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FACULTY OF TRANSPORTATION ENGINEERING AND VEHICLE ENGINEERING
DEPARTMENT OF TRANSPORT TECHNOLOGY AND ECONOMICS

THESES FROM THE PHD DISSERTATION WITH THE TITLE

Modelling of the integrated system of information of road transportation, influencing the operational characteristics

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1. Relevance of the research theme

The continuous growth of mobility demands create newer challenges for the designers, operators and participants of the transportation systems. Road transportation has a dominant position within the whole transportation sector. The traffic growth together with the increase of needs causes the biggest challenge (accidents, congestions, pollution) in road transportation *White Paper* (2011), *ITS Action Plan* (2008). Several developments are conducted in order to mitigate the negative effects of the traffic growth and in this way achieve a capacity expansion without significant infrastructure investment. In favour of the objectives, intelligent transportation systems (ITS) are used, which increase safety, network efficiency and the comfort of travel as well as mitigating pollution and harmful environmental impacts.

With the use of these systems a considerable amount of information is generated in the road transportation – it is partially related to the spread of the systems and partially to the development of data collection technologies. Data processing and utilization – followed after the data collection – is realized mostly only by the data owner (organization who is responsible for the data collection), while other organizations often have a need for data.

The available **information can be shared** with the integration of present info communication solutions. Thus, the efficiency of the transportation system can be increased (e.g. more efficient management of road traffic and road operation according to the objectives of operators and users). **Unexploited resources** remain in road transportation due to the separate management of information, which **adversely affects the stakeholders of transport**.

The significance of this problem is appreciated in the future, because numerous data collection technologies – currently under development – are expected to be introduced in road traffic management. New technology will revolutionize data collection both in quantity and quality, because it will be broadened both vertically (data quality) and horizontally (scope of the area). Often it is not even known how the management of raw and heterogeneous data from different sources will be implemented.

The **scope of intelligent transportation systems and services is** continuously **growing**. New services emerge, which increase the participants' **needs for integrated information management**. In line with this, the role of integration is appreciated, thus it is necessary to build **interoperable** (cross-border) **solutions**.

Data collection methods and the available technologies **are evolving**, therefore it is possible to collect a considerable amount of data about the users and the base transportation process. In many cases this amount of information is much bigger than the available computing devices are able to manage. With the collection of information large databases – so-called "*BigData*" – can be produced. With the analysis of these databases the resource efficiency of the transportation system can be increased. The design and construction of databases, data warehouses and data portals are an up-to-date and significant task and several European initiations and approaches exist concerning these problems.

Since the mid 90s it has been suggested that instead of individual developments, the creation of databases would be more practical by the interconnection of individual systems. In this way comprehensive traffic management can be provided. The structure of the system also allows the reduction of installation and operational costs too *Boltze et al.* (2005), *Hasberg* (2001), *Allekotte et al.* (2003), *Sandrock and Riegelhuth* (2014), *Monigl* (2001).

Transportation characteristics can be influenced on three "sides" by the use of ITS applications – which is realized in a more and more personalized way in our days:

- ***On the demand side***: *soft* influence, information service (the intervention is realized on the user's side by the information and decision influence).

- ***On the supply side***: *hard* influence, traffic control (influence of the operation of the basic transportation system and the basic processes by the interventions made on the infrastructure).
- ***During the assignment of demand and supply***: forming of multimodal transport and travel chains, the support of the implementation of modal shift ("*personalized*" user information and infrastructure-based interventions together).

The European Union has appointed the share and use of information as a target. The "ITS Directive" drew as a priority action that traffic and especially safety related information affecting the road users should be shared across the boarders by the use of interoperable devices, and accessibility to these kinds of information has to be provided *ITS Directive* (2010), *885/2013/EU*, *886/2013/EU*, *C(2014) 9672*. The integration can be enhanced by the share of information – with the promotion of the cooperation of the stakeholders, who are in the value chain of the traffic information service – thus strengthening the competitiveness of the economy.

2. Research objectives

At the determination of the research topic I aimed to establish the developments which realize the improvement of efficiency from a user and operational approach and show **towards the integration** (rational and adaptive use of resources considering the actual traffic demands).

I aimed to **facilitate the telematics integration** in road transport, which already eventuated in rail and air transportation decades ago. My objective is to provide accessibility to the information for all participants of transportation in order to increase the efficiency of the traffic management from both an operational and a user viewpoint. Road transportation consists of several members with different sizes and duties. For this reason, **the road transportation sector is more complex**, because the number of connections is higher if there are more members. Thus, the integration requires an execution approach that is different from the other sectors.

My objective was to create a common structure for the **integrated management of information** according to the structure of information. The objectives of the integrated information system are the comprehensive and systematic managing of the road transportation information; and the production, sharing and transmission of value added information to the participants of transportation; thus supporting the more efficient management of road traffic, - which adapts better to the actual needs - from the point of view of operators and users too.

The objective of the **transportation basic research** is the development of the model of the integrated road transportation system of information (*Chapter 2. and 3. in the dissertation*). According to the model, the creation of an ordered structure for the storage and management of information – comming from different participants (individuals and organizations) – was also an objective. I was looking for the answer to the following questions:

- What kind of relationships exist between the components of the information system?
- Where is the managed information utilized or where can it be utilized beside the data owner[1]?
- Which participants is the information exchanged between? What does it refer to? What kind of characteristics do the connection have?

During the **applied research** my objective was to reveal the possibilities of influencing the operational characteristics according to the structure of information models on the areas which have high research potential and actuality. These areas are in line with the objectives of the ITS systems: safety, traffic efficiency, comfort and environmental protection. In connection with the research sub-topics I was looking for the answer to the following questions:

- What are the classification aspects of the **parking methods**? What kind of characteristics do the parking methods have? What functions are fulfilled by the parking management systems?

[1] Data owner: data handler organization, who primarilty takes part in the data collection and procession.

What kind of characteristics do they have from an operational viewpoint? How does the information influence the operational characteristics? Is it possible to develop a solution, which is able to fit the parking process into the whole traffic management by alinging supply and demand as well as taking the users' preferences into consideration? The objective of the solution is the support of the development of multimodal travel chains in passenger transportation and the support of the development of intermodal transport chains in freight transportation by ensuring modal change information. (*Chapter 4.*)

- What kind of effects does the **temporary heavy goods vehicle overtaking ban** have on the flow of traffic and the drivers? What kind of driver and operational experiences can be revealed in connection with the regulation? How efficient is the regulation from the point of view of traffic? What kind of effects may the implementation of dynamic (fitting to the actual traffic characteristics) heavy goods vehicle overtaking ban have? How is it possible to measure the efficiency of the current and the planned regulation? (*Chapter 5.*)
- What kind of data can be retrieved from the information system used at the **public transport organizations**, with the help of which the **flow of traffic can be analysed**? What kind of physical processes do the data involve / refer to? What kind of factors influence the accuracy of the public transportation and how? Within this, how can the dwelling times at stops can be estimated taking the main influencing factors into consideration? (*Chapter 6.*)

During the reply of the questions my objectives were:

- the determination of the necessary input data by the transportation basic research **according to the structure of information model**,
- the identification of how a certain service can be accessible (related to which function of an organization).

3. Impoundment of the research and the applied methodology

During the research I focused on road transportation, with a view of the complexity of the transportation system as well as considering the connection possibilities of the different sectors. This approach is essential for the organization and operation of multimodal freight and passenger transportation chains. I took the requirements – related to the transportation needs – of operators and individual users into consideration.

I did transportation basic research (*Chapter 2. and 3. 1st Thesis*) and applied research (*Chapter 4., 5. and 6. 2nd, 3rd and 4th Thesis*), with a systems thinking and process analysis approach typical of the department.

During the modelling, both the information system[2] and the system of information[3] were analysed from a structural and operational viewpoint. The components, processes inside them and the connected information were identified. During the development of the model I took the static (construction) and dynamic (operation) structures of the systems into consideration. I used **system of information approach** for the analysis. ***Machine components*** and the process inside them were not analysed in detail because their solutions significantly depend on the actual level of technical development. Thus, the **conclusions are limited to the system of information** in order to achieve result valid for a long period. The modelling of the system of information also assumes the (structural and operational) modelling of the road transportation system, because the data map the components and processes.

[2] **Information system**: is part of the company (subsystem), which provides procedures for creating, recording, processing and accessing the information. It is related either to the organization or to its specific part and it assists the organization to reach its goal. Information systems are the representations of the organizations, which provide information about the status of the organization for the managing elements located at different levels in the hierarchy. For this purpose the machine system of the organization is used, which may consist of several subsystems.

[3] **System of information**: is a structured system of data, a set of well-structured and well-systematized information considering certain aspects. Part of the information system.

I applied the following research methods:

- creation of data model,
- set-theoretic approach, groupings,
- linear algebra,
- algorithm development,
- regression analysis,
- on-line questionnaire,
- data mining techniques (regression, segmentation, clustering, time series analysis),
- database management, with special regard to the combination of different types of data emerging at different space and time.

During the research of the sub-topics I put emphasis on the data recording and the characteristics of the physical processes according to the content of information. The identification of the contacts and the common use of heterogeneous data – comming from different sources – meant a significant challenge.

During the applied research I divided the complete road transportation system into subsystems and I grouped them according to the characteristics of traffic flow and the management of transportation (Figure 1.). In the figure I indicated only the organization forms where the locomotions are realized by vehicles.

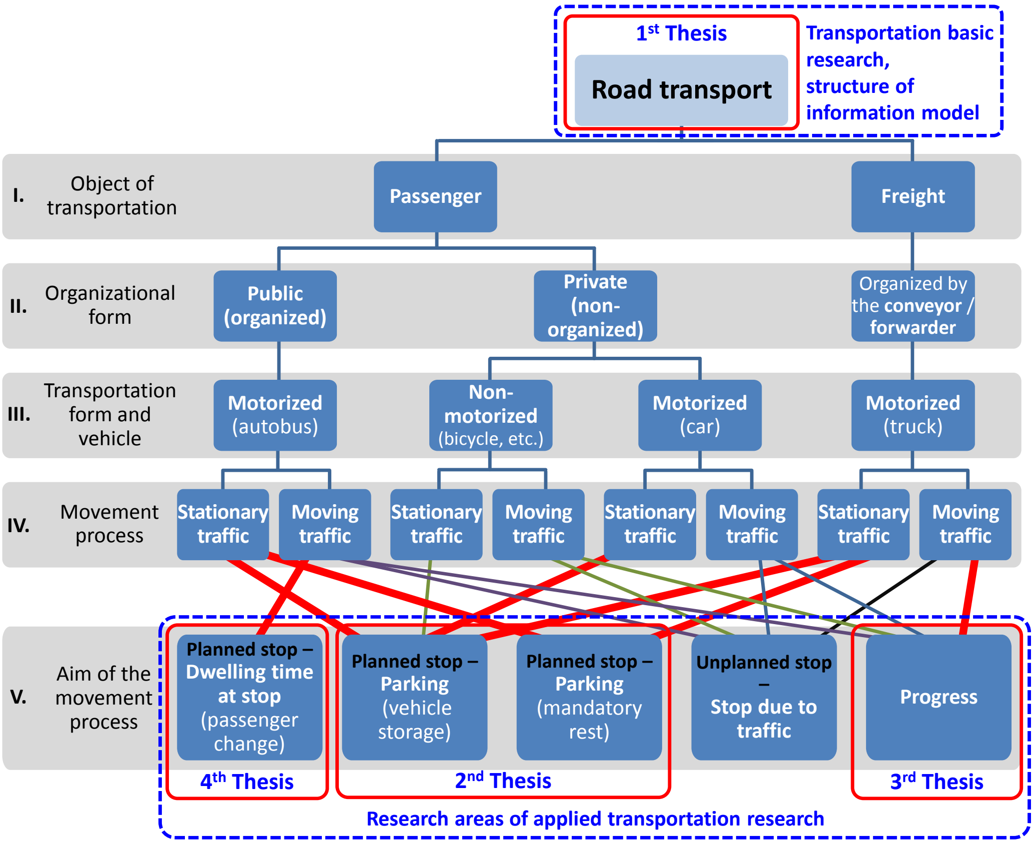

Figure 1. Grouping of the road transportation subsystems

In the figure I indicated the areas which were analysed for the determination of the thesis. The topics analyse the issues of the traffic management related to stationary and moving traffic. Each area belonging to a specific thesis is marked with red lines:

- Interfaces of the individual motorized passenger transportation and parking management in the whole road transport including freight transportation vehicles too (vehicle storage, parking, multimodal travel chains, mandatory rest, booking of parking place, etc.) (*Chapter 5. 2nd Thesis*).
- Management of the traffic of trucks regarding the progressing traffic (*Chapter 6. 3rd Thesis*).
- Management of the traffic of public transportation regarding the dwellings at stops (*Chapter 7. 4th Thesis*).

4. Short literature summary

Svidén dealt with the development of transport informatics. In the 80s a **forecast was carried out for the development of technical solutions** about how and what the new services will change in the next decades (between 1990 and 2040) by *Svidén* (1988). The research referred to the spread of systems, the development of traffic and accidents and the equipment of vehicles. According to the currently applied systems and research it can be stated that the objectives which were set a quarter of a century ago are still relevant and the vision – which was established in 1988 – has been fulfilled in accordance with the schedule made at the time.

Researchers state in each case that the intelligent transportation applications apply several data collection and data processing technologies together *Feng et al.* (2005), *Nasser* and *Abdullah* (2013). Within them it is possible to find implementations which apply raw and pre-processed data (coming from several sources) in an integrated way and give feedback too *Meier et al.* (2005). However, the **majority of the implementations support the achievement of a specific objective** (e.g. information provision), while the integrated accessibility between the functions is not insured.

The development of **communication standards** is essential in order to provide the interoperable operation of systems. With the standards the communication between traffic management centres and user devices becomes smoother. Since the emergence of the ITSs and the increase in demands for **interoperable systems** several standards have been elaborated *Tibaut et al.* (2012). Among them, in Europe and also in Hungary the following standards have been spread in public transportation: TransModel for data storage and SIRI for data transmission. In road transportation Datex II standard is used for data exchange *EasyWay DTX-DG01* (2012).

With the spread of smartphones the **possibilities of data collection have extended** both in space and regarding the content. New technologies allow the collection of large amounts of users' data compared to the ordinary roadside data collection devices. In this regard, smartphones point towards the integrated data collection and insure the spread of new services (even for profit) and information solutions *Chang et al.* (2009).

Mussa and *Upchurch* (2002), *Nozick et al.* (1998) dealt with the physical establishment of **integrated systems** and the **data flow** within the systems. These studies did not report on specific applications – applied at transportation organizations – the give information only the necessary background for the operation.

The Austrian **VAO (Verkehrsauskunft Österreich) system is one of the most exemplary developments** of recent years. The system provides integrated information services for the VOR region: comprehensive multimodal journey information, booking possibilities for public and private travelling – car-sharing, bicycle, etc. A continuously updating GIP platform insures the base of the system. The German Bayerninfo is a similar system, which covers Bavaria with multimodal information. In Hungary, the www.utvonalterv.hu online route planner service provides multimodal information for the travellers *EasyWay TIS-DG07* (2012), *Siegler* (2010). According to the technical implementations the leader is the VAO system, which is able to manage a huge amount of data coming from different sources. The German implementation provides information with fewer data sources. The Hungarian system is able to provide similar services in terms of functionality, but due to lack of incoming data it cannot operate similar services.

The list of national literature is quite short, because in connection with the topic only a few interconnected scientific "workshops" published results. *Csiszár* és *Westsik* (2014) summarized the departmental history of the research and education of transport informatics.

Ágnes Lindebach's work is exemplary. The **beginning of the national research of ITSs** and the determination of the benefits of integrated systems are connected to her name *Lindenbach* (1996, 2000, 2001). The system approach thinking applied in her dissertation forms the basis of the subjects connected to the topic. The publication of the first Hungarian scientific book connected to the ITS is also linked to her *Lindenbach* (2004).

Munkácsiné (1996), *Tóth et al.* (2000), *Csiszár* (2001, 2003, 2004, 2006), *Tóth* (2003, 2005) dealt with **integrated informatics solutions**. In the studies the following systems and models were elaborated: models of the support of passenger and freight transportation processes, model of the information system of river transport, information system for the electronic data exchange related to freight transportation and the information system of road operator organizations. *Juhász* és *Munkácsiné* (2008) dealt with the utilization of real-time traffic information for route choice within the applied solutions.

Jancsó és *Siegler* (2007) and *Lindenbach* (2007) analysed the installation of the necessary systems and the services provided by intelligent transport systems. *Hladon* és *Perjés* (2007) dealt with the elaboration of the **requirements of ITSs** (*HITS - Hungarian National ITS Framework*). With the help of HITS the harmonized ITS system developments is assurable, which result in joint and interoperable implementations.

Publications about the Hungarian transport informatics development can rarely be found in the scientific literature. Nonetheless several – EU-funded – projects have been implemented and within the projects significant developments were executed *Lindenbach* (2011). Intelligent traffic management systems were installed on the metropolitan and the national motorway network in order to handle the increasing traffic efficiently (decrease of congestion) *Jenovai* és *Rónai* (2010), *Jákli* és *Tomaschek* (2010).

Transport Information System and Database created by the Hungarian Transport Administration is an **exemplary from among the national transport informatics developments**. The implementation allows the transmission of technical base data between the sectorial transportation systems and organizations by the use of standardized channels and communication protocols. The system provides a joint topological registry of sectorial networks with a common interface.

According to the Hungarian and international literature reviews only a few researchers have dealt with the modeling and scientific research of the integrated transportation information systems and the connecting system of information. Thus, scientific documents in the field of transport informatics can rarely be found. Despite the fact of lack of publications, integrated systems – which provide traffic management and information functions – have already been applied in cities.

Based on the literature review it can be stated that several researchers have already taken steps in order to develop integrated transportation informatics systems, however, no significant breakthroughs have been born yet in the field of road transportation (e.g. solutions for the parking problems and the congestion). There is a lack of research that handles road transportation as a whole with a system thinking approach are missing. This specific approach is necessary because the use of a complex approach is required in the road sector due to its size and scale.

5. New scientific results

1st Thesis (*Chapter 2. and 3.*)

I elaborated the model of the road transport information system and the road transport system of information with the use of the components of the information system and the system of information.

Part 1 (*Chapter 2.*)

I elaborated the data structural model of the integrated system of information of road transport.

The result of the model is the *data structural matrix* (Table 1.), which summarizes what kind of datasets (D_n^i) are required for the operation of a specific function (F_i) of a given organization type (O_i). The model demonstrates a data structure for the identification and classification of the managed information related to the basic process of road transportation. The cells of the matrix contain the managed information sets (indicated the elements of the first row of the matrix according to the temporal validity as examples).

The model was elaborated based on the following steps:

1. Identification of the components of the information system (organization type, function, dataset).
2. Analysis of the functions of the organization types according to their duties.
3. Identification of the managed information, assignment of datasets to the functions and organization types.

Table 1. Structure of the data structural matrix and examples for the content of the cells

		static data			semi-dynamic data			dynamic data		
O_i	F_i	D_1^s	…	D_5^s	D_1^{sd}	…	D_5^{sd}	D_1^d	…	D_5^d
O_1	F_1	road network, data of sectorial connections (maps)	…	-	data of proposed traffic modifications	…	user profile data	traffic and road weather data	…	data of user information needs
	…									
	F_8									
…	…									
	…									

Legend:

O_1 organization type: organizations responsible for the management of moving traffic
F_1 function: traffic reporting
D_1^s: static network, facility and traffic data
D_5^s: static user data (organization type in the example does not manage any date related to the given function)
D_1^{sd}: semi-dynamic network, facility and traffic data
D_5^{sd}: semi-dynamic user data
D_1^d: dynamic network, facility and traffic data
D_5^d: dynamic user data

I determined the method of the increase of depth resolution of integrated systems of information with the use of the data structural model and I extended it for every component.

Based on the model I made a proposal for a method which can be applied for the analysis of the information of organizations.

Publications connected to the Thesis:

- *Sándor* and *Csiszár* (2015)
- *Sándor* és *Csiszár* (2015a)
- *Sándor* és *Csiszár* (2015b)

Part 2 (*Chapter 3.*)

I elaborated the connection model of the integrated system of information of road transport (*information connection model*).

The result of the model is the *information connection matrix* (Table 2.), which summarizes where (at which organization type and function) a managed dataset related to a function at the data owner can be utilized as an input information.

During the creation of the matrix the model was revealed gradually and step-by-step. The sequence of organization type, function, dataset was followed. At each step, the analysis was extended with a new component. Gradually the investigation was broadened horizontally (model wideness) and vertically (model breakdowns) too.

The model was elaborated based on the following steps:

1. Identification of the organization types, which are connected with each other.
2. Revealing of the context between the organization types and their functions.
3. Identification of the flowing datasets within the connections.

Based on the information connection model I revealed the datasets, which embody the connections. The interpretation of the information connection matrix is illustrated in Figure 2.

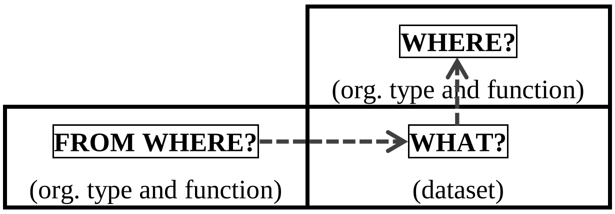

Figure 2. Interpretation of the information connection matrix

To each ***O_iF_i*** – ***O_jF_j*** pair a *mini matrix* is connected (Figure 3.), which contains the transmitted dataset. In the mini matrix the transmission of the dataset is indicated by an "X" symbol in the cell of the dataset.

D_1^s D_1^s	D_1^{sd}	D_1^d
D_2^s	D_2^{sd}	D_2^d
D_3^s	D_3^{sd}	D_3^d
D_4^s	D_4^{sd}	D_4^d
D_5^s	D_5^{sd}	D_5^d

Figure 3. Notation of the datasets in the mini matrix

Table 2. Information connection matrix (part)

		O_3																							
		F_1			F_2			F_3			F_4			F_5			F_6			F_7			F_8		
O_1	…	…			…			…			…			…			…			…			…		
	F_2					X	X					X	X						X			X		X	X
						X						X												X	
							X						X						X						X
					X	X	X				X	X	X	X	X	X							X	X	X
							X						X												X
	…	…			…			…			…			…			…			…			…		

Legend:

O_1, O_3 organization types: O_1: Organizations responsible for the management of moving traffic

O_3: Fleet operator organizations

F_1- F_8 functions: F_2: Management of traffic related process

X: transmitted dataset

*Example (**blue cell**): Organization type O_1 transmits D_1^{sd} dataset (semi-dynamic network, facility and traffic data) related to its F_2 function to the provision of F_2 function of organization type O_3.*

I determined the analysis method of the connections of information systems based on the model. With the method the characteristics of the flow of information can be identified:

- connected components,
- directions,
- transmitted (part) datasets,
- quantity of transmitted data,
- transmission frequency,
- transmission technology.

With the use of the model I determined the so called *information nodes*, which are organizations with special positions. Their tasks is to synthetize the information coming from several sources and produce value added information.

Publications connected to the Thesis:

- *Sándor* and *Csiszár* (2015)
- *Sándor* és *Csiszár* (2015a)
- *Sándor* és *Csiszár* (2015b)

2^{nd} **Thesis** (*Chapter 4.*)

I elaborated the model of the integrated parking management information system, which operates with the cooperation of the participants of the road transportation systems.

The efficient (from the viewpoint of traffic) and *personalized* **management of parking demands** requires the sharing of information between the traffic management and operation control systems of several organization types:

- road operators (O_1),
- parking facilities (O_2),
- fleet operators (O_3),
- public transport operators (O_4).

The efficiency of traffic is realized in the decrease of the parking lot searching traffic and the decression of time necessary to find a parking place.

The steps of the development of the model:

- Identification of the parking methods, revealing of their characteristics, determination of the aspects that influence the choice of parking location.
- Elaboration of the **structural and operational model of the integrated parking management information** system **fitted to** with the **locomotion processes** considering the information management procedures.
- **Elaboration of the procedure for the support of parking choice**, which provides a personalized ranking of the available parking facilities taking the user preferences, the static and dynamic characteristics of parking places and the actual traffic situations into consideration.

The parking choice supporting algorithm assigns resistance values to each available facility, which is a dimensionless, dynamically changing unit. Its domain is positive integers. The resistance expresses how favourable a certain facility is for the user depending on the actual circumstances.

The resistance of a specific parking facility can be calculated with the following formula:

$$r = \bar{s} \cdot \bar{p}_s^T + \bar{d} \cdot \bar{p}_d^T \quad (1)$$

where

r resistance,

$\bar{s}$ vector of the static features,

$\bar{p}_s$ vector of the personal preferences related to the static features,

$\bar{d}$ vector of the dynamic features,

$\bar{p}_d$ vector of the personal preferences related to the dynamic features.

Values of the personal preference vectors indicate the importance of a specific feature – values range from 0 to 1, where the lower value indicates the less important and the higher values the more important features. Values are determined by questions regarding the given feature. Thus, the features that are unimportant or less important for the users fall out (by the multiplication with zero or low values), while the important values remain, forming the individual resistance value for a facility.

Publications connected to the Thesis:

- *Sándor* and *Csiszár* (2014b),
- *Sándor* (2014a),
- *Sándor* and *Csiszár* (2013a),
- *Sándor* and *Nagy* (2012b),
- *Sándor* and *Csiszár* (2012a),
- *Sándor* and *Csiszár* (2012b),
- *Sándor* és *Nagy* (2011b),
- *Sándor* és *Nagy* (2011c),
- *Sándor* és *Csiszár* (2010a),
- *Sándor* és *Csiszár* (2010b).

3rd Thesis (*Chapter 5.*)

I determined the characteristics of the (speed reducing) effects of the temporary heavy goods vehicle (HGV) overtaking ban on the traffic flow.

Based on the results I elaborated the **structural and operational model** of the traffic management and information system for the **dynamic overtaking ban**.

I assessed the user **experiences and the satisfaction** by questionnaires. Based on the results it can be stated that the regulation is not efficient from the viewpoint of traffic. Negative effects are dominant on the user side, and the traffic safety objectives set at the introduction has not been realized. The acceptance of the regulation is low. Based on the analysis of the user experiences I determined that the respondents would change the actual static regulation to dynamic control as a solution for the current problems. I determined that drivers require the presence of **variable message signs for the display of information related to the overtaking ban**.

I analysed the spatial and temporal characteristics of the traffic with the use of traffic count data related to the management of traffic related process ($\boldsymbol{F_2}$) by the road operator ($\boldsymbol{O_1}$). I determined the proportion of offending heavy goods vehicles (which is 2-15% of the total HGV traffic, in an extreme case it can be even 20-30%) and I identified the effects of the regulation on the traffic flow. I demonstrated that during the period of the regulation on the affected sections the speed of trucks decreases. The decrease is generally between 0-3 km/h depending on the period and traffic composition. Therefore, the regulation has a hold up effect, which increases the effect of stress on the drivers.

Based on the existing subsystems I ela**borated the structural and operational model of the dynamic traffic information control system** for the dynamic overtaking ban in order to reduce the negative traffic effects of the regulation. During the dynamic regulation the ban is controlled according to the actual traffic situation, thus – compared to the current temporal static regulation – it provides a more efficient, adaptive traffic management, which generates less detention. The ban is controlled according to the actual traffic composition (number and proportion of trucks), not to schedule. This effect is summarized in a diagram, with the traffic limits necessary for the activation and deactivation.

Based on the analysis of the traffic effects of the proposed traffic control system it can be determined that depending on the traffic load the length of expressway sections and the periods affected by the regulation decrease (currently limited period: 6-22) (Figure 4.).

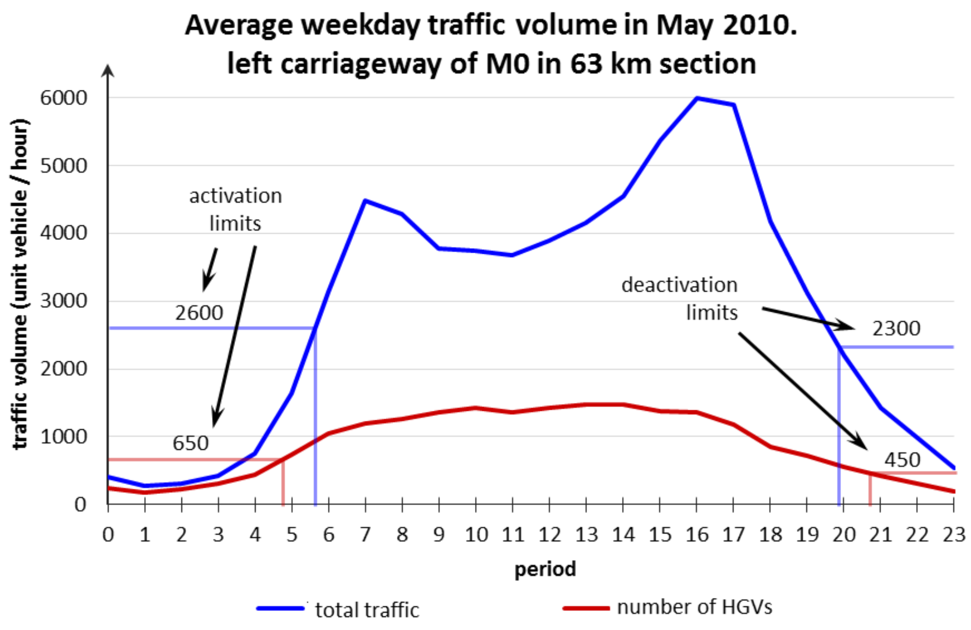

Figure 4. Application of the dynamic HGV overtaking ban

Publications connected to the Thesis:

- *Sándor* (2014b),
- *Sándor* and *Nagy* (2012a),
- *Sándor* és *Nagy* (2011a),
- *Sándor* és *Nagy* (2011d).

4^{th} **Thesis** (*Chapter 6.*)

I elaborated a method for the analysis and prediction of the punctuality of public bus transportation services, which is based on data management. It is based on the data used in the management of traffic related process (F_2) and in the operation control (F_3) by the public transport operators (O_4).

I developed an extended data model and database based on the static (infrastructure, proposed schedule and vehicle) data of the public transportation base system and the dynamic data managed by the fleet tracking system. The database contains data from external sources (weather data).

The steps of the analysis method:

- identification of physical processes, separation of movement phases and dwellings at stops,
- identification of the beginning and end of passenger change including the delays,
- identification of the major influencing factors causing deviation in the schedule,
- revealing of the characteristics of schedule deviations (regularities) of vehicles.

I analysed the characteristics of the public bus transportation in Győr according to several aspects and aspect combinations: period, weather, features of vehicles, passenger volumes of stops, extent of the delay.

Based on the analysis I drew the following conclusions:

- The major influencing factors causing deviation in the schedule are: passenger volumes of stops, period, weather and the floor height of the vehicle.
- Driving dynamics properties of the vehicle do not have any significant effect on punctuality.

I elaborated a forecast method for the dwelling times at stops with the identification of the major influencing factors. I verified the validity of the method with sample calculation. The forecast method can be used for traffic prediction models, transport organization and traffic control processes. The method can also be applied when the historic database does not contain the necessary data. In such cases, the prediction of the dwelling times at stops is calculated by correction factors.

Publications connected to the Thesis:

- *Sándor* and *Csiszár* (2014a),
- *Sándor* és *Csiszár* (2013b).

6. Applicability of the scientific results and further research

Use of research results

Results of the transportation basic and applied research can be utilized in education, during further research and also the applied engineering activities (planning / operations). In Table 3. I summarized the utilization possibilities of the results in various fields.

The results are partly included in the newest *Transport Informatics* lecture notes.

Tasks regarding the development of information systems are extremely complex. The outlined (expected) integrated system development is complex and requires a long time due to the necessary integration processes. Therefore planning and implementation may last for decades. In addition, the technical development is only one necessary area. For its implementation, the integration must be realized on the legal, economic and technical fields together and with the creation of the necessary preconditions. In the future, in order to support the integration aims, implementations related to specific areas are expected, which can be developed much faster with modular development.

One of the most illustrative examples of the application of the structure of information models is the reorganization of the State Motorway Management Company (ÁAK Zrt.) and the Hungarian Public Road Non-profit Private Limited Company (MK). During the organizational transformation road operation and all related activities were merged and certain organizational units of the ÁAK were integrated into the MK.

The following factors – elaborated as a result of the basic transportation research – encumber the demonstration of the practical applicability of the models:

- It is very difficult and cumbersome to access the documents which provide the input data (organizational characteristics) necessary for the models.
- Sometimes the organizations have already known or surmised the results which can be detected using the model.
- At those road organizations where the applicability of the models could be demonstrated the most expressively, the results are reputed as sensitive knowledge because resource-wasting areas can be revealed. This knowledge (input and output data of the models) is qualified as a secret even in case of public organizations.

The further development possibilities of the models mean the enhancement of the resolutions with which the analysis of certain information management tasks can be achieved until the level of actions.

Table 5. Use of research results

	Results of the transportation basic research *1st Thesis (Part 1 and part 2)*	**Results of the transportation applied research** *2nd, 3rd and 4th Theses*
Education (academic and practice)	Modernization of the subjects of bachelor and master courses. Integration of the results and the method of the model creation into the curriculum. The aims of these are the establishment of the synthetized, comprehensive system and process-oriented thinking. Scope: analysis concerning to the operation of the organizations, development of information systems. • *Transportation information systems I*: field of parking and the basics of ITS. • *Transport informatics:* interstation of the structure of information and information flow models into the development of information supply of organizations. • *Passenger transport:* use of the analysis and design methods of information systems.	Interstation of applied database management methods into the practical training. • *Transportation information systems I and II,* • *Transport informatics.* The confident acquirement of the use of the methods (e.g. design of database and system of information, identification of components, revealing the operation, definition of connections and relationships between the components, mapping of transport systems and processes with data, simplifying complex databases and processing them according to several aspects, joint processing of heterogeneous data, organizational analysis, etc.).
Research	Determination of the characteristics of the contacts by the analysis of the flow of information and the enhancement of the resolution of the structure of information. Expansion of the structure of information models, and their use in case of different sectors, identification of the sectorial interfaces, revealing and identification of the flowing information.	Expansion of the details of the models the more accurate prediction, which covers a larger time horizon. Refinement of the research methods and expansion with new variables. Transportation and generalization of the results in order to apply them to different areas. The use of the applied research methods in different sectors.
Design / Operation	Analysis of transport organizations (auditing) for the implementation of the organizational restructuring (rationalization). Although In case of an organization with significant administration, regulations regarding information management exist, but the use of them are mostly ineffective. With the use of the models the organizational processes can be analysed, and the resource effective operation can be enhanced by reorganization based on the identified deficiencies.	The use of the results during the design and operation of road traffic systems (road and fleet operation; even on tactical and operational level). Results provide input data for decision support to enhance resource efficient operation. Multi aspect data processing, assessment of the effects and efficiency of interventions become possible by database management.

Further research, future plans

The transportation implementations of the future must find the answers for the ever-increasing social challenges, which have significant relations to transportation. These are:

- safety,
- congestion, network efficiency,
- increasing demand for mobility,
- pollution,
- conscious and sustainable transportation system.

These challenges can be managed individually and collectively too. With the integrated approach and the creation of transportation integration the emerging issues can be managed collectively. The coordination between the sub-areas and functions can be proved with synergic interaction, which facilitates both horizontal and vertical integration *Kövesné* (2007).

The regulation of road transportation will increase in the next years / decades, and integration is one tool of the process. This integration already eventuated in rail and air transportation decades ago and it has continued ever since. Two main factors boost the future developments:

1. The use of large databases "*BigData*" and the optimal use of information accumulated in recent years due to the information and the interconnection of systems, which nowadays becomes more intense. This supports the developments from the data side. The phenomenon is boosted by the spread of smartphones which provide a huge amount of user data. Furthermore with the spread of new communication implementations this huge amount of data can be transmitted to computing centres with high capacity.
2. Appearance and spread of new services, which gradually replace the conventional driver's functions. Thus, the rate of regulation in road transport becomes more significant. For this reason, the emergence of new systems and services is expected. (e.g. control, enforcement, management systems, etc.).

Based on this, the directions of the future research with the use of process and system-oriented approach are the following:

1. Facilitation of the integration *from the information side*

- The use of the elaborated system of information models is the first step of the integration. Today - in many cases - one obstacle of the integration is that the information management elements have knowledge only about the information which belongs to their duties. In order to eliminate this phenomenon – initially – I reveal the information managed by the information management elements in detail. Thus, it is possible to create those kinds of databases which contain the actually available metadata in detail.

- With regard to the fact that the data from several sources have different quality and reliability I examine:
    - the reliability of the information,
    - the importance and usefulness of the information,
    - and the change of the above mentioned both in space and in time (examination of the dynamic characteristics of the information).
- In the time-based analysis of the information, the examination covers the accuracy, value, cost and lapse of the information.
- During the spatial analysis I determine the scope of the necessary information required at the different phases of the locomotion and their effects on the traffic flows (driver, pedestrian, bicycle, etc.).
- During the integration, information must be ranked based on their values. For this purpose I am looking for the answers to the following questions:
    - Where can the necessary information be obtained and at what cost?
    - Depending on the time, what is the value of the information until the lapse?
    - What is the price of information transmission and what are the conditions?
- I elaborate an information analysis / assessment procedure for the determination of the above mentioned values. On the basis of the values the method of the usage of certain information for the integration aims can be defined.

2. Facilitation of the integration *from the service side*

- Data collection possibilities are extending due to the spread of smart devices. Services emerge, which were previously not available because of their considerable data needs. The devices can be used for information display besides data collection. In order to avoid the isolated application of these devices, I facilitate the integration of the solution into the whole transportation system.

- For the integration I explore the information needs of the new services, analyse the flow of information and with the implementation of information into the model I enhance the integration (e.g. development of data portals and data warehouses).
- Based on expert expectations, after the removal of legal barriers these devices can be used for enforcement, too, which is the most effective tool of the enhancement of safety. In order to be able to put it into practice, the continuous and reliable operation of data-based services must be provided. I would like to contribute to this aim with my future research.
- Due to the development of mobility culture the proportion of individual car usage will decrease, the use of transportation modes will become more conscious, with multimodality in the focus. In order to achieve this, it is necessary to create interfaces between individual motorized transportation, public transportation and individual non-motorized transportation forms. The interface is a place, where modal change can be realized. Thus, I will study parking as a priority area in detail. During my work:
    - I assess the effects of the transmitted information on the drivers (how they influence the drivers' decisions – vehicle and mode choice, routing, etc.).
    - I identify the latent information, determine the modes of information provision and the traffic management tools with the help of which the decisions of drivers and users can be influenced, diverting them to the lower resistance transportation modes.

During the further research I examine its economic background with economic methods – like demand management – so that the benefits and the available changes provided by the system can be monetized. In favour of this, I intend to conduct my own assessment.

With the help of the data I perform a qualitative assessment within the transportation system. I develop the necessary methodology for the measurement of the quality and I also determine the measurable quality parameters. Based on the results it is possible to improve the quality too.

Own publications connected to the theses

Published:

Sándor (2014a): SÁNDOR Zsolt: *Intelligens tehergépjármű parkolás-irányító rendszer moduláris fejlesztési lehetősége*. ***AZ ASZFALT: A MAGYAR ASZFALTIPARI EGYESÜLÉS (HAPA) HIVATALOS SZAKMAI LAPJA*** 19:(1) pp. 48-54. (2014)

Sándor (2014b): SÁNDOR Zsolt: *Effects of traffic safety measures on motorway traffic*.Konferencia előadás, **2nd Conference on Effective Road Safety Campaigns: CERSC 2013**. Budapest, Magyarország, 2013.09.25-2013.09.27. Budapest: Premium Relations, 2014. pp. 52-64. ISBN:978-963-12-0089-8

Sándor and *Csiszár* (2013a): Zsolt SÁNDOR, Csaba CSISZÁR: *Development Stages of Intelligent Parking Information Systems for Trucks*. ***ACTA POLYTECHNICA HUNGARICA* 10:**(4) *pp. 161-174. Paper 42.* (2013)

Sándor és *Csiszár* (2013b): SÁNDOR Zsolt Péter, CSISZÁR Csaba: *Késési események elemzése helyi autóbusz közlekedésben*. **Innováció és Fenntartható Felszíni Közlekedés Konferencia 2013**. Budapest, Magyarország, 2013.08.28-2013.08.30. Budapest: Magyar Mérnökakadémia, *pp. 36-41. Paper 6.* ISBN: 978-963-88875-2-8

Sándor and *Nagy* (2012a): Zsolt SÁNDOR, Enikő NAGY: *Overtaking ban for heavy goods vehicle in Hungary on the national motorway network*. ***POLLACK PERIODICA* 7:**(1) *pp. 83-95.* (2012)

Sándor and *Nagy* (2012b): Zsolt SÁNDOR, Enikő NAGY: *Intelligent Truck Parking on the Hungarian Motorway Network*. ***POLLACK PERIODICA* 7:**(2) *pp. 91-101.* (2012)

Sándor and *Csiszár* (2012a): Zsolt SÁNDOR, Csaba CSISZÁR: In*tegration of Parking Information Systems into Traffic Management*. European Platform of Transport Sciences (EPTS): **X. European Transport Congress in Budapest**. Budapest, Magyarország, 2012.11.08-2012.11.09. Budapest. *pp. 93-99.* ISBN: 978-615-5298-00-4

Sándor and *Csiszár* (2012b): Zsolt SÁNDOR, Csaba CSISZÁR: *From information to central navigation - Development stages of intelligent parking information systems*. **8th International PhD & DLA Symposium**. Pécs, Magyarország, 2012.10.29-2012.10.30. Pécs: Pollack Mihály Műszaki Kar, Pollack Press, *pp. 126.* ISBN: 978-963-7298-48-6

Sándor és *Nagy* (2011a): SÁNDOR Zsolt, NAGY Enikő: *Nehéz tehergépjárművek előzési tilalma a hazai gyorsforgalmi úthálózaton*. ***KÖZLEKEDÉSTUDOMÁNYI SZEMLE* 61:**(4) *pp. 47-58.* (2011)

Sándor és *Nagy* (2011b): SÁNDOR Zsolt, NAGY Enikő: *Intelligens tehergépjármű parkolás irányítási rendszer a hazai gyorsforgalmi úthálózaton*. ***KÖZLEKEDÉSTUDOMÁNYI SZEMLE* 61:**(4) *pp. 59-66.* (2011)

Sándor és *Nagy* (2011c): SÁNDOR Zsolt, NAGY Enikő: *Külföldi megoldások az intelligens tehergépjármű parkolás területéről és a hazai alkalmazási lehetőségek*. **Innováció és fenntartható felszíni közlekedés Konferencia 2011.** Budapest, Magyarország, 2011.08.29-2011.08.31. *pp. 274-282.* ISBN: 978-963-88875-3-5

Sándor és *Nagy* (2011d): SÁNDOR Zsolt, NAGY Enikő: *Európai és hazai megoldások - a nehéz tehergépjárművek előzési tilalma és továbbfejlesztési lehetőségei Magyarországon*. **Innováció és fenntartható felszíni közlekedés Konferencia 2011.** Budapest, Magyarország, 2011.08.29-2011.08.31. *pp. 174-183.* ISBN: 978-963-88875-3-5

Sándor és *Csiszár* (2010a): SÁNDOR Zsolt Péter, CSISZÁR Csaba: *Integrált informatikai rendszerek a hazai gyorsforgalmú úthálózaton*. ***KÖZLEKEDÉSTUDOMÁNYI SZEMLE* LX:**(3) *pp. 38-45.* (2010)

Sándor és *Csiszár* (2010b): SÁNDOR Zsolt Péter, CSISZÁR Csaba: *Integrált informatikai rendszerek a hazai gyorsforgalmú úthálózaton – a jelen és jövő lehetőségei*. **Innováció és Fenntartható Felszíni Közlekedés Konferencia 2010.** Budapest, Magyarország, 2010.09.02-2010.09.04. Budapest. *pp. 1-9. Paper CD.* ISBN: 978-963-88875-0-4

Submitted:

Sándor and *Csiszár* (2014a): Zsolt SÁNDOR, Csaba CSISZÁR: *Methodology for Analysis of Delays in Local Bus Transportation and Prediction of Dwelling Times at Stops*. ***TRANSPORT***. (under review)

Sándor and *Csiszár* (2014b): Zsolt SÁNDOR, Csaba CSISZÁR: *Role of Integrated Parking Information System in Traffic Management*. ***PERIODICA POLITECHNICA CIVIL ENGINEERING*** (under publish)

Sándor and *Csiszár* (2015): Zsolt SÁNDOR, Csaba CSISZÁR: *Modelling and Analysis Methods of Integrated Information Systems of Transportation.* Conference proceeding, **Models and Technologies for Intelligent Transportation Systems**, MT-ITS 2015 June 3-5. Budapest, Hungary (under publish)

Sándor és *Csiszár* (2015a): SÁNDOR Zsolt, CSISZÁR Csaba: *A közúti közlekedés információrendszerének modellje I. (információszerkezeti modell)*. ***KÖZLEKEDÉSTUDOMÁNYI SZEMLE*** (megjelenés alatt, várható megjelenés 2015 II. negyedév)

Sándor és *Csiszár* (2015b): SÁNDOR Zsolt, CSISZÁR Csaba: *A közúti közlekedés információrendszerének modellje II. (információkapcsolati modell)*. ***KÖZLEKEDÉSTUDOMÁNYI SZEMLE.*** (megjelenés alatt, várható megjelenés 2015 II. negyedév)

Literature referred to in the present summary:

- *885/2013/EU*: A BIZOTTSÁG 885/2013/EU FELHATALMAZÁSON ALAPULÓ RENDELETE az intelligens közlekedési rendszerekre vonatkozó 2010/40/EU európai parlamenti és tanácsi irányelvnek a teher- és haszongépjárművekkel igénybe vehető biztonságos és védett parkolóhelyekre vonatkozó információs szolgáltatásnyújtás tekintetében történő kiegészítéséről. Brüsszel 2013. május 15.
- *886/2013/EU*: A BIZOTTSÁG 886/2013/EU FELHATALMAZÁSON ALAPULÓ RENDELETE a 2010/40/EU európai parlamenti és tanácsi irányelvnek a közúti biztonsággal kapcsolatos, minimális általános forgalmi információk lehetőség szerinti, a felhasználók számára térítésmentes biztosításához szükséges adatok és eljárások tekintetében való kiegészítéséről. Brüsszel 2013. május 15.
- *Allekotte et al.* (2003): ALLEKOTTE, D., GANSER, M., DINTER, M., WILLEMS, F.: Neue Lösungen für das strategische Verkehrsmanagement in der IGLZ Frankfurt am Main. *Vortrag bei den verkehrswissenschaftlichen Tagen*. Dresden 2003.
- *Boltze et al.* (2005): BOLTZE, M., WOLFERMANN, A., SCHÄFER, P.: *Leitfaden Verkehrstelematik - Hinweise zur Planung und Nutzung in Kommunen und Kreisen*. Leitfaden für die Planung und Nutzung der Telematik für kommunale Planungsträger zur Verbesserung der Verkehrsbedingungen in Städten, Gemeinden und Landkreisen. Technische Universität Darmstadt 2005 (pp. 9-40).
- *C(2014) 9672*: A BIZOTTSÁG EU FELHATALMAZÁSON ALAPULÓ RENDELETE a 2010/40/EU európai parlamenti és tanácsi irányelvnek az EU egészére kiterjedő valós idejű forgalmi információs szolgáltatások nyújtása tekintetében történő kiegészítéséről. Brüsszel, 2014.12.18.
- *Chang et al.* (2009): CHANG, Y.F., CHEN, C.S., ZHOU, H.: Smart Phone for Mobile Commerce. *Comput. Stand. Interfaces*, 31 (4) (June 2009), pp. 740–747
- *Csiszár* (2001): CSISZÁR, Csaba: Az integrált intelligens utasinformatikai rendszer modellje. *PhD. értekezés*, Budapest 2001.
- *Csiszár* (2003): CSISZÁR, Cs.: Model of Integrated Intelligent Passenger Information Systems. *Periodica Polytechnica-Transportation Engineering* 31:(1-2) pp. 17-44. (2003)
- *Csiszár* (2004): CSISZÁR, Csaba: Nagy települések személyforgalmának integrált dinamikus irányítása telematikai eszközökkel. *Városi Közlekedés*. XLIV.évf. 2.szám 84.-97.o. Budapest, 2004.
- *Csiszár* (2006): CSISZÁR, Csaba: Telematikailag irányított térben-időben rugalmas közforgalmú közlekedés. *Városi Közlekedés*, 2006. (46. évf.) 3. sz. 151-161. old.
- *Csiszár* és *Westsik* (2014) CSISZÁR, Csaba, WESTSIK György: A közlekedési informatika kutatása és oktatása a BME Közlekedésüzemi és Közlekedésgazdasági Tanszékén. *Közlekedéstudományi Szemle* LXIV:(2) pp. 44-52. Paper B11. (2014)
- *EasyWay DTX-DG01* (2012): EasyWay Deployment Guidelines: Data Exchanges DATEX II Supporting Guideline DTX-DG01. Version 02-00-00. December 2012.
- *EasyWay TIS-DG07* (2012): EasyWay Deployment Guidelines: Traveller Information Services – Co-modal traveller information TIS-DG07. Version 02-00-00. December 2012.
- *Fehér Könyv* (2011): FEHÉR KÖNYV: Útiterv az egységes európai közlekedési térség megvalósításához – Úton egy versenyképes és erőforrás-hatékony közlekedési rendszer felé. COM(2011) 144, Brüsszel, 2011.3.28.
- *Feng et al.* (2005): FENG, J., ZHU, Y., MUKAI, N., WATANABE, T.: Integrated management of multi-level road network and transportation networks. *Lect. Notes Comput. Sci*., 3683 (2005), pp. 677–683
- *Hasberg* (2001): HASBERG, P.: Straßenverkehrsmanagement in Großstädten. *Rahmenbedingungen und das Projekt stadtinfoköln*. 18. Verkehrswissenschaftliche Tage, Dresden 17.-18.09.2001
- *Hladon* és *Perjés* (2007): HLADON, Andrea, PERJÉS, Tamás: A magyar ITS rendszerfelépítési terv. *Közúti és mélyépítési szemle*. 57. évf. 4. sz. / 2007
- *ITS Action Plan* (2008): Cselekvési terv az intelligens közlekedési rendszerek alkalmazásának európai bevezetésére. COM(2008) 886, Brüsszel, 16.12.2008
- *ITS Direktíva* (2010): 2010/40/EU: AZ EURÓPAI PARLAMENT ÉS A TANÁCS 2010/40/EU IRÁNYELVE Az intelligens közlekedési rendszereknek a közúti közlekedés területén történő kiépítésére, valamint a más közlekedési módokhoz való kapcsolódására vonatkozó keretről. Strassburg, 2010. július 7.
- *Jákli* és *Tomaschek* (2010): JÁKLI, Zoltán, TOMASCHEK, Tamás Attila: ITS-fejlesztések az ÁAK Zrt. hálózatán a CONNECT / EASYWAY projektek keretében. *Közlekedésépítési szemle*, 2010. (60. évf.) 4. sz. 11-15. old.
- *Jancsó* és *Siegler* (2007): JANCSÓ, Ferencné, SIEGLER, Andrásné: A magyar ITS felhasználói igénylista és a meglévő rendszerek szolgáltatásai. *Közúti és mélyépítési szemle*. 57. évf. 4. sz. / 2007

- *Jenovai* és *Rónai* (2010): JENOVAI, Zoltán, RÓNAI, Gergely: A budapesti forgalomirányító központ funkciójának bővítése intelligens eszközökkel. *Közlekedésépítési szemle*, 2010. (60. évf.) 4. sz. 16-21. old.
- *Juhász* és *Munkácsiné* (2008): JUHÁSZ, János, MUNKÁCSINÉ, Lengyel Erzsébet: Útvonalválasztás az aktuális közlekedési információk felhasználásával. *Városi Közlekedés* XLVIII:(3) pp. 137-141. (2008)
- *Lindenbach* (1996): LINDENBACH, Ágnes: Korszerű forgalombefolyásolási rendszerek a mobilitás okozta közúti közlekedési problémák kezelésére, *PhD disszertáció*. Budapest, 1996. 160 p.
- *Lindenbach* (2000): LINDENBACH, Ágnes: Telematikai alkalmazások az úthálózatokon az EU közúti közlekedési stratégiája tükrében. *Közúti és mélyépítési szemle*, 2000. (50. évf.) 2. sz. 41-46. old.
- *Lindenbach* (2001): LINDENBACH, Ágnes, SLAMA, Abdoalgader Mohamed.: Az integrált közlekedési információs rendszerek jelentősége - az ENTERPRICE projekt eredményei. *Közúti és mélyépítési szemle*. 51. évf. 2001/3. p. 98-105.
- *Lindenbach* (2004): LINDENBACH, Ágnes, BARSI, Árpád, LOVAS, Tamás: Az intelligens közlekedési rendszerek alkalmazása a közúti közlekedésben, Budapest, 2004. *szerzői kiadás*, ISBN 963 460 019 0, 140 p.
- *Lindenbach* (2007): LINDENBACH, Ágnes: Forgalmi menedzsment rendszerek és az autópálya-hálózat TERN hálózati elemein szükséges forgalomszabályozó rendszerek. *Közúti és mélyépítési szemle*. 57. évf. 4. sz. / 2007
- *Lindenbach* (2011): LINDENBACH, Ágnes: Intelligens közlekedési rendszerek és szolgáltatások Magyarországon az európai tendenciák tükrében – alkalmazások és feladatok, *EURÓPAI TÜKÖR* 16: (5) pp. 59-66. (2011)
- *Meier et al.* (2005): MEIER, R., HARRINGTON, A., CAHILL, V.: A Framework for Integrating Existing and Novel Intelligent Transportation Systems. *Proceedings of 2005 IEEE Intelligent Transportation Systems Conference*, Vienna, Austria (Sep. 2005), pp. 154–159
- *Monigl* (2001): MONIGL János: A telematika szerepe a városi és környéki közlekedés modális integrációjának javításában. *Városi közlekedés*, ISSN 0133-0314 , 2001. (41. évf.) 6. sz. 332-337. old.
- *Munkácsiné* (1996): MUNKÁCSINÉ, Lengyel Erzsébet: Folyami szállításirányításhoz szükséges számítógépes nyilvántartási rendszer struktúrájának felépítése. *Doktori értekezés* - 1996.
- *Mussa* and *Upchurch* (2002): MUSSA, R.N., UPCHURCH, J.E., 2002. Simulator evaluation of incident detection by transponder-equipped vehicles. *Transportation* 29 (3), 287–305.
- *Nasser* and *Abdullah* (2013): NASSER, K., ABDULLAH, A.H.: A Survey on Intelligent Transportation System. *Middle-East J. Sci. Res*. (2013), pp. 629–642
- *Nozick et al.* (1998) : NOZICK, L., LIST, G.F., TURNQUIST, M.A., Wu, T.-L., 1998. Potential Effects of Advanced Technologies at Commercial Border Crossings. *Transportation Research Record* 1613, 88–95.
- *Sandrock and Riegelhuth* (2014): SANDROCK, M., RIEGELHUTH, G.: Verkehrsmanagementzentralen in Kommunen: Eine vergleichende Darstellung. Springer Vieweg; 2014 edition. (pp. 25-67.)
- *Siegler* (2010): SIEGLER. Vera: Multimédiás útvonalajánló és utastájékoztató portál*:* *www.utvonalterv.hu* *Közlekedésépítési szemle*, 2010. (60. évf.) 4. sz. 22-25. old.
- *Svidén* (1988): SVIDÉN, O.: Future information systems for road transport: A Delphi panel-derived scenario. *Technological Forecasting and Social Change*, Volume 33, Issue 2, April 1988, Pages 159-178, ISSN 0040-1625, http://dx.doi.org/10.1016/0040-1625(88)90079-0.
- *Tibaut et al.* (2012): TIBAUT, A., KAUČIČ, B., REBOLJ, D.: A standardised approach for sustainable interoperability between public transport passenger information systems. *Computers in Industry*, Volume 63, Issue 8, October 2012, Pages 788-798, ISSN 0166-3615, http://dx.doi.org/10.1016/j.compind.2012.08.002.
- *Tóth* (2003): TÓTH, János: Szárazföldi áruszállítási folyamatok kísérése az elektronikus adatcsere alkalmazásával. *PhD. értekezés*, Budapest 2003.
- *Tóth* (2005): TÓTH, János: Globalizáció és az áruszállítási rendszerek informatikai kérdései. „Magyarország az ezredfordulón". *Stratégiai kutatások a Magyar Tudományos Akadémián, VI. fejezet: A közlekedés és technika infrastruktúrája*. ISBN 963-508432-3, ISSN 1585-9681. BUDAPEST, 2005.
- *Tóth et al.* (2000): TÓTH, János, CSISZÁR, Csaba: Korszerű utasinformációs rendszerek. *Városi Közlekedés* XL:(6) pp. 345-347. (2000)