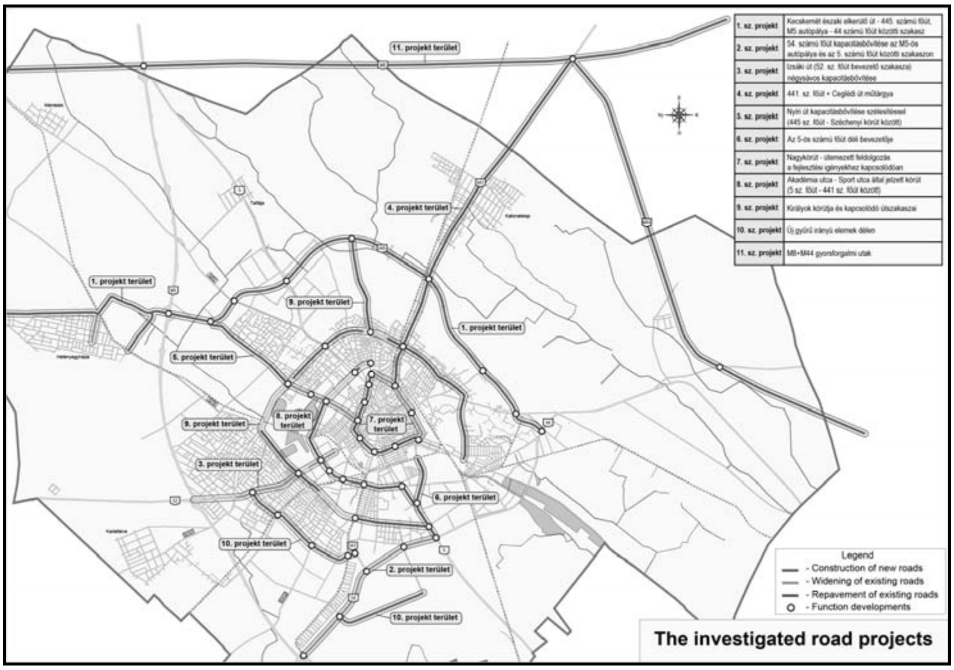


Figure 2. The investigated road infrastructure projects (FOMTERV)

4.2. Modelling

The central model was a normal four-step model according to the common practice. However it failed to capture the traffic conditions on the new bypass and the benefits of the traffic management measures.

With the bypass the mezzo model

- was not able to react on the large scale national network measures (like new motorway buildings);
- the national role of the road was overestimated;
- the travel time savings were unrealistic.

In case of the traffic management measures the mezzo model

- was too rough to react on travel time savings;
- the usage of true impedances in the city non-sense detours on the network;
- the travel time savings were unrealistic also.

These problems were considered in the planning phase therefore the three-step approach was used as below:

- Macro model: National model which is used to run at country-level.
- Regional model: A very detailed city and regional model covering all transport means and the four-stage planning scheme.
- Micro model: A micro-simulation model taken from the regional model thus the traffic forecast, composition and route choice were the same as in the regional model.

The models were coupled with input-output volumes which proved to provide consistent forecasts on all three levels. The models were built by using PTV VISION transport modelling suite.

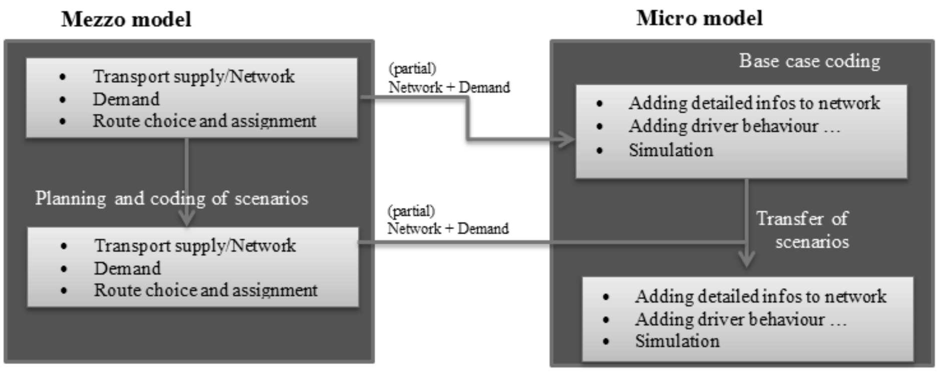


Figure 3. The workflow between mezzo and micro model

The key features can be summarized in Table 1.

Table 1. Key features of the model levels (Kecskemet)

	Macro	Mezzo	Micro
Network description	base network	detailed public and private transport network	enhanced node layout and traffic signalling
Transport demand	on interurban level	zone level, traffic retained at cordon zones	interchange level, traffic flows retained
Mode choice	not modelled	on zone level	not modelled in micro level
Route choice	on interurban level	detailed impedance calculation	mezzo routes kept
Validation	against screen lines and cross section counts	against macro model, city screen lines, cross section counts and GPS routes	against mezzo model and counts on turns

In this way the evaluation of the individual measures and CBA-s were consistent and the expert estimations were replaced by model results. It's added more transparency reliability to the results.

5. Modelling of the planned "V0" Budapest bypass

The Association of Hungarian Logistics Service Centers trusted the „V0 Magyarorszag consortium", consisting of FONTERV Ltd. and AKMI Ltd., with COWI Hungary Ltd. and Mott MacDonald Hungary Ltd. with carrying out the Feasibility Study of „V0, the Budapest southbound bypass rail line", which is part of the TEN-T corridors. Its main goal is to build a priority rail freight axis and to release Budapest from the high rail freight traffic [5].

Figure 4 shows that the rail freight of Hungary is very much depend on the international connections.

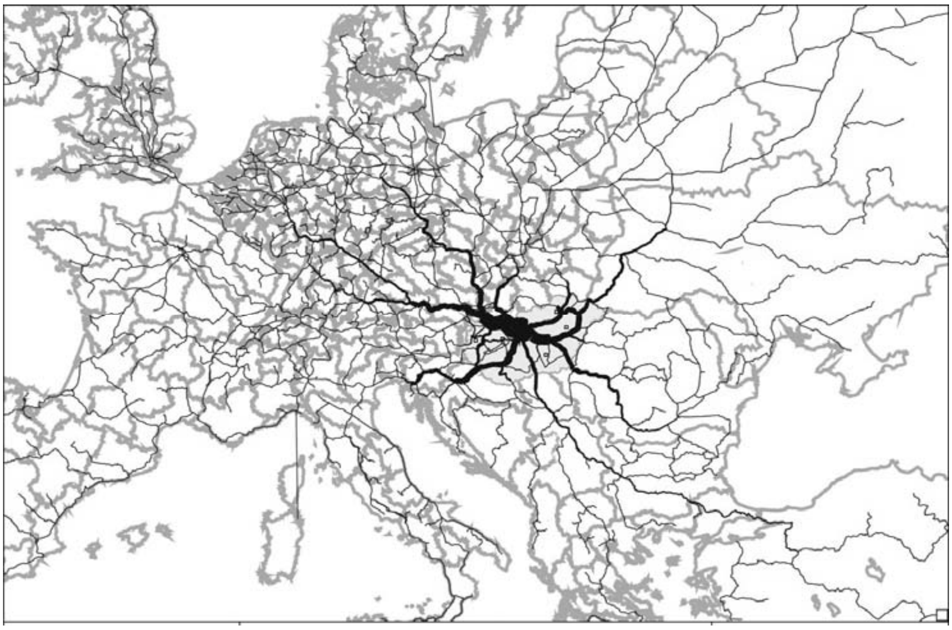


Figure 4. The rail freight connections of Hungary

Looking the statistics it is evident that three quarter of the traffic is international related. Therefore a national model is not enough to model large scale interaction measures.

Table 2. The distribution of rail freight transport by relation (source KSH)

	2005 thousand ton		2010 thousand ton	
Internal	13440	26%	11398	25%
Export	11377	22%	11859	26%
Import	15471	30%	12768	28%
Through	10564	21%	9769	21%
Total:	50851		45794	

5.1. Tasks for transport modelling

The objective of transport modelling is to show the passenger and freight transport reactions induced by the infrastructure. However a number of complementary measures are planned as well, like launching of a mileage based road toll or a new rail infrastructure charging scheme. Therefore transport modelling need to have answers for the following questions:

What are the impacts caused by external measures, like:

- the implementation of EU railway packages,
- the internalisation efforts of all transport costs by charging,
- the changes of raw material and energy prices,
- the changes of subsidies,
- the other road and rail infrastructure measures.

While an infrastructure measure usually can handle the infrastructure bottlenecks in this case the special task was to set up a new transport policy guideline and look whether in a changing transport environment such a new railway line could generate enough benefits to cover its costs.

Therefore the modelling exercise was a threefold issue:

- Cover the international traffic changes in transport demand development and investigate the IV. transport corridors against the competing ones.
- Look for the national transport infrastructure investments in terms of transport time and costs including the road interactions.
- Analyse the current and future rail network with the recent and the future timetables to justify the infrastructure developments needs considering the user (private rail operators and their clients and passenger rail services) needs and the service parameters (especially the availability of free train paths during the whole day in four hour intervals).

5.2. Modelling

The modelling scheme was developed to cover the needs of the examinations as below:

- European macro model, to
  - cover the whole Europe on NUTS 3 level by using the TRANSTOOLS and ETIS results
  - model the impacts of the planned economic and transport scenarios
- Regional model to
  - cover the close investigation area
  - be enough detailed to include the infrastructure developments on national level
- Rail traffic simulation
  - timetable level investigations
  - discover the real rail transport processes (like the effects of priority rules)

For this reason a large modelling system was set up. It is presented with the model schema on Figure 5.

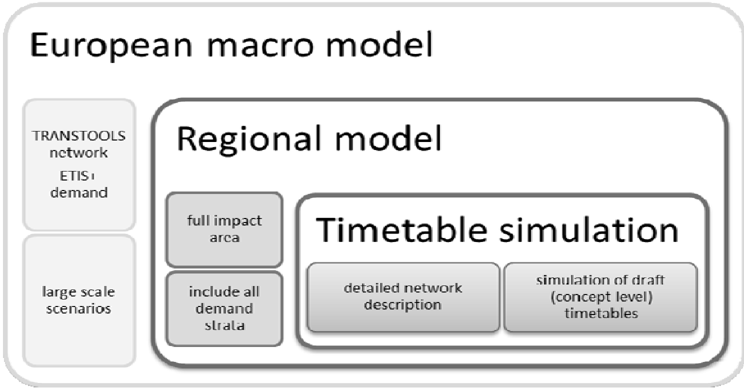


Figure 5. The three-step modelling scheme of V0 rail line

In the developments of the submodels it is crucial emphasise the differences in demand data. While in European model the base unit is the good itself in the regional model the base unit is the vehicle as well as in simulation.

Thus the model components were built according to Figure 6.

The key features can be summarized in Table 2.

In this way the evaluation was able to capture all relevant benefits of V0. Without this approach the benefits would have been underestimated.

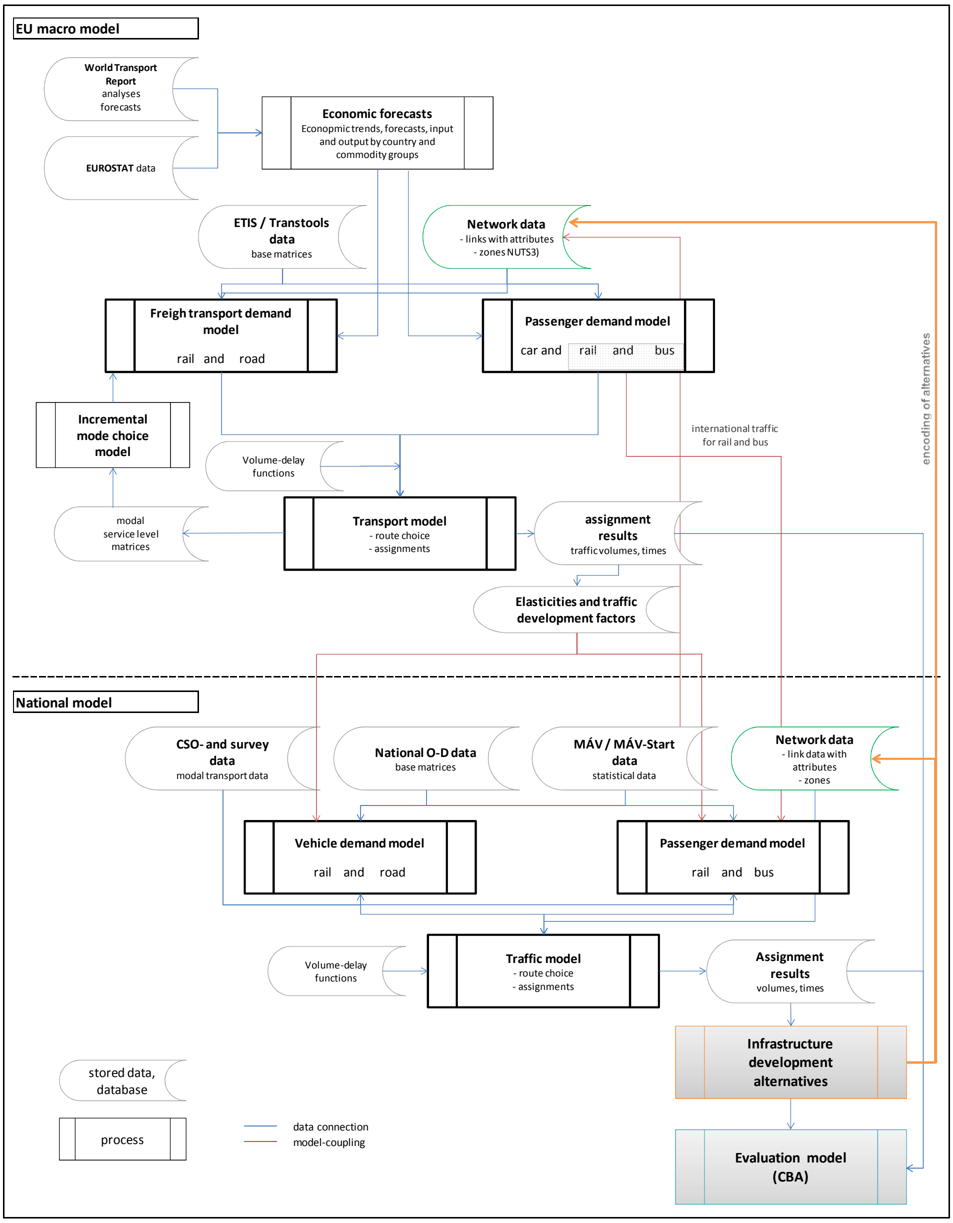


Figure 6. The model components according to the three-level scheme

Table 2. Key features of the model levels (V0)

	EU Macro	Regional	Simulation
Network description	EU wide	Region wide with detailed public and private transport network	Tight impact area with enhanced rail network and signalling
Transport demand	NUTS 3 level by commodity group	zone level, vehicle base, elasticties and growth factors derived from EU level	vehicle based, traffic volumes retained
Mode choice	incremental	not modelled	not modelled
Route choice	according to TRANSTOOLS	Timetable based at rail and equilibrium at road	timetable based
Validation	against screen lines and Central Statistical Office figures	against macro model, Central Statistical Office figures and surveys	against mezzo model

References

[1] Transport Operational Programme (TOP / KözOP) July 2007 Reference number (CCI) of the Operational Programme: 2007HU161PO007

[2] MOTOS Transport Modelling: *Towards Operational Standards in Europe* (DG TREN 2006-2007)

[3] TRANSTOOLS *Transport modelling for policy impact assessments* (DG MOVE 2011-2013)

[4] FOMTERV*: Feasibility study of improving the regional accessibility of Kecskemet* (2010-2011)

[5] FOMTERV-AKMI: *Feasibility study of V0, the Budapest southbound bypass rail line* (2011-2012)

Quantitative Description of Applicability of Vehicles with Methods of Reliability Analysis

S. Zvikli

Széchenyi István University Department of Transport
telephone: 96/503 494, fax: 96/613 561,
e-mail: zvikli@sze.hu

Abstract: This publication makes an attempt to quantitatively evaluate the structure of applicability system of the specified stock of vehicles with the help of the reliability characteristic analysis

Keywords: reliability, maintenance strategy, availability

Introduction

A real demand appears on behalf of transport organizations for the implementation of an "availability based" operational strategy that treats maintenance as an integrated part of vehicle purchasing and in the case of very valuable stock of vehicles it is destined for considerable use. Within the framework of this there is also a need for an availability and applicability function prognosis in order that the maintenance-supply system is able to flexibly adapt to the expectations determined by the fixed availability level that is required by its use.

The present document attempts to highlight some reliability-theoretical relations of the foundation of the strategy that it refers to. In particular to show a method, applied to the specified (advanced) phase of permanent use for quantitative evaluation of maintenance structure, in accordance with using probability and the quantitative prognosis of the change of applicability.

1. Connection of quality, operation efficacy and reliability

According to our explanation the reliability of vehicles on the one hand can be considered as a generic term, suitable for the probability description of performability, and on the other hand as a signal regarding the quality of the tools. In an expanded definition, reliability can also be named – through applicability – as a determinant component of operation efficacy, furthermore it is suitable for a quantitative description of operation safety (see figure 1).

In a wider sense the technical reliability of a technical tool can mean the ability to preserve its quality (original conditions) under determined conditions of operation. So reliability can be identified as a notion. It is suitable for the description of time change of quality.

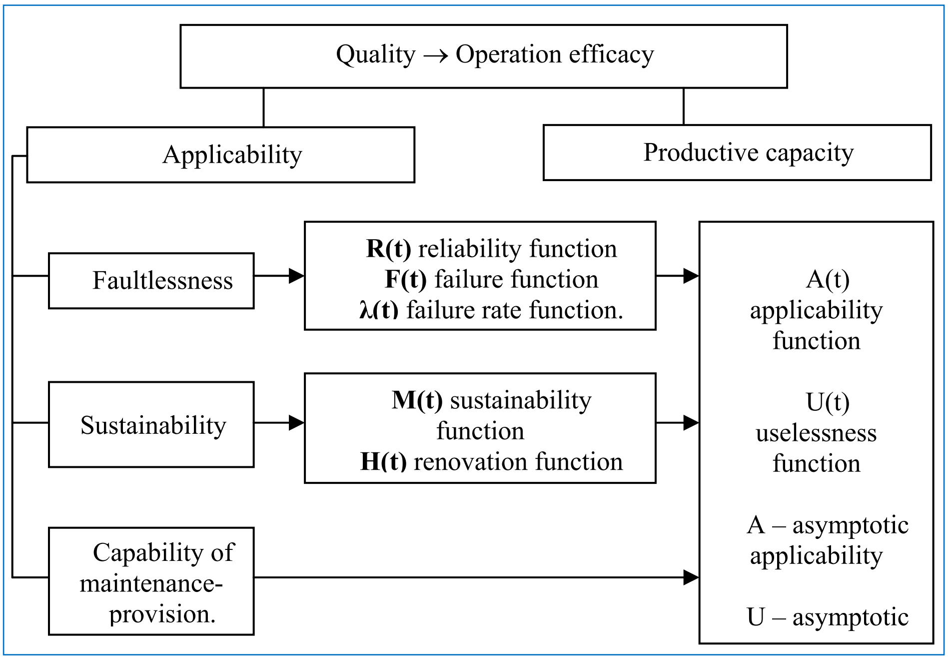


Figure 1. Connection of efficacy – applicability and notions, suitable for their quantitative description

[The notions, describing reliability are interpreted as follows:

Applicability is the ability of the system (product) to provide its specified functions in the specified moment, or interval, under specified conditions, presuming that the necessary (external and internal) resources are available.

Faultlessness is the ability of the system to be able to provide its specified functions under specified conditions, in a specified moment, or interval.

Sustainability is the ability of the system that - under specified operation conditions – it *can be kept in such a state, or can be reset to a condition* in which *it can perform its specified functions*, if its maintenance is performed according to the specified conditions and by using the specified procedures, resources

The maintenance-supply is a property of the connecting organizational system that makes *resources available* – under specified conditions – that are necessary for maintenance, besides the specified maintenance policy (strategy, cycle order, technology).]

In general the Q(t) quality of a technical tool can be described with time/performance-dependant $q_i(t)$ parameter, being n finite number [4]:

$$\overline{Q(t)}=\left[q_1(t),q_2(t),q_3(t),\ldots,q_i(t),\ldots,q_n(t)\right] \tag{1}$$

As $q_i(t)$ parameters are in connection with the utilisation, age, maintenance conditions of the tool and other random effects not always known, $\overline{Q(t)}$ vector can be considered as random variant in time. According to this the vector – regarding the technical tool - describes an n dimensional curve, as a function of time.

The knowledge of the complete value range of $\overline{Q(t)}$ is generally uninteresting regarding the reliability analysis. It appears to be sufficient to divide it to disjoint subsets, which are not necessarily constantly connected and contain equivalent parameters in terms of applicability description.

If we divide the n dimensional T status space, containing every possible condition of $\overline{Q(t)}$ to m finite-numbered [Z_1, Z_2, Z_3, … , Z_j, … , Z_m] subsets, excluding the elements of one another,

$$\overline{Q(t)} \in T \tag{2}$$

can be stated

$$\bigcup_{j=1}^{m} Z_j = T \tag{3}$$

where: $Z_i \cap Z_j = \emptyset$ null set, if $i \neq j$.

If we introduce a continuous time z(t) variable, having a discrete value range, which - in the case of an m state – can take values from [1,2,3, …,m] positive integers, in a specified t moment, that number can be identified, as the index of technical tool condition – so if z(t) = k, then $\overline{Q(t)} \in Z_k$, this means that the examined object is in a possible k^{th} state $k \in m$.

Let the nomination of certain conditions (subsets, containing equivalent parameter values) in our study be the following:

- Z_1 – the subset of conditions of the technical tool, able to perform its functions without limitations
- Z_2, Z_3, Z_4, … Z_m – subsets, belonging to out of order states.

2. State probability functions of bistable system, homogeneous Poissonmodel

On the basis of what was previously defined, let us survey a stock of vehicles – operating under known conditions – which's elements have only two possible consecutive conditions, one in working order (Z_1) and another that is in an out of order (Z_2) condition (see figure 2). In the course of their use, the elements of the stock of vehicles with one in one condition and one in the other condition – after troubleshooting they are in working order again – so, if beginning with a specified t moment/performance value to Δt time/scale their behaviour is observed, it can be experienced that either they overturn from their initial condition to their other possible condition or stay in their former condition.

The introduced operation mechanism can be named, as a stochastic process - continuous in its time-space and discrete in its status space – which (as a working hypothesis) can be identified as the Poisson process (having a frequent occurrence in practice), and supposes that the three necessary conditions (that are not too strict) are met, namely [3]:

- *The rareness condition:* the probability of two events coming into being at the same time (two event points have contact) is insignificantly small [(o(Δt) scale]
- *Independent increment*: the number of two event-points (that do not intersect each other), in Δt time interval, is independent from each other
- *Linear probability*: the probability of occurrence of 1 event point in a short Δt interval is proportional to the length of Δt interval, apart from an insignificantly small [(o(Δt) scale] value [this response factor is called event density and in the case of homogenous Poisson failure process it is identical with λ failure rate and in case of homogeneous Poisson reconstruction process it is identical with the μ reconstruction rate parameter].

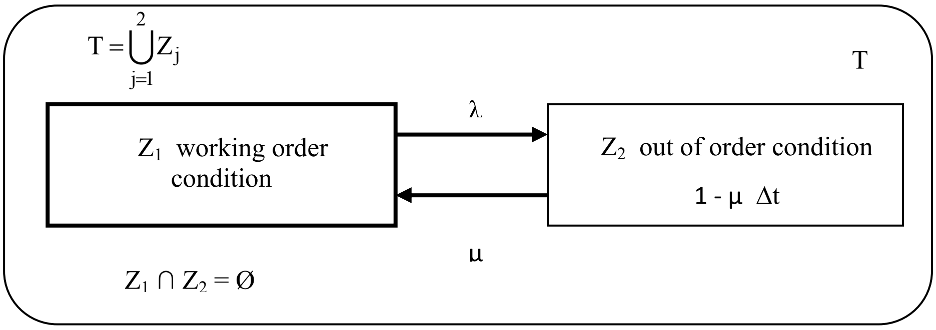


Figure 2. Condition-transitional graph

According to the markings and the specified marginal conditions of the above mentioned figure 2 , λ Δt will be the probability in which the vehicle - monitored in the course of Δt interval - overturns from its 1st condition to 2nd condition, and returns to its 1st condition with μ Δt probability. The complementary specified probabilities (1–λΔt), and (1–μ Δt) supply the probability of remaining in the certain conditions.

It results from the accomplishment of our pre-set simplifying conditions that both the process of failure and restoration has an exponential character, so besides the fulfilment of

$$f_{\lambda}(t) = \lambda \cdot e^{-\lambda t} \tag{4}$$

$$f_{\mu}(t) = \mu \cdot e^{-\mu t} \tag{5}$$

density functions, $T_{\lambda} = 1/\lambda$ = const. and $T_{\mu} = 1/\mu$ = const. the expected (average) staying times can be calculated.

In the examined case the description of the probability process can be performed by the known Chapman matrix differential equation. If it is referred to two conditions, it can be produced in the form of the next (6) general differential equation system, where $P_i(t)$ is the condition probability function that can be assigned with the certain discrete conditions:

$$\left[\dot{P}_1(t) \quad \dot{P}_2(t)\right] = \left[P_1(t) \quad P_2(t)\right]\begin{bmatrix} -\lambda & \lambda \\ \mu & -\mu \end{bmatrix} \tag{6}$$

the solution of (6) equation-system can be determined in analytical form with the Laplace transformation in the forms (7) and (8) [1].

$$P_1(t) = \frac{\mu}{\mu+\lambda} + \frac{\lambda}{\mu+\lambda} e^{-(\mu+\lambda)t} \tag{7}$$

$$P_2(t) = \frac{\lambda}{\mu+\lambda} - \frac{\mu}{\mu+\lambda} e^{-(\mu+\lambda)t} \tag{8}$$

It is easy to see that in the examined case $P_1(t)$ function can be identified with R(t) reliability function of the system, while $P_2(t)$ function can be identified with F(t) failure function.

If we accept the assumption that the external resources necessary for use and maintenance are available, it can be stated:

$$P1(t) \equiv R(t) \equiv A(t) \tag{9}$$

$$P2(t) \equiv F(t) \equiv U(t) \tag{10}$$

where A(t) is a function, suitable for describing the time change of applicability, U(t) is a function, suitable for describing the time change of uselessness.

Examining a proper length operational interval (calculating with $t \to \infty$ theoretical bound transition) the (6) simultaneous equation can be transformed into the Kolmogorov algebraic equation-system, representing the balance condition of the operational structure:

$$\left[0 \quad 0\right] = \left[P_1 \quad P_2\right]\begin{bmatrix} -\lambda & \lambda \\ \mu & -\mu \end{bmatrix} \tag{11}$$

With the solution of (11) the following result can be presented:

$$A \equiv P1 = \mu / (\mu + \lambda) \tag{12}$$

$$U \equiv P2 = \lambda / (\mu + \lambda) \tag{13}$$

where A marks asymptotic applicability, U marks asymptotic uselessness.

If in the course of our procedure we succeed in giving a reliable estimation regarding the vehicles - chosen according to aspects, unspecified here – for λ and μ parameters, occurring in equations (4) and (5), there is a way to give approximate estimation as a function of operation time/performance, as an independent variable on the basis of (7), regarding an extended operational interval for the tendency of the numerical value of applicability function (operational probability), and on the basis of relation (12) for the numerical value of asymptotic applicability index, which is characteristic of the balance condition of the operational system.

3. Analysis of data of failure realizations

From the database of a company, operating urban rail-mounted transport vehicles, the (proportionally distorted) failure-occurrence events – seen in table 1 – could be produced.

The data – containing failure events (their occurrence frequency) – applied to a specified vehicle-series (more than 100 vehicles within it) and yearly time intervals.

Within the connotation of our former justifications and within this set it has no significant relevance from the aspect of considerations. It is to be conceived that the occurred failure event happened on the line, or not, or what type of fault of which functional unit caused the registered failure.

In the lines of the table (1) the following data were determined regarding the specified Δt = 1 year time interval and every vehicle:

- the $f(\Delta t)$ empiric relative occurrence frequency of technically justified faults, giving an estimation for the value of empiric density function of failures

Table 1. Registered failure events of vehicles

Failure events					
Time interval, year	2006	2007	2008	2009	2010
Total technical failure event, piece	5446	6471	5593	6577	5615
Relative fault frequency $f(\Delta t)$/month	0.015	0.018	0.016	0.018	0.016
Cumulated error rate $F(\Delta t)$	0.000	0.217	0.401	0.590	0.811
Empiric reliability function values $R(\Delta t)$	1.000	0.783	0.599	0.410	0.189
Empiric failure rate function values $\lambda(\Delta t)$, 1/month	0.015	0.023	0.026	0.045	0.083

- the $F(\Delta t)$ cumulative empiric relative occurrence frequency of technically justified faults, giving an estimation for the value of empiric distribution function of failures
- the $R(\Delta t) = 1 - F(\Delta t)$ empiric index-number of reliability function of technically justified faults
- $\lambda(\Delta t) = f(\Delta t) / R(\Delta t)$ numerical value of the empiric failure rate function.

λ for the average value of the above-mentioned table - considering the data, that occurs in the last line - the following estimation was produced: λ = 0.04/month.

4. Originating the applicability (expected value) function

The numerical value of μ average reconstruction rate function, that is necessary for further calculations was defined as a parameter and its start value was determined in the same dimension as λ at μ = 0.05 value with preliminary expert estimation. The restoration activity, which is more effective than the estimated item stimulates considerably higher restoration rate (than the specified). The restoration activity, which is less effective, than the estimated induces considering lower restoration rate (than the specified).

In the course of modelling of the applicability probability function, within the meaning of the above, the following generator matrix and basis-equations can be applied:

$$\overline{\overline{Q}} = \begin{vmatrix} -0.04 & 0.04 \\ 0.05 & -0.05 \end{vmatrix} \tag{14}$$

$$\left.\begin{aligned} \dot{P}_1(t) &= -0.04\,P_1(t) + 0.05P_2(t) \\ \dot{P}_2(t) &= 0.04\,P_1(t) - 0.05P_2(t) \end{aligned}\right\} \tag{15}$$

$$A(t) = P_1(t) = \frac{0.05}{0.05+0.04} + \frac{0.04}{0.05+0.04}\, e^{-(0.04+0.05)t} \tag{16}$$

(16) applicability function provides the possibility for preparing prognosis/estimation for the relative alteration of quantitative index-number of applicability in the case of further use of vehicles.

Table 2 contains the necessary calculations for that. In the table the 2005 function value appears, as the basis for determination of relative change of $A(t) = P_1(t)$ applicability function. The produced calculation results are represented by figures 3-5.

Table 2. Calculation of applicability function values

Calculation of prognosed values of (t) = P_1(t) empiric applicability function								
year	t, month	λ, 1/month	μ, 1/month	μ/(μ+λ)	λ/(μ+λ)	e exp[– (μ+λ)t]	P_1 (t)	P_1 relative variable
2005	0	0.040	0.050	0.556	0.444	1.000	1.000	0.000
2006	12	0.040	0.050	0.556	0.444	0.341	0.707	–29.301
2007	24	0.040	0.050	0.556	0.444	0.116	0.607	–14.121
2008	36	0.040	0.050	0.556	0.444	0.040	0.573	–5.602
2009	48	0.040	0.050	0.556	0.444	0.013	0.562	–2.022
2010	60	0.040	0.050	0.556	0.444	0.005	0.558	–0.703
2011	72	0.040	0.050	0.556	0.444	0.002	0.556	–0.241
2012	84	0.040	0.050	0.556	0.444	0.001	0.556	–0.082
2013	96	0.040	0.050	0.556	0.444	0.000	0.556	–0.028

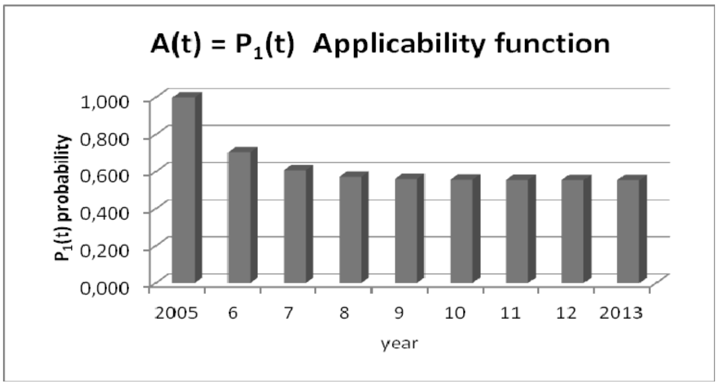


Figure 3. Applicability function

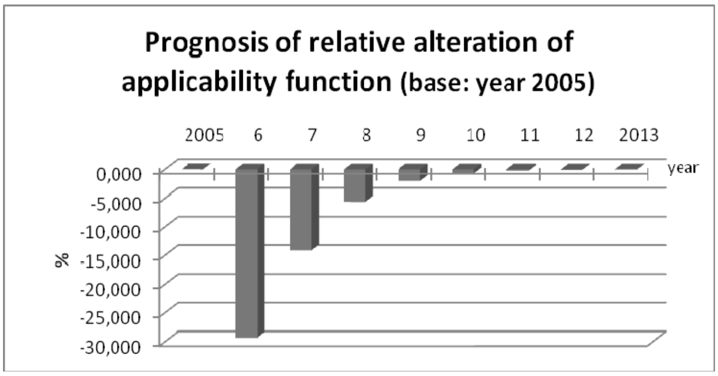


Figure 4. Prognosis of relative alteration of applicability function of a vehicle series

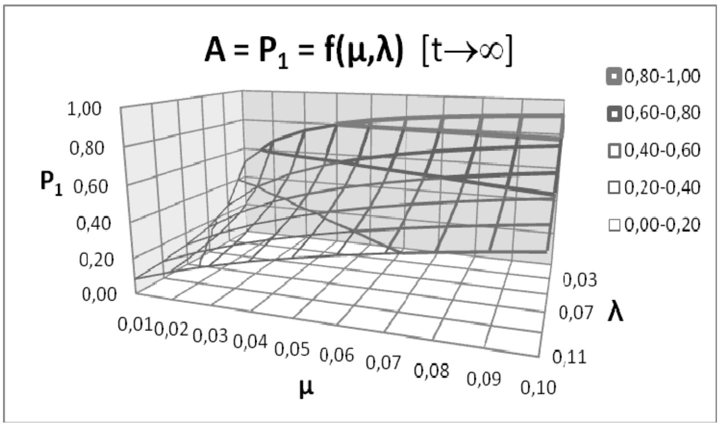


Figure 5. The alteration of applicability index as a function of the alteration of failure and restoration rate

On the basis of the produced results. general findings can be made - connected to the prospective tendency of the further use of the examined vehicle-series - according to the following:

- Besides the expected values of the assessed failure and restoration function. in the balance condition of the system. at least 0.556 applicability probabilities can be realized as a consequence of the failure rate representing an undesirable high value. In favour of improving applicability. it seems to be necessary to considerably reduce the value of failure rate. Reducing the index-number of the failure rate to a 0.01 month^{-1} value. could establish the increase of applicability potential to about 83% (see figure 5)
- Mutatis mutandis. the realized value of the restoration rate also has an influence on the numerical value of the specified applicability index of vehicles. The favourable increase of this can also contribute to the sensible increase of the indicated low applicability limit value. Besides an unaltered failure rate. reducing the time requirement of restoration to half could make it possible to improve the potential applicability to 64%
- Reducing the failure rate to a 0.01 value and increasing the restoration rate to a 0.1 value at the same time establishes the 91% limit value of applicability potential
- By taking into consideration the data series. represented by the starting base of calculations and choosing conditions of the homogeneous Poisson process realization, and representing the base of calculation method. Emphasis has to be laid on our presented results and established information content, and – according to this – on the basis of our data. Our established prognoses are fundamentally suitable for laying down the character of tendencies.

Summary

In the course of our examination. the reliability of vehicles was interpreted as the probability of movement tasks to be performable (applicability of vehicles) and in a wider sense as a signal referring to the application quality of these devices. The analysis of use processes of vehicles – becoming effective in a stochastic way – was performed with help of expedient modelling the conditional and event space of processes. Within the framework of this. The use/operational system of vehicles was described as an effectiveness of a Poisson course of events. Being *bistable. continuous in its time space. and discrete in its condition space.* As an output function of the used model the probability time-functions of the *applicability* of vehicles were performed. On the basis of the produced relations specific recommendations were composed to increase the efficiency of the further-use of vehicles.

References

[1] Dr. Sándor Zvikli: *Operation. maintenance I.*. Universitas-Győr Ltd.. Győr, (2008)

[2] Dr. Sándor Zvikli: *Reliability analysis of applicability of vehicles,* Transport science conference, Győr. (2012), pp. 187-196.

[3] Dr. István Zobory: *Reliability theory II.*, BME. Department of Transportation engineer. Bp. (1994).

[4] Dr. György Farkas, Dr. Tibor Héray: *Quality ND reliability*, Universitas-Győr Ltd., (2000).