# COMMUNICATIONS

*Dear Readers,*

*This volume of the journal Communications – Scientific Letters of the University of Zilina is devoted to transport and its technology, control and economics. Transport system represents a complex of measures and tasks which have to be solved. The research priority of solving transport problems is of direct concern to authorities, businesses, citizens and the transport industry. It addresses both passengers and freight transport.*

*Transport today plays a key role in the daily lives of people and is an important factor in economic development, competitiveness and employment. The support of its sustainable development with minimal environmental damage, non-discriminatory access and accessibility for everyone is now a priority. This positive development is also necessary to promote adequate research and education activities.*

*Marian Sulgan*

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Jiri Jelinek *

# MUNICIPAL PUBLIC TRANSPORT LINE MODELLING

*This contribution deals with modelling and simulation of a transport system of a public transport line as one of the ways leading to deeper insight into the system and thus also to its development and its quality and effectiveness improvement. Professional software for simulation model creation was used for implementation of the model. Questions related to accessibility of real data for the model setting and their processing will also be discussed.*

***Keywords:*** *Simulation, transport system modelling, public transport.*

## 1. Introduction

Transport systems represent a strategic sphere for each society or organization, their operation is vital for such a society. This is why permanent attention is particularly paid to effectiveness of these systems. Modelling and simulation of these systems is one of the ways leading to better understand them. This is what this contribution is also focused on.

There are several approaches to choose from in modelling method selection. The specific choice is usually based on both, the aim we create the model for and the set of data we have available for creation of the model.

Modelling by means of so called system dynamics [1] is the first approach. This approach (identified as SD) is based on the view of the modelled system as a whole and requires input data at the same level (i.e. global). SD approach usually strives for exact (structural) modelling, i.e. a system model based on the same structures as in the modelled system. The ”black box” method may however also be used when the system is only modelled by its inputs and adequate outputs without imitating its internal structure.

Modelling upon discrete events (DE) is the second possibility. In this case the modelled subject is characterized by events taking place inside that and activities related to them. This is thus a process modelling method.

Creation of a model upon data of behaviour of its parts, objects – agents of the same type the model consists of, which are usually multiple, is the third possible way. Behaviour of individual elements actually creates behaviour of the system as a whole. This method may also be advantageously used in transport systems which consist of, e.g., means of transport, transported people etc. These are then so called multi agent models (MA) [2]. This approach is usually used where objects – agents show some signs of autonomous behaviour.

A method based on so called state diagrams, which is similar to the DE approach, but where initiation of an event is not bound to time but more likely to a met condition, may also be used for modelling. Algorithmic modelling based on flow charts as a subject behaviour description tool may also be used. In practice we may also see hierarchical models enabling separation and independent modelling of different levels of the system or its components even by means of different techniques.

The purpose of this contribution is to show application of modelling techniques (particularly DE) to modelling of a transport system consisting of one public transport line using professional software for simulation model creation. The aim is then to show that the created model can be applied to detection of problematic points in operation of such a line and to its optimization.

## 2. Present state of art

Upon research of available resources we may observe that particularly DE models are applied to transport system, but MA models have been used more and more often recently. As a whole they may also be modelled on SD bases. Particularly the multi-agent modelling based on cellular automates proves to be very interesting. Its application has particularly increased in recent years, when instruments supporting this approach have arisen. An example of MA approach to modelling of a crossroad or a more complex system (St. Petersburg Metro) can be found in [3]. It is obvious particularly on the latter example how complicated systems with numerous internal links and processes

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can be modelled by means of the MA approach. A DE model of a railway transport system can be explored at the same place. The user requirements on the transport system are discussed in [4].

AnyLogic professional tool [3] enabling also creation of heterogeneous models can be used for all the above approaches except others.

## 3. Proposal of the model

### 3.1 Task characteristics

As mentioned above an analysis of a chosen transport system and its operation and subsequent creation of a simulation model was the aim of the assignment. The data the operator has available on the system (public transport line) consist particularly of an operation schedule of the line (timetable of the services), which is divided into 3 time zones, namely the day zone (6 a.m. – 6 p.m.), night zone (10 p.m. – 4 a.m.) and low operation zone (4 a.m. – 6 a.m., 6 p.m. – 10 p.m.). Three different service schedules are available for these zones. The schedule for the peak zone from 6 a.m. to 6 p.m. was used for the purpose of the model verification. The operator had also access to the data on delays that have cumulative character (the delay of each service arrival to the particular stop against the timetable is available for each stop).

The interval data on occupancy rate of the individual services are also available; however the starting points and destinations are not obvious from them so the due adjustment of the model from this point of view was very difficult.

The created model particularly concentrated on the passage of the service through the line route. The aim was to examine the delay values, however no more in the form of cumulative values but the delay values occurred at the individual sections of the line, always between two stops.

### 3.2 Model description

It is necessary to repeat at this point that the choice of model creation methodology has to be based on the aims we create the model for and also on the data available on the system. In our case these were the above described data and the generally known character of the system corresponding to the public service system.

A diagram based on discrete events was chosen for description of the modelled system, while one stop was the basic structure element of the diagram. Its model is in the picture [Fig. 1].

The shown model includes not only the stop itself and the vehicle behaviour at that point but also the passage throught the section from the previous stop. After the service arrival (output of the "wayTo" structure) a particular number of passengers who subsequently get off leaving the diagram by means of the "end" element. After that new passengers get on, while these are generated by the "source" and join the "queue" (the structures have identical names). The actions of getting on and off have no time duration and are included mainly because of complexity of the created model and possibility of its extension.

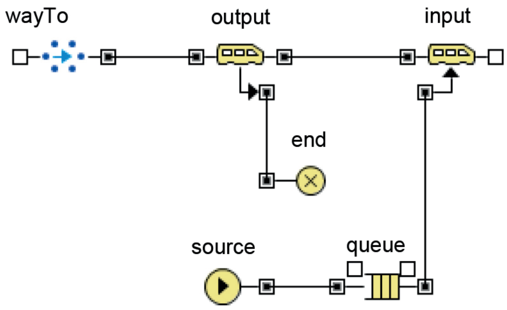


*Fig. 1 DE model of a stop*

The above model of the stop is repeatedly used for description of the model of the whole public transport line [Fig. 2]. There is one so called 2D histogram for each stop in [Fig. 2] showing the sum of delays the services have taken in the section immediately preceding their arrival at the particular stop. A graphic element illustrating the vehicles moving on the line was added to the diagram to make it more illustrative. A real schedule of the line was implemented in the diagram for higher credibility of the diagram.

The core of the model is particularly a mathematic description of behaviour of the services, which is mostly included in the sub-model illustrating a stop. The passage time for each section *i* between stops *i-1* and *i* can be determined according to formula [3]:

$$m_i = \sum_{j=1}^{i} t_j + k_1 - \sum_{s=1}^{i-1} m_s = \sum_{j=1}^{i} (t_j + e_j) - \sum_{s=1}^{i-1} m_s, \quad (1)$$

Therein $t_i$ is the time set by the schedule for passage of the *i-th* section and $k_i$ is cumulated delay at that stop. The sum of $m_s$ values specifies when the service really left the previous stop. Calculation of delay $e_i$ upon available data is substantial for simulation.

$$e_i = \left(\sum_{j=1}^{i} t_j + k_i\right) - \left(\sum_{s=l}^{i-l} m_s + t_i\right) = k_i - \sum_{j=1}^{i-1} (m_j - t_j), \quad (2)$$

The first parenthesis in the above formula [1] says when the service really arrived at stop *i*, the second when the service really left the previous stop. The expression can be transformed to another form, which already involves the cumulated delay value $k_i$ which was determined empirically.

After arrival at the stop (output from the "wayTo" element) the time data related to the time of passing the latest monitored section and the stay at the stop (these two steps cannot be

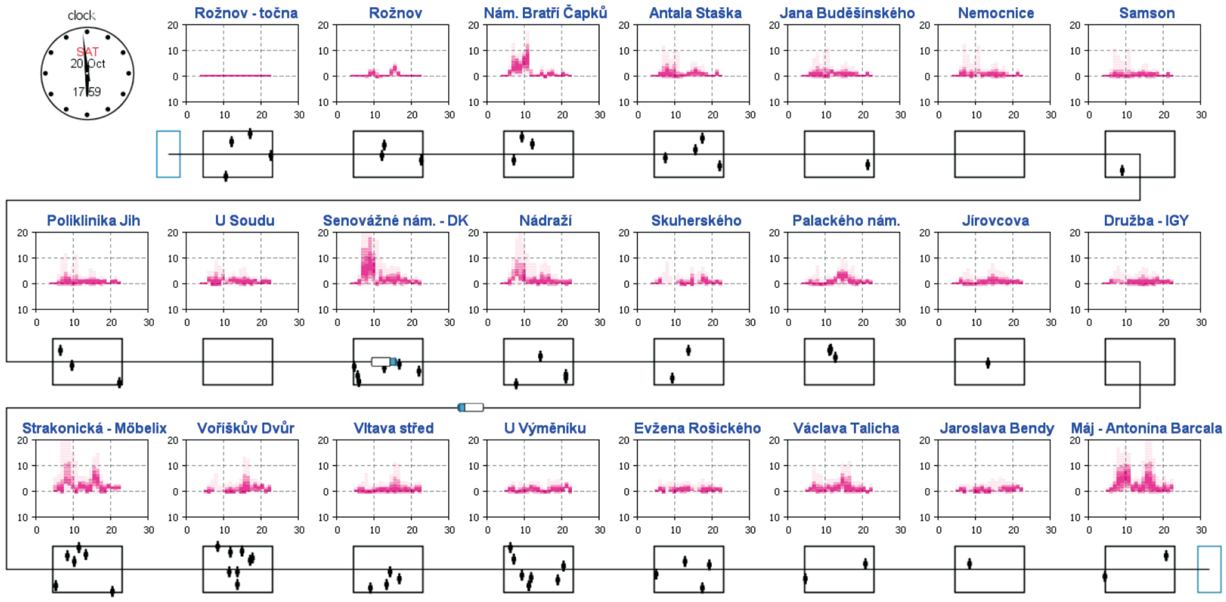


*Fig. 2 The model overall structure Small graphs show the delay during the day in the section before the station*

differentiated upon the available data) are stored in the data repositories. The model is even prepared for modelling the number of transported people, however the empiric data obtained from the traffic survey were not enough detailed for this purpose.

### 3.3 Delay curve modelling

The $e_i$ value is not in fact a constant but it is a function of the time of day (in our case time in minutes from 4:00 of each day), so $e_i = f_i(t)$. A question arose during the modelling how to model this curve for each stop. An example of the obtained values is presented in [Fig. 3] (the Delay line). Two iteration methods based on estimation of 6 parameters of approximating function $f_i(t)$ defined as combination of two Gauss curves (twice the mean value, standard deviation and amplitude) were tested for creation of analytic description of the presented values. Both, genetic algorithms and the Solver tool from MS Excel had been used for the estimation. The comparison shows that both the methods practically led to the same setting, just with small differences.

However application of the above approximating function leads to adjustment of constant delay values for given time without influence of stochastic events (e.g. fluctuation of traffic) and the calculation procedure is demanding. This is why random variable with triangular distribution of probability density with limits in the maximum and minimum of the chosen floating interval <t-15; t+15> (time in minutes) and with centres in the moving average was finally used for modelling delay in the model.

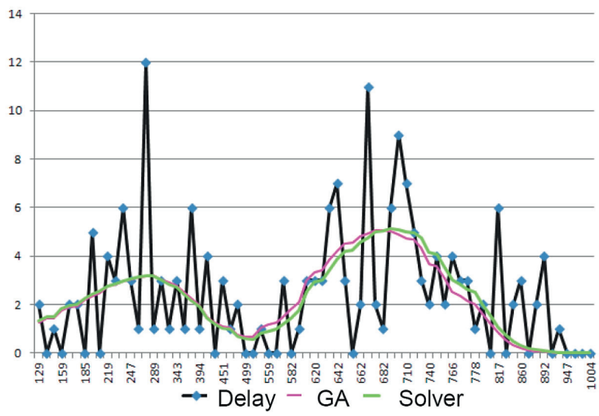


*Fig. 3 Empirically determined values of cumulated delay between two stops and the course of approximation function with different parameter petting (both axes in minutes)*

## 4. Simulation experiments

The proposed model was implemented in AnyLogic simulation tool. Apart from animation showing the passage of the means of transport through given line the system also shows some aggregate data. A histogram of service delay at the terminal [Fig. 4] is the first output. Delay of services in minutes goes on the *x* axis and frequency of that delay goes on the *y* axis.

It is obvious from the picture that the distribution is Gauss type and it clearly demonstrates that except for approximately 17 % all the services are delayed. A delay of more than 10 minutes is likely for substantial percentage of services, which will influence

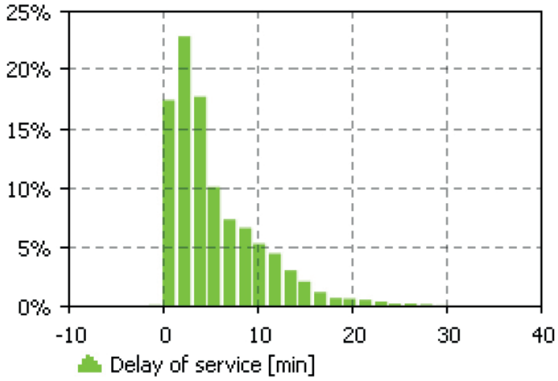


*Fig. 4 Histogram of service delay*

negatively the whole schedule of the line as well as linked lines (from the point of view of servicing with the same vehicles).

2D histogram of service delay distribution during a day is the second output [Fig. 5] (the more saturated colour the more delay occurrences). Time of a day in hours goes on the *x* axis and the rate of the delay goes on the *y* axis. It is obvious from the graph that there are two critical peaks of the delay function during the day, namely within the morning rush hour from 7 to 11 a.m. and then in the afternoon from 2 to 5 p.m. Critical moments are between 8 and 9 a.m. and between 3 and 4 p.m.

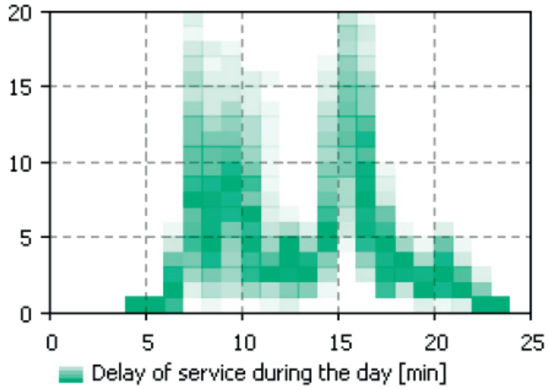


*Fig. 5 2D histogram of service delay during the day (x-axis in hours, y-axis in minutes)*

The last aggregate diagram [Fig. 6] is an estimate of waiting time for service arrival within the whole line. Time of a day in hours goes on the *x* axis and waiting time for a service goes on the *y* axis. This time is in fact an estimation only and is based on Poisson probability distribution ($\lambda=3$) of times between comings of passengers to the individual stops (a simplifying premise that the numbers of passengers at the individual stops are the same was applied). The graph shows that the longest waiting times occur during the day except for morning and evening periods when intervals between the services are longer than during rush hours, particularly at about 10 a.m. – 1 p.m.; morning and afternoon rush hours are covered very well in the existing adjustment (waiting times are relatively short).

Examination of a delay occurred in a particular line section (i.e. between a chosen stop) was also interesting. An example of a histogram of this delay is in [Fig. 7]. The values show that the biggest problems occur at about 8 a.m. and 4 p.m. at this section. There should be thus more time for passage through the given section at that time. Another result is that the schedule being used, taking into account only the day, evening and night operation is insufficient. Apart from general day schedule there should also be introduced a rush-hour schedule, implementation of which might eliminate the delays in the above mentioned periods.

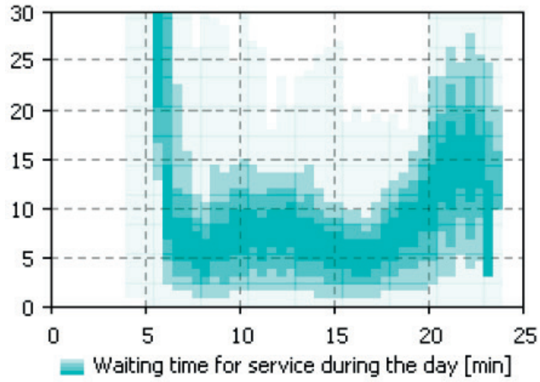


*Fig. 6 2D histogram of waiting time during the day (x-axis in hours, y-axis in minutes)*

Further simulation experiments that brought, except others, clear conclusions regarding the character and availability of input data were also performed together with the model. The presented model was based on the data from the operator; however the results have shown that data describing traffic density at the individual line sections would lead to more accurate delay simulation, however they are not available at this moment.

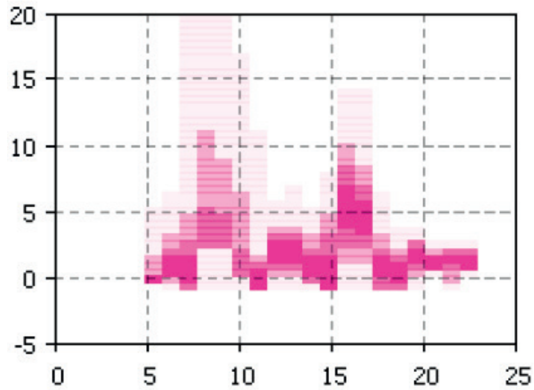


*Fig. 7 - 2D histogram of delay in a particular section during the day (x-axis in hours, y-axis in minutes)*

Examination of numbers of transported passengers and modelling of this value upon similar empirically obtained data with suitable structure would be beneficial for further extension of the model. This would also enable us to determine more exactly the time spent by the vehicle at the bus stop, when the getting off and on would no more be an action without time dimension (like in this model). There is another result, that the time differentiation of data from the operator (e.g. data of cumulated delay) with 1 minute unit is insufficient for more exact modelling. Obtaining data directly from the board control units, complemented where necessary by further technical devices (e.g. collection of data on weight of transported people) would be an ideal solution of most of the problems.

## 5. Conclusions

The present model shows how a modelling technique based on the DE approach can be applied to a description of a public transport line, particularly from the point of view of working with time information concerning this line (time of passages of individual sections, delay rate etc.). The model may be extended by simulation of numbers of passengers of the individual services, provided these data are available.

Further work on the model will focus particularly on more exact verification of the model against the empirically obtained data. Application would be then possible, apart from the simulation itself, also to preparation of methodology of collecting data from the real system in a structure applicable also to simulation modelling and particularly extension of the scope of the proposed model (e.g. for modelling occupancy rate of services). Data from control units of vehicles might also be included.

The aim for the future is to apply the obtained experience to a design of a multi-agent model based on an active means of transport with characteristic adopted from the above described DE model. Application of such a model is particularly possible in the field of complex modelling of a public transport system (more lines).

## Reference


[1] FORRESTER, J. W.: *Industrial dynamics,* Cambridge, MA : MIT Press, 1961

[2] SIEBERS, P. O., AICKELIN, U.: Introduction to Multi-Agent Simulation, [ed.] F. Adam and P. Humphreys. *Encyclopedia of Decision Making and Decision Support Technologies,* Pennsylvania : Idea Group Publishing, 2008, pp. 554-564

[3] AnyLogic Company: *AnyLogic.* [Online] 1992-2012, [Cited: 2. 11. 2012.] http://www.anylogic.com

[4] KAMPF, R., LIZBETIN, J., LIZBETINOVA, L.: Requirements of a Transport System User, *Communications - Scientific Letters of the University of Zilina*, vol. 14, No. 4, 2012, pp. 105-107.

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# LOGISTICS INFORMATION AND COMMUNICATION TECHNOLOGY

*As technology costs decline and usage becomes easier, logistics managers are managing information electronically at lower logistics expense with increased coordination results in enhanced services by offering better information and services to customers. This article deals with logistics information system, which is to be used in company. Logistics information system (LIS) must have a good structure for every company. LIS characteristics as availability, accuracy, timelines, exception-based LISs, flexibility and appropriate format are described in article.*

***Keywords:*** *System, logistics, input, output, advantage, disadvantage.*

## 1. Introduction

One of the by-products of the computer era is that managers are often faced with more information than can be effectively used for decisions. This abundance of data has several detrimental effects, among which are slower decisions, confused decisions, and the obscuring of important information. Consider, for example, a warehouse manager at a consumer products company receiving weekly reports from corporate management. If unwieldy computer output is delivered, with important and unimportant information mixed, the inexperienced manager will have difficulty finding the data that he or she really needs. More adept managers will find the decision-relevant information but will lose time developing the expertise to do so. Both novice and experienced managers may simply stack the reports in a corner of the office, to read when they have time. Of course, the managers will continue making decisions based on some other source of information and when reading time becomes available much of the formerly relevant information will be obsolete. Giving managers more than they need to know can be very dangerous when it keeps them from effectively receiving and using the information relevant to their current problems. Decisions support systems screen out irrelevant information so it cannot be misused or merely slow down use of the important data [1]. In other words, managers need to have the precise data to deal with the issue at hand without examining a lot of extraneous and irrelevant information [2].

## 2. Lis characteristics

The characteristics that should be concerned with in designing and evaluating LISs are as follows [3].

Availability

The rapid availability of information is absolutely necessary in responding to customers and in improving management decisions. Customers frequently need quick access to inventory and order-location. Many times it calls for decentralized logistics operations so that the information system can access information updated from anywhere.

Accuracy

Logistics information must accurately reflect both current status and periodic activity for customer orders and inventory levels. Accuracy is defined as the degree to which LIS reports match actual physical counts or status. Increased information accuracy reduces inventory requirements.

Timelines

Timelines refer to the delay between the occurrence of an activity and the recognition of that activity in the information system. Timely information reduces uncertainty and identifies problems, thus reducing inventory requirements and increasing decision accuracy.

Exception-based LISs

Sometimes LISs require reviews to be done manually particularly when decisions require judgment on the part of user. The central issue is identifying these exception situations that require management attention and decision making. LISs should be strongly exception oriented and utilized to identify decisions

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that require management attention, particularly for very large orders, products with little or no inventory, delayed shipments, and declining operating productivity.

Flexibility

An LIS must be flexible in meeting the needs of both system users and customers. It must be able to provide data tailored to meet the requirement of a specific customer.

Appropriate format

Logistics reports and screens must contain the right information in the right structure and sequence.

### Logistics information and communication technology

Advances in information systems are transforming the way logistics is managed. Automating the order-processing function leads to better customer services and the storage of more information for later analysis. The growing use of decision-support systems (DSSs) in logistics is helping managers to improve both their decision making and forecasting capabilities (Fig. 1). EDI is another technology that is used for transferring information in an efficient, secure, and lower-cost way than manual systems. Finally, technological advances in various types of hardware will continue to enhance the quality of information available to managers, improve customer service, and lower response times [4].

Nowadays, IT is mentioned as an opportunity to change the structure of logistics system in a firm. IT applications in logistics can be listed as follows:

- Data collection: optical scanning, electronic-pen notepads, voice recognition, and robotics,
- Identification: bas codes, radio frequency (RF) tags and antennas, smart cards and magnetic strips, and vision systems,
- Positional systems (GPS-MPSGIS-Navigator),
- Communication networks and data exchange (EDI-XML-Internet-Satellite-LAN-WAN-EPOS),
- Data storage: data marts and data warehouses,
- Software: DSSs, artificial intelligence, general software, and LIS modules.

## 3. LIS structure

The LIS structure has three main components: input, database and output.

### Input

The input phase is a collection of data sources and data transfer methods and means for making appropriate data available to the computing portion of the system. The LIS data can be obtained from many sources and in many forms, particularly from the following sources.

Customers: customer data are captured during their sales activities, order entries, and deliveries. The obtained data are useful for forecasting, planning and operating decisions. Freight bills, purchase orders and invoices are typical sources for this type of data. The primary source of information in logistics system is sales order because it contains basic data about customer and demanded items. Typical data from the customer locations, their demands, weight, and value of demanded items, date of order and date of shipping, shipment size, packaging, transportation mode, and so on.

Company records: much valuable information can be obtained directly from a company's internal reports, and various operating reports are examples of this type of information source.

Company data are often an untapped source of excellent data. However, such data are neither located at a single point within the company nor are organized in any meaningful way for logistics decision making.

Published data: Professional journals, trade magazine, and government reports are some sources of this type of data. This type of data is more generalized than internally generated data.

Management predictions of future sales level, action of competition, availability of purchased materials are just a few examples of information that are judgemental.

These types of data are maintained in the minds of company personnel, not in company files, computer records, or libraries. Company personnel such as managers, internal consultants and planners and activity specialists are close to data sources and become good sources themselves. Also, clerks who receive customer feedback are valuable sources of such data.

### Database management

The most important component of an information system is the converting module in which data are converted to information and information systems converted to useful knowledge for decision making. Database management contains three main functions: data selection, analysis method selection, and basic data-processing procedure to implement.

The maintenance of data in a database depends on the answers to these four questions:

1. How critical is the information to the decisions the logistician must make in a particular firm?
2. How rapidly does the information need to be retrieved?
3. How frequently is the information to be accessed?
4. How much effort is required to manipulate the information into the form needed?

Because logistical decisions vary in their frequency and in how rapidly required information for them must be made available, storage, retrieval methods should reflect these needs. Generally, the more accessible the information, the more costly the storage and retrieval. Therefore, computer storage and electronic retrieval and display can be justified for the most frequent planning and storage problems. Demand forecasting, inventory control, freight-bill preparation, shipment scheduling, and cost report preparation are just a few of the daily, weekly, or monthly logistics management activities.

Activities such as warehouse location, facility layout, and material handling equipment review require information at approximately yearly intervals. Computer storage is not usually economical. Most of the information is retained in company files as records.

Finally, infrequent planning and control activities such as private-warehouse construction and private-transportation equipment review usually do not justify maintaining information in a ready form. Rather, information in its raw form can be generated from primary data sources.

The three-tiered or ABC approach to information-storage requirements is a good approximation method from ranking and identifying how information and data should be stored, if at all. This then becomes a basis for deciding what types of storage capacity are needed and how much.

Data retrieval refers to the capacity of recalling data from a database in essentially its raw form or in only slightly modified form.

Data processing is one of the most popular features of the information system. Data-processing activities are relatively simple and straightforward conversations of data in files to more useful forms such as preparing transport bills of lading. Processing data into information is a very basic function of the information system. Data processing usually contains simple operations on data such as sorting and summarizing, coding, and arithmetic manipulations that convert data to useful information for logistics decision making and reporting.

Data analysis is the most sophisticated and newest use made of the information system. The system may contain any number of mathematical and statistical models. Such models provide information that is useful in dealing with some of the most difficult planning and control problems. These models use the database or the output of data- processing steps to find trends and forecast future level of activities and other information that is useful for planning.

### Output

The output of an information system is the interface with the user of system. The outputs in LIS cab are grouped in three types: reports, prepared documents, and results of data analysis from mathematical and statistical models.

1. Reports:
   - Summary reports of financial and performance indicators refer to information on which the logistician may take action. They do not in themselves initiate action. Inventory-level reports are of this type.
   - Status reports of current activities are special-purpose reports on the date of order receipt and date shipped are examples.
   - Exception reports that compare actual performance with goals are special reports that, for example, report on unplanned events such as when transportation costs as a percent of sales a replanted ratio.
   - Reports that initiate actions are commands sent out by the LIS to perform some activity. Examples are stock-replenishment orders, trucks-routing schedules, and order-picking list. These reports are based on management rules that are incorporated into the computer-based information system.
2. Prepared documents are common and printable documents such as shipment documents and freight bills.
3. Results of data analysis from mathematical and statistical models for instance, demand forecasting in one of the most useful and important outputs can be obtained from data analysis.

### System modules

This LIS should be comprehensive and capable enough to allow for communication not only between functional areas of a firm (marketing, production, finance, logistics, and so on) but also between members of the supply chain (vendors and customers) [5]. According to Frazelle [6], LIS modules can be listed as follows:

- Customer response system (CRS),
- Inventory management system (IMS),
- Supply management system (SMS),
- Transportation management system (TMS),
- Warehouse management system (WMS).

The CRS and SMS can be seen as parts of the order management system (OMS), and ordinarily WMS contains the IMS module. So LIS has three main modules: OMS, WMS, and TMS.

## 4. The order management system

The OMS is the first point of logistics system contact with customers by managing order receiving and placement. It is front-end system of the LIS. The OMS are closely related to WMS for checking product availability. The customer-ordered items may be available from inventories or may be seen in the production schedules.

This provides information about the location of the product in the supply network, quantity available, and possibly the estimated time for delivery. After checking product availability and accepting the delivery time by the customers, the next step is credit checking. In this step, the OMS communicates with the financial information system to check a customer's credit status. Once the order is accepted, the OMS will allocate the product to the customer order, assign it to a production location, decrement inventory, and prepare and invoice when shipping has been confirmed.

The OMS does not stand in isolation from the firm's other information systems. If the customer is to be served effectively, the information must be shared.

It should be noted that although the discussion has focused on the orders being received by a firm, there is a similar OMS for the purchase orders placed by the company (sometimes called the SMS). Whereas in customer-based OMS a firm's customer data are important, in a purchase-based OMS the focus is on the company's vendor's data such as their delivery-performance ratings, soft-costs and terms of sale, capabilities, availabilities, an financial strength [5]. The ways customer orders can be placed vary form completely manual to automatic when a customer's computer directly connects to the seller's system without human involvement. There are clear trade-offs in each situation between cost and information quality. In automatic order placement, the speed and accuracy of the process increases. However, initial costs are more than manual orders because of the need for system facilities.

Automating the order-processing function has many advantages for companies. The first one is improving customer services through increases in speed and accuracy. For example, by increasing the speed of the order-placement process, the order-cycle time can be reduced, which means that customers do not need to hold so much safety stocks. In this case, when a customer order is received, the system is able to inform customers immediately about order status, including item availability, shipping dates, and credit availability.

If the order is allocated from inventory, the inventory levels are updated automatically; if the item is not in stock, then, according to production planning, the estimated delivery date is provided to customers. Another benefit to a firm is avoiding human interference in order-handling functions because these activities are now largely computerized. Automation also has financial benefits such as generating customer invoices on the same day as shipments, which accelerates cash flow. Finally, there are fewer billing errors and clerical mistakes [4].

### The transportation management system

The WMS system focuses on a firm's inbound and outbound transportation. Like the WMS, it shares information with other LIS components such as order content, quantity, weight and cube, delivery date, and vendor shipping schedules. The function of TMS as a part of LIS is planning and controlling a firm's inbound and outbound transportation activities. This involves the following:

- Mode selection
- Freight consolidation,
- Routing and scheduling shipments,
- Fleet management
  - Maintenance scheduling,
  - Vehicle parts control,
  - Fleet administration,
  - Fleet costing,
  - Tachograph analysis,
- Claims processing,

The Warehouse Management system:

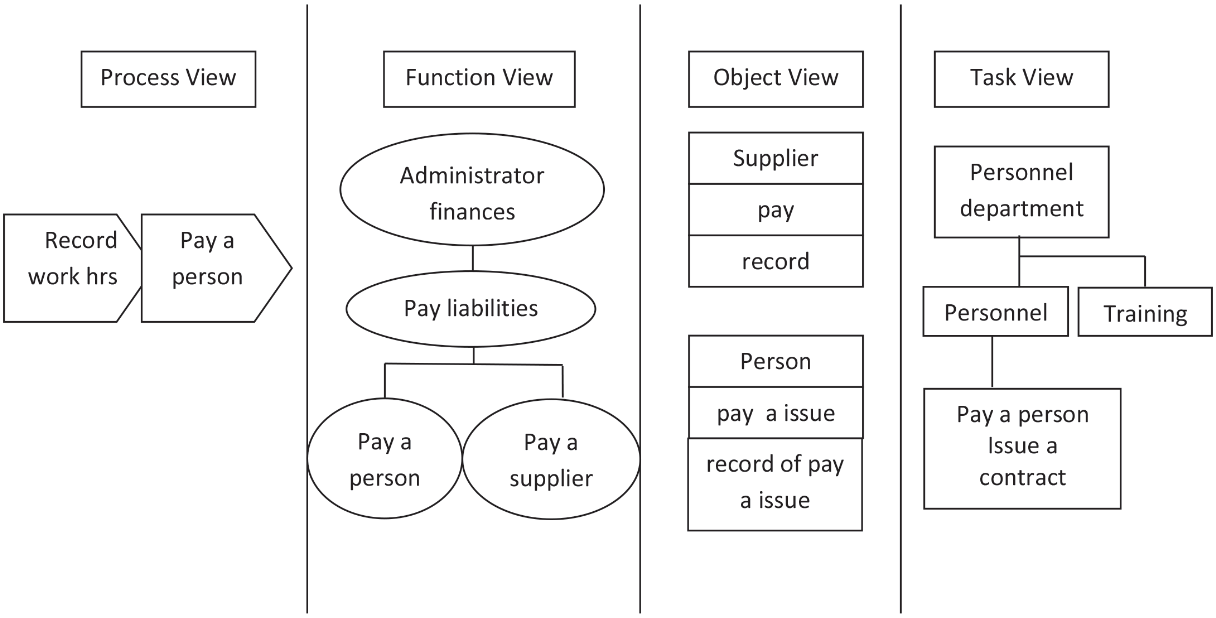


*Fig. 1 Four views of information systems for business processes [7]*

- Tracking shipment,
- Freight-bill payment and auditing.

## 5. Conclusion

As important as the order processing system is, it is but one component of the firm's logistics information system (LIS). Indeed, as businesses adopt a more global posture, the need for an LIS is being recognized as an essential ingredient for success in today's marketplace. Unfortunately, managers often find that logistics information can only be obtained by piecing it together from several rather poorly integrated information systems. As logistics channels become longer and more complicated, involving more channel members, efficient coordination becomes the key to effectiveness [8].

The integration of information from varied sources within the firm is a goal that many companies are establishing. Information integration makes available to management multiple bits of information that previously were generated, analysed, and stored in many places throughout the organization. This integrated information source permits managers to examine the operation of the organization in total, rather than in a fragmented, functionally isolated way. In fact, the whole idea behind a decision support system (DSS) is that making data available to managers will enable them to make better decisions. Thus, a logistics decision support system includes appropriate information files from across the logistics function, but, more importantly, it links these through a database system with access to appropriate modelling software [9].

This intent of any LIS is to link all facets of the firm's operation together into a cohesive whole so information flows freely to all of the managers who need it. However, there is also a growing demand for individual company systems to be linked with those of all the partners in a supply chain [10] [11]. Not only must the company's LIS result in more efficient internal operations, but it must also provide customers with better information on order status and shipment location [12] and [13, 14].

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## References

[1] KENT N. GOURDIN: *Global Logistics Management and Competitive Advantage for the 21st Century*, Second edition, Blackwell publishing, 2006, ISBN 978-1-4051-2713-4.

[2] KALASOVA, A., KRCHOVA, Z.: *Analysis of Road Traffic Accident Rate in the Slovak Republic and Possibilities of its Reduction through Telematics Applications*, Transport Systems Telematics: 10th conference, TST 2010: Katowice - Ustron, 2010: selected papers. - Berlin: Springer - Verlag, 2010. - ISBN 978-3-642-16471-2, pp. 463-468 (Communications in Computer and Information Science, 104, ISSN 1865-0929).

[3] LUCAS D. INTRONA: The Impact of Information Technology on Logistics, Intern. J. of Psychical Distribution & Logistics Management, 21(5), 1991, pp. 32-37.

[4] eLOGMAR-M *Chinese, European Forum one logistics*, Shenzhen, P. R. China, 2006.

[5] BALLOU, R.: Business *Logistics/Supply Chain Management Planning*, Organizing and Controlling the Supply Chain, Pearson Education, New York, 2004.

[7] SINGH, R., AILAWADI, S.: *Logistics Management*, Prentice Hall of India: New Delhi, 2006.

[8] FRAZELLE, ED: *Supply ChainStrategy: The Logistics of Supply Chain Management.* McGraw-Hill: New York, 2001.

[9] BARDI, E. J., RAGHUNATHAN, T. S., BAGCHI, PRABIR, K.: Logistics Information Systems: The strategic role for top management. *J. of Business Logistics,* vol. 15, No. 1, 1994, p.72.

[10] SIMON, M.: America's Systems, *J. of Commerce*, vol. 5, No. 2, January 12, 2004, p. 117.

[11] BOOKBINDER, J. H., DILTS, D. M.: Logistics Information Systems in a Just in Time Environment, *J. of Business Logistics*, vol. 10, No. 1, 1989, p. 52.

[12] FARAHANI, R. Z., REZAPOUR, S., KARDAR, L.: *Logistics Operations and Management,* Elsevier Insights, 2011, ISBN 978-0-12-385202-1.

[13] SOSEDOVA, J., SULGAN, M., RIEVAJ, V.: *European Transport Corridors and Slovakia,* second revised edition, EDIS - University of Zilina, 2010, ISBN 978–80–554–0255–0.

[14] LOVECEK, T., RISTVEJ, J., KAMPOVA, K., VACULIK, J., GAMBOA, R., ZAGORECKI, A.: Portal of Security and Safety Engineering as Tool to Increase the Sustainable Development of Higher Education in Security in the European Union and Beyond., *Communications – Scientific Letters of the University of Zilina*, No. 2, 2013, ISSN 1335- 4205.

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# DRAFT GUIDELINES FOR THE ALLOCATION OF PUBLIC LOGISTICS CENTRES OF INTERNATIONAL IMPORTANCE

*This paper deals with the design of methodology for the allocation of public logistics centres (VLC) of international importance in the Slovak Republic. The decision on the location of the logistics centre can be seen as a decision problem; for this type of task the multi-criteria analysis method is used. The first part of the paper (except introduction) includes a description of the general procedure for multi-criteria assessment of the variants. The second part presents the identification of the variants and the establishment of the evaluation criteria. The third part of the paper provides an identification of appropriate methods for a given type of task. The last part of the contribution presents the creation of a criteria matrix and the determination of prioritizing variants using the method of weighted sum, the weights being determined on the basis of Saaty's pairwise comparison method.*

***Keywords:*** *Public logistics centre, multi-criteria analysis, SAATY method, weighted sum analysis.*

## 1. Introduction

Multi-criteria decision making theory is based on mathematical modelling. Mastering the basic multi-criteria optimization techniques can be done with very simple mathematics [1].

The decision means in a given situation choosing one option from a list of potentially viable variants against a large number of criteria. Next to the list of criteria indirectly forming the objective of the decision analysis it is necessary to have a list of variants from which to choose. Cases where a clearly defined list of potential variants is available are more or less the exception than the rule. This list can be explicitly specified as the sum of a finite number of options, or implicitly specify the conditions that are considered acceptable and with which the decision options must comply. Even at this stage of the decision-making process it is generally difficult to avoid subjective influences, having to finding out experts´ opinion or that of the customer [2].

## 2. General multi-criteria evaluation of variants

In order to standardize, define and select methods of evaluation for multi-criteria evaluation of variants which support decision making, it is necessary to know the following [3]:

- what is to be decided,
- what goals are to be met (what objectives are to be achieved and under what conditions),
- aspects of what is to be decided (what aspects the decision-making process must comply with)
- the time line for the outcome of the decision making process.

The general procedure for the multi-criteria evaluation of variants involves six relatively distinct steps - identification of variants, establishment of a set of criteria, determination of criteria weightings, determination of criterion examples, partial evaluation of variants, selecting the most suitable variant [4].

The general procedure for multi-criteria evaluation of variants as an integral part of a multi-criteria decision-making process of variants assumes that there are at least two possible variants as solutions for the issue [5].

In the paper, we decided that the process of multi-criteria evaluation of variants would be adjusted to include 4 key points: identification of variants, establishment of a set of criteria, determination of criteria weightings and the selection of the most suitable variant.

## 3. Identification of variants and establishment of set of criteria

### Identification of variants

In stage one it is necessary to identify a set of variants from which the final solution will be chosen. The regions of Slovakia where the Public Logistics Centres (VLC) of international

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importance should potentially be placed were identified as those of: Bratislava, Trnava, Trencin, Nitra, Zilina, Banska Bystrica, Presov and Kosice.

### Establishment of a set of criteria

Stage two of the process of multi-criteria analysis involves establishing a set of criteria which influence the process of decision making in the selection of variants. [6].

Developing a tailor-made system of evaluation criteria is an important step in the whole multi-criteria analysis process, one which can significantly affect the overall outcome of the evaluation. The rational formation of evaluation criteria significantly depends on a thorough knowledge of the object of evaluation and on a systemic understanding of its structure and its functions. The set of criteria must be comprehensive i.e. it must reflect the essential characteristics of the objects (variants). If the latter is not the case, a gross distortion in the results may occur [6], [7] and [8].

After determining the objectives of the analysis of available knowledge, relevant to this article, 10 criteria primarily from socio-economic areas were defined. For these criteria critical data were obtained based on the study of the functions and perspectives that are related to the activities carried out in a VLC. Due to the prerequisite that all the data (associated with different factors) should be related to the same time period, only data collected for 2010 appears in this article [7].

For clarity, the criteria (factors) are summarized in the following Table 1. Table 2 shows the specific values of criteria related to individual variants (regions in the SR).

## 4. Identification of crucial methods used for the design of methodology of allocating public logistics centres

Proposing the placement of VLC can be viewed as a decision problem in which the final decision is influenced by a group of external factors. For the purpose of solving decision making

Overview of criteria related to the solution of the problem of allocating VLC of international importance Table 1

| Criteria | Acronym (designation) |
|---|---|
| GDP per capita (PPS) | GDP |
| Average GDP growth over 5 years | GDPGR |
| Value of direct foreign investment (EUR thousands) | FDI |
| Amount of transported goods via public roads (thousands tonnes) | TGR |
| Number of large companies (> 250 employees) | NBE |
| Number of small and medium size companies (< 250 employees) | NSME |
| Population size | NP |
| Average gross monthly wage (EUR) | AGW |
| State of road network (km) | RN |
| Regional connections with network of railway lines AGTC | AGTC |

Source: authors

Actual values of criteria related to individual variants Table 2

| Criterion / Variant | GDP | GDPGR | FDI | TGR | NBE | NSME | NP | AGW | RN | AGTC |
|---|---|---|---|---|---|---|---|---|---|---|
| Bratislava region | 43063 | 1.055 | 25182386 | 8255 | 180 | 49420 | 628686 | 991 | 241.75 | 3 |
| Trnava region | 20078 | 1.067 | 3109697 | 5651 | 61 | 13136 | 563081 | 705 | 360.87 | 3 |
| Trencin region | 15823 | 1.057 | 1803931 | 8921 | 73 | 11781 | 598819 | 657 | 508.52 | 2 |
| Nitra region | 14841 | 1.044 | 1552909 | 2875 | 51 | 14301 | 704752 | 636 | 517.99 | 2 |
| Zilina region | 15826 | 1.072 | 2283702 | 4320 | 61 | 13390 | 698274 | 686 | 593.54 | 2 |
| Banska Bystrica region | 13215 | 1.062 | 816171 | 3968 | 48 | 12525 | 652218 | 635 | 733.89 | 0 |
| Presov region | 10104 | 1.041 | 415900 | 4258 | 58 | 13120 | 809443 | 594 | 715.43 | 2 |
| Kosice region | 14109 | 1.047 | 2500399 | 6369 | 52 | 14744 | 780000 | 716 | 371.88 | 2 |

Source: [9] - [11]

problems the methods of multi-criteria analysis are used and these methods can therefore be used in deciding the location of VLC.

There are many different methods of multi-criteria analysis which can help in the allocation of VLC. In practice, however, many methods cannot be used because they do not allow for the processing of all the intricacies [4] and [5].

On this basis it was decided to use the weighted sum method - WSA, which appears to be relatively easy to handle and easy to apply to the complex and difficult task of allocating VLC. The weighted sum method requires cardinal information, criteria matrix $Y$ and a vector of criteria weightings $v$. It constructs the overall rating for each variant and so it can be used for finding one of the most appropriate variants as well as for arranging variants on a scale from the best to the worst.

In its calculation the Weighted Sum Analysis method uses criteria with set weights. Again, there are several methods to determine the criteria weights. For the purposes of this article the Saaty pairwise comparison method was chosen [4].

This is a method of quantitative pairwise comparison of criteria. For the evaluation of paired comparison of criteria, a 9 point scale is used. It is also possible to use intermediate values (2, 4, 6, 8). The researcher compares each pair of criteria and enters the sizes of preferences of *i*-thin relation to the *j*-th criterion in the Saaty matrix. In case *j*-th criterion is preferred above that of the *i*-th criterion, inverse values are entered into the Saaty matrix ($sij$=1/3 for low preference, $sij$=1/5 for strong preference, etc.) [12].

## 5. Setting up criteria matrix and ranking of variants

In the theory of Multiple Criteria Decision Making we work with a general number of criteria $k$ and with a general number of $p$. The value achieved by variant $i$ for *j-th* criterion is labelled as $y_{ij}$ and is called the criterion value. The next step is to arrange these values into a matrix which we call the criteria matrix. The rows of the criteria matrix are formed by the individual variants. The columns of the criteria matrix correspond with the individual criteria.

In our case the criteria matrix is identical to Table 2.

a) Transfer of criteria to the same type

For the purposes of tasks related to the criteria matrix it is appropriate that all the criteria are of the same type (minimization or maximization). Transfer of the criteria to the same type is not difficult because each minimization criterion can be easily converted to maximization criterion [4]. In our case it is necessary to perform a modification in the initial criteria matrix at the eighth criterion, that of average monthly wage. For average wage the highest value is EUR 991, the transformation will replace the original criteria value $y_{i8}$ with the value 991 - $y_{i8}$.

b) Ideal and basal variant

***Ideal variant*** is the best option which can be theoretically or practically achieved.

***Basal variant*** is the worst variant which can be theoretically or practically achieved.

c) Normalization of criteria matrix

If we know the ideal and basal variants, we simply normalize the criteria matrix. All values in the criteria matrix will be in the interval <0,1>, the ideal value of the criteria matrix will then be represented by the number 1 and the basal by the number 0. An important feature of this normalized criteria matrix is that it is completely independent of the units [4].

If we mark the basal value for criteria $j$ as $D_j$ and the ideal value for criteria $j$ as $H_j$ then the normalized criteria matrix ($r_{ij}$) arises from the initial criteria matrix ($y_{ij}$) as follows:

$$r_{ij} = \frac{y_{ij} - D_j}{H_j - D_j}. \tag{1}$$

According to the above formulae we set up the required matrix (Table 3):

Normalized criteria matrix — Table 3

| Criterion / Variant | GDP | GDPGR | FDI | TGR | NBE | NSME | NP | AGW | RN | AGTC |
|---|---|---|---|---|---|---|---|---|---|---|
| Bratislava | 1 | 0.4516 | 1 | 0.8898 | 1 | 1 | 0.2663 | 0 | 0 | 1 |
| Trnava | 0.3026 | 0.8387 | 0.1088 | 0.4591 | 0.0985 | 0.036 | 0 | 0.7204 | 0.242 | 1 |
| Trencin | 0.1735 | 0.5161 | 0.056 | 1 | 0.1894 | 0 | 0.1451 | 0.8413 | 0.5421 | 0.6667 |
| Nitra | 0.1437 | 0.0968 | 0.0459 | 0 | 0.0227 | 0.067 | 0.5751 | 0.8942 | 0.5613 | 0.6667 |
| Zilina | 0.1736 | 1 | 0.0754 | 0.239 | 0.0985 | 0.0427 | 0.5488 | 0.7683 | 0.7148 | 0.6667 |
| Banska Bystrica | 0.0944 | 0.6774 | 0.0162 | 0.1808 | 0 | 0.012 | 0.3618 | 0.8967 | 1 | 0 |
| Presov | 0 | 0 | 0 | 0.2287 | 0.0758 | 0.0356 | 1 | 1 | 0.9625 | 0.6667 |
| Kosice | 0.1215 | 0.1935 | 0.0842 | 0.5779 | 0.0303 | 0.0787 | 0.8805 | 0.6927 | 0.2644 | 0.6667 |

Source: authors

d) Determination of criteria weightings

As mentioned above, the determination of criteria weightings will be made using the Saaty pairwise comparison method. The first step of the Saaty method is to determine the relationship between each pair of criteria when the level of significance (preference) is determined in a spot range between 1-9. This is determined as follows [4] and [13]:

To ensure the greatest possible objectivity in the allocation methodology for the allocation of VLC, five members of the research team (a team was formed for the purpose of solving the tasks in the post) were asked to determine preferences between individual criteria. Each of the five members of the team set a level of significance for each pair of criteria. For each element of the matrix a sum of the sub-matrices of all members of the team was established and then the average was calculated.

Table 4 contains the individual values obtained from a procedure of the determination of criteria weightings.

Elements of the Saaty method were used for further calculations. The values obtained for the individual criterion in the intermediate calculations and the final values of the vector of weights of individual criterion are given in Table 5.

From this overview of setting criteria weightings using the Saaty pairwise comparison method it is clear that the highest priority is assigned to the transport infrastructure and also to the transport characteristics of the region. The least important criteria are the number of large state enterprises and the level of direct foreign investment in the region [14] and [15].

e.) Selecting the most suitable variant using the WSA method

**1.** Calculation of normalized criteria matrix – see Table 3

**2.** Multiplication of normalized matrix by the vector of weights indicated by Saaty method. Calculation of this procedure is summarized in Table 6.

Resulting Saaty matrix — Table 4

| | Criterion | GDP | GDPGR | FDI | TGR | NBE | NSME | NP | AGW | RN | AGTC |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | GDP (PPS) | 1.00 | 2.00 | 3.00 | 0.33 | 2.00 | 1.00 | 1.00 | 0.50 | 0.33 | 0.50 |
| 2. | GDPGR | 0.50 | 1.00 | 2.00 | 0.20 | 1.00 | 0.50 | 0.50 | 0.25 | 0.20 | 0.25 |
| 3. | FDI (EUR 000) | 0.33 | 0.50 | 1.00 | 0.17 | 1.00 | 0.33 | 0.50 | 0.20 | 0.14 | 0.20 |
| 4. | TGR (tons 000) | 3.00 | 5.00 | 6.00 | 1.00 | 5.00 | 2.00 | 3.00 | 2.00 | 1.00 | 2.00 |
| 5. | NBE | 0.50 | 1.00 | 1.00 | 0.20 | 1.00 | 0.50 | 0.50 | 0.25 | 0.20 | 0.25 |
| 6. | NSME | 1.00 | 2.00 | 3.00 | 0.50 | 2.00 | 1.00 | 1.00 | 0.50 | 0.50 | 0.50 |
| 7. | NP | 1.00 | 2.00 | 2.00 | 0.33 | 2.00 | 1.00 | 1.00 | 0.50 | 0.33 | 0.50 |
| 8. | AGW (EUR) | 2.00 | 4.00 | 5.00 | 0.50 | 4.00 | 2.00 | 2.00 | 1.00 | 0.50 | 1.00 |
| 9. | RN (km) | 3.00 | 5.00 | 7.00 | 1.00 | 5.00 | 2.00 | 3.00 | 2.00 | 1.00 | 2.00 |
| 10. | AGTC | 2.00 | 4.00 | 5.00 | 0.50 | 4.00 | 2.00 | 2.00 | 1.00 | 0.50 | 1.00 |

Source: authors

Values obtained using the Saaty method — Table 5

| | Criterion | Sum of elements | Tenth square root of sum | Resulting weight of criterion |
|---|---|---|---|---|
| 1. | GDP (PPS) | 0.326700 | 0.894159 | 0.07198 |
| 2. | GDPGR | 0.000625 | 0.478176 | 0.03850 |
| 3. | FDI (EUR 000) | 0.000026 | 0.347934 | 0.02801 |
| 4. | TGR (tons 000) | 10800.000000 | 2.531293 | 0.20378 |
| 5. | NBE | 0.000313 | 0.446226 | 0.03593 |
| 6. | NSME | 0.750000 | 0.971642 | 0.07823 |
| 7. | NP | 0.217800 | 0.858629 | 0.06913 |
| 8. | AGW (EUR) | 160.000000 | 1.661162 | 0.13374 |
| 9. | RN (km) | 12600.000000 | 2.570615 | 0.20696 |
| 10. | AGTC | 160.000000 | 1.661162 | 0.13374 |
| | | | | ∑= 1.00000 |

Source: authors

Intermediate calculation of the order of variants Table 6

| Criterion / Variant | GDP | GDPGR | FDI | TGR | NBE | NSME | NP | AGW | RN | AGTC |
|---|---|---|---|---|---|---|---|---|---|---|
| Bratislava | 0.07198 | 0.01739 | 0.02801 | 0.18132 | 0.03593 | 0.07823 | 0.01841 | 0 | 0 | 0.13374 |
| Trnava | 0.02178 | 0.03229 | 0.00305 | 0.09356 | 0.00354 | 0.00282 | 0 | 0.09635 | 0.05008 | 0.13374 |
| Trencin | 0.01249 | 0.01987 | 0.00157 | 0.20378 | 0.00681 | 0 | 0.01003 | 0.11251 | 0.11219 | 0.08916 |
| Nitra | 0.01034 | 0.00373 | 0.00129 | 0 | 0.00082 | 0.00524 | 0.03976 | 0.11959 | 0.11617 | 0.08916 |
| Zilina | 0.01250 | 0.03850 | 0.00211 | 0.04870 | 0.00354 | 0.00334 | 0.03794 | 0.10275 | 0.14794 | 0.08916 |
| BanskaBystrica | 0.00679 | 0.02608 | 0.00045 | 0.03684 | 0 | 0.00094 | 0.02501 | 0.11992 | 0.20696 | 0 |
| Presov | 0 | 0 | 0 | 0.04660 | 0.00272 | 0.00278 | 0.06913 | 0.13374 | 0.19920 | 0.08916 |
| Kosice | 0.00874 | 0.00745 | 0.00236 | 0.11776 | 0.00109 | 0.00616 | 0.06087 | 0.09264 | 0.05472 | 0.08916 |

Source: authors

**3.** For each of the variants the elements of the matrix for all criteria were counted and placed in descending order whereby the order of variants was identified [16]. The order of variants is shown in Table 7.

Identifying the order of variants Table 7

| Variant | Resulting value | Order of variants |
|---|---|---|
| Bratislava | 0.56501 | **2.** |
| Trnava | 0.43721 | **6.** |
| Trencin | 0.56841 | **1.** |
| Nitra | 0.38610 | **8.** |
| Zilina | 0.48648 | **4.** |
| BanskaBystrica | 0.42299 | **7.** |
| Presov | 0,54333 | **3.** |
| Kosice | 0.44095 | **5.** |

Source: authors

## 6. Conclusion

Based on the calculations performed for a decision on the allocation of one VLC of international importance and two other VLCs of regional importance using the weighted sum - WSA (multi-criteria analysis method), using all of the above criteria, the following regions in the following order were selected as suitable variants:

- Trencin Region,
- Bratislava Region,
- Presov Region.

The method allows for the reduction in the number of criteria that are taken into account in search of solutions. Several calculations with different numbers of criteria were made and always with more or less the same result - the first two positions according to the method of weighted sum were always taken by the Bratislava and Trencin regions (or in reverse order).

However, when taking into account the density of the road network and the amount of the average monthly nominal wages in the regions when assessing the variants, the region of Zilina was selected as the third most suitable region instead of Presov. The reason for this change is that for these important criteria the Presov region, compared with other regions, has relatively high values.

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**References**

[1] FIALA, P. at al.: *Multi-Criteria Decision Making.* VSE, Praha, 1994. ISBN 80-70709-748-7.

[2] BROZOVA, H., HOUSKA, M., SUBRT, T.: *Models for Multicriteria Decision*. Prague: Credit 2003m ISBN 80-213-1019-7.

[3] FOTR, J. et al.: *Management Decisions, Procedures, Methods and Tools*. Prague, Printer Havlickuv Brod, a. s., 2006. ISBN 80-86929-15-9.

[4] KALCEVOVA, J.: *Study Materials - Multi-Criteria Analysis*. [Electronic source]. [Citation 2013-01-21]. 2008. Accessible via: <http://jana.kalcev.cz/vyuka/kestazeni/EKO422-KriterialniMatice.pdf>; <http://jana.kalcev.cz/vyuka/kestazeni/EKO422-Kardinalni1.pdf>. *Study Materials - Methods for Determining Weights of Criteria.* [Electronic source]. [Citation 2013-01-21]. 2008. Accessible via: <http://jana.kalcev.cz/vyuka/kestazeni/EKO422-Kardinalni1.pdf >.

[5] KLICNAROVA, J.: *Multi-Criteria Evaluation of Alternatives - Methods.* Faculty of Applied Mathematics and Informatics, University of South Bohemia, Ceske Budejovice, Faculty of Economics. [Electronic source]. [Citation 2013-01-14]. 2010.

[6] TRIANTAPHYLLOU, E.: *Multi-Criteria Decision Making: A Comparative Study*. Dordrecht: Kluwer Academic Publishers, 2000. ISBN 0-7923-6607-7.

[7] TUCNIK, P.: *Multiple Criteria Decision Making in Multi-Agent Systems*. [Citation 2013-02-20] Accessible via: <http://hilbert.chtf.stuba.sk/KUZV/download/kuzv-tucnik.pdf>.

[8] Institute of Automation and Computer Science – Internet page*. Multi-Criteria Decision Making*. [Electronic source]. [Citation 2013-01-23]. 2010. Accessible via: <www.uai.fme.vutbr.cz/~jdvorak/vyuka/osa/Vicekrit.pp>.

[9] Statistical Office of the Slovak Republic – Internet page of National Office for Statistics: *Regional GDP 1995 - 2010*. [Electronic source]. [Citation 2013-03-02]. 2013. Accessible via: <http://portal.statistics.sk/files/Sekcie/sek_300/330/rev_hdp/reg_rev_hdp_1995-2010.pdf>. <http://portal.statistics.sk/showdoc.do?index=110&words=obyv&docid=108>. <http://portal.statistics.sk/showdoc.do?docid=1724>. <http://portal.statistics.sk/showdoc.do?docid=187>. <http://portal.statistics.sk/files/Sekcie/sek_600/Demografia/Obyvatelstvo/vyvoj_obyvatelstva_sr/vyvoj-2010.pdf>.

[10] SARIO – Internet page of Slovakian Agency for Development Investment and Commerce: *The inflow and outflow of foreign direct investments in 2010.* [Electronic source]. [Citation 2013-02-07]. 2009 SARIO. Accessible via: <http://www.sario.sk/?pzi-prilev-odlev>.

[11] Slovak Road Administration – Internet page of Transport Databanks: *Summary Data on the Network of Roads.* [Electronic source]. [Citation 2013-02-03]. 2013. Accessible via: <http://www.cdb.sk/sk/Vystupy-CDB/Statisticke-prehlady/k-1-1-2011.alej>.

[12] LIZBETIN, J., KLAPITA, V.: *Intermodal Transport,* 1 edition. Displaced the EDIS Publishing, Zilina University in October 2010. ISBN 978-80-554-0266-6.

[13] SAATY TH. L., VARGAS L. G., WENDELL R. E.: Assessing Attribute Weights by Rations. *Omega, Intern. J. of Management Science*, 2, No. 1, pp. 9-13, 1983, *Priority Setting in Complex Problems.* In: Hansen, P.: Essays and Surveys on Multiple Criteria Decision Making. Proc. of the Fifth Intern. Conference on Multiple Criteria Decision Making, Berlin/Heidelberg/New York : Springer-Verlag, pp. 326-336, 1983., *Axiomatic Foundation of the Analytic Hierarchy Process in Management Science*, 32, No. 7, pp. 841-847, 1986.

[14] KALASOVA, A., KRCHOVA, Z.: *Analysis of Road Traffic Accident Rate in the Slovak Republic and Possibilities of its Reduction Through Telematic Applications.* Transport Systems Telematics: 10th conference, TST 2010, Katowice - Ustron, 2010: selected papers - Berlin: Springer - Verlag, 2010. ISBN 978-3-642-16471-2, pp. 463-468 (Communications in computer and information science, pp. 104. ISSN 1865-0929).

[15] SOSEDOVA, J., SULGAN, M., RIEVAJ, V.: *European Transport Corridors and Slovakia.* Second revised edition. EDIS - Publishing University of Zilina, 2010, ISBN 978–80–554–0255–0.

[16] SOSEDOVA, J., SLESINGER, M., BARIAK, M.: Telematics in Inland Navigation. *Communications - Scientific Letters of the University of Zilina*, vol. 12, 3/2008, EDIS - ZU Zilina, pp. 66 - 68, ISSN 1335 - 4205.

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# TRANSPORT APPLICATION OF HYBRID SIMULATION

*Simulation of a road or rail vehicle is a very complex task. There are many possibilities to build the mathematical model according to the goals of the simulation. It can be built either as a general full-editable block model, which will cover all possible structures of the vehicle or as a single-purpose model built for the specific structure and its calculation. Each approach can follow suitable results, but the building and calculating time and work consumption can be incomparable.*

***Keywords:*** *Transportation, simulation, hybrid mathematical model, vehicle.*

## 1. Introduction

Mathematical models of complex transport system (such as vehicle) can be modelled as a combination of time-driven elements (vehicle body and transmission components) and the event-driven elements (automatic transmission controller, driver model).

Event-driven dynamics define the class of Discrete Event Systems (DES). The main difference between time-driven system and event-driven systems is the behaviour of the answer to the independent variable change [1] and [2].

The mathematical models, which use both of the elements, are so called hybrid models (hybrid systems - Fig. 1). It is possible to build them using the appropriate calculation tools and solvers (e. g. Simulink - time-driven elements and Stateflow - event-driven elements).

Stateflow extends Simulink with a discrete-event simulation model of computation.

## 2. Road vehicle simulation

The simulation of a road vehicle can contain many of its components or just a particular part of the complex structure [3]. Generally, the area of the simulation can be understood as an interaction between:

- driver,
- vehicle,
- load,
- environment.

## 2. DES driver model

The driver interferes with the vehicle by (Fig. 2) [3] and [4]:

- steering (influences the lateral dynamics),
- accelerator and brake pedals, clutch and gear shifting (influences the longitudinal dynamics of the vehicle).

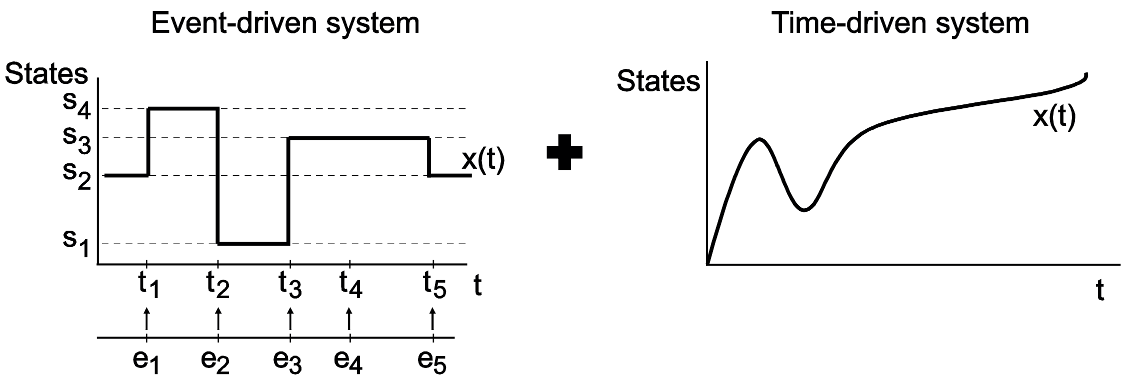


*Fig. 1 Structure of the hybrid system (Source: authors)*

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The driver is gathering the information for his driving decisions from:

- vehicle (vibrations, sounds, instruments data),
- environment (climate, traffic density, track).

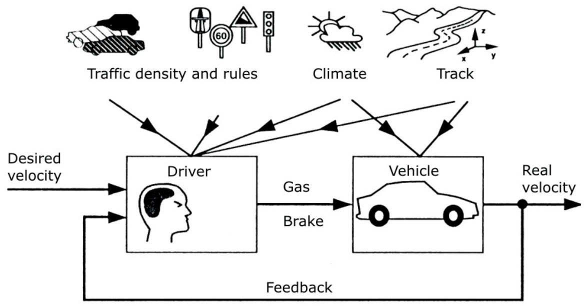


*Fig. 2 Interactions between the driver, vehicle and environment (Source: authors)*

Many driving manoeuvres require inputs of the driver at the steering wheel and the gas pedal which depend on the actual state of the vehicle. A real driver takes a lot of information provided by the vehicle and the environment into account. He acts anticipatory and adapts his reactions to the dynamics of the particular vehicle. The modelling of human actions and reactions is a challenging task. That is why driving simulators operate with real drivers instead of driver models. However, offline simulations will require a suitable driver model.

The decisions made in the driver model do not lend themselves to well-formulated equations. Thus, it is also much better suited for a Stateflow representation.

The presented Stateflow driver model controls the position of the gas (alpha), clutch (gamma) and brake (beta) pedal and the speed gear inserted (i) according to the required driving manoeuvre, driving strategy and the desired command variable obtained from the time-driven model of the vehicle dynamics.

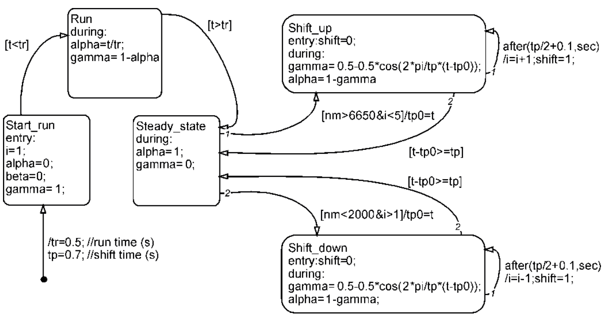


*Fig. 3 DES driver Stateflow model structure (Source: authors)*

The driver model is very simple according to the desired driving manoeuvre (acceleration to maximum vehicle speed). The input variable is the engine speed value, which has to be maintained within the desired range. If the engine speed exceeds the maximum value, the driver model shifts up. The model also allows the downshifting, but the brake pedal is in the simplest representation non-active [5].

The Stateflow block which implements gear selection for the transmission and the pedals position is shown in Fig. 3.

## 2.2 Dynamic vehicle model

The vehicle has to be depicted in mathematically describable substitute systems for computer calculations. The generation of the equations of motion, the numeric solution as well as the acquisition of the data require great expenses. At an early stage of development often only prototypes are available for field and/or laboratory tests. The model of a vehicle contains quantum of particular subsystems. The number of the subsystems and their complexity depends on required accuracy of simulation results and the amount of available input data.

Every part of the subsystem can be described by equations that fit the function of the technical system into mathematical model by selected level of simplification.

## 2.3 Load model

The load of the vehicle is mostly represented as a driving resistance in longitudinal direction. The load depends on the vehicle mass, the rolling resistance of the tires, and aerodynamic drag. Then, the simulation is based on motion equations calculated in each simulation step according to possible driving force generated by the vehicle motor and driver decisions affecting the gas and brake pedal (also gear shifting by manual gearboxes) [6].

## 2.4 Environment model

The environment influences driver's decisions by the track profile, the weather conditions (dry, rain, fog, snow – rolling resistance between tire and road), traffic density (free road, traffic jam, stop and go drive) and traffic rules (traffic lights, road signs, overtaking and turn off rules) [6] and [7].

The track can be defined either as a full parallel (two) or simplified 2D data model (x – z, Fig. 4), which can be used by longitudinal dynamics calculations, or 3D data model (x – y – z, Fig. 5) that can be used by the longitudinal and lateral dynamics calculation. Both models allow to calculate the vertical dynamics of the vehicle (damping).

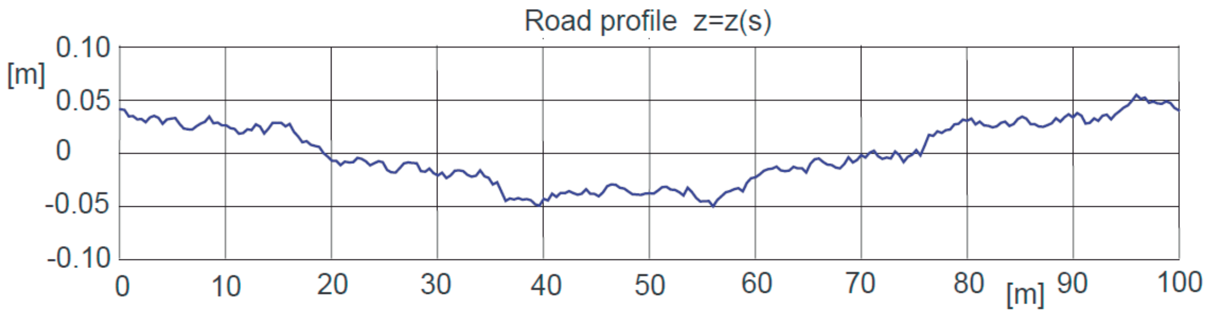


*Fig. 4 Vertical road profile example of a simplified centreline track model (Source: authors)*

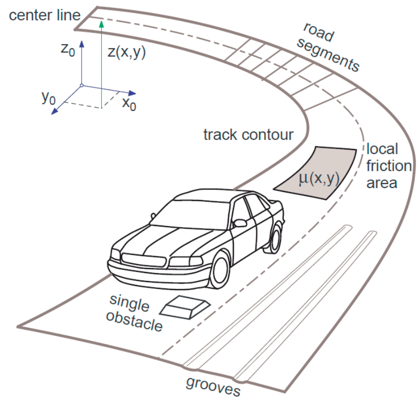


*Fig. 5 Complex track model (Source: authors)*

## 3. Hybrid block model description

The described hybrid block model example represents the typical road vehicle drivetrain with manual gearbox.

Figure 6 shows the power flow connections (based on torque and speed) in a typical automotive drivetrain block model with manual gearbox. Nonlinear ordinary differential equations model the engine, dry clutch, five-speed manual transmission, non-rigid shafts, differential, vehicle body, wheel and tire in the Simulink environment.

The driver is modeled as DES via Stateflow according to Fig. 3.

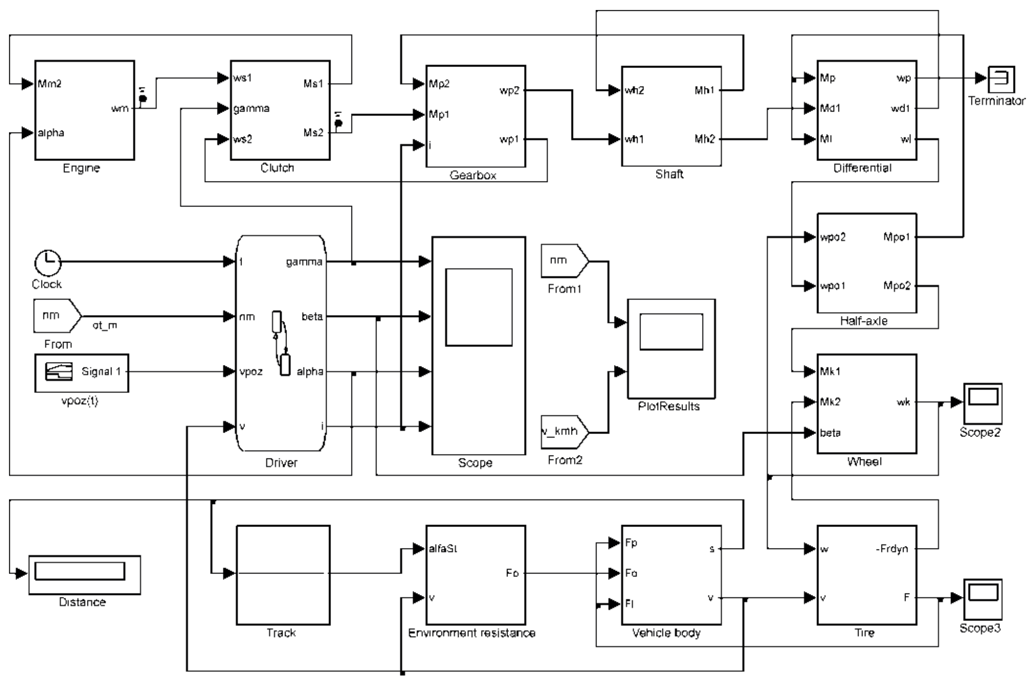


*Fig. 6 Vehicle hybrid block model layout (Source: authors)*

## 4. Simulation results

The simulation example of the road vehicle model represents the maximum acceleration manoeuver. The simulation time was defined to 60 seconds. The time behaviour of the selected variables observed during the simulation is shown in Figs. 7, 8 and 9.

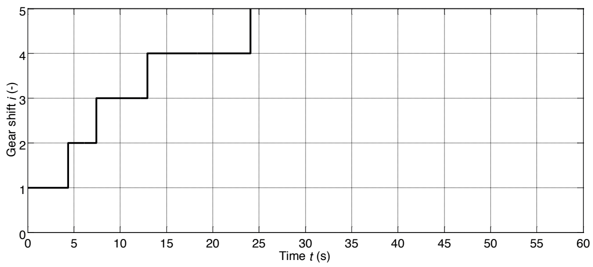


*Fig. 7 Gear shift procedure (Source: authors)*

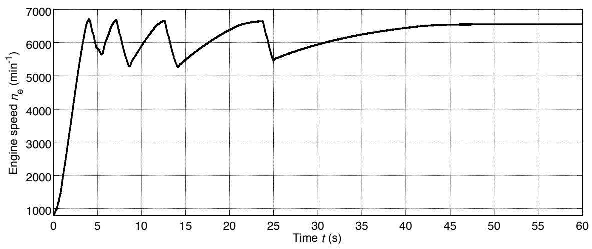


*Fig. 8 Engine speed behaviour (Source: authors)*

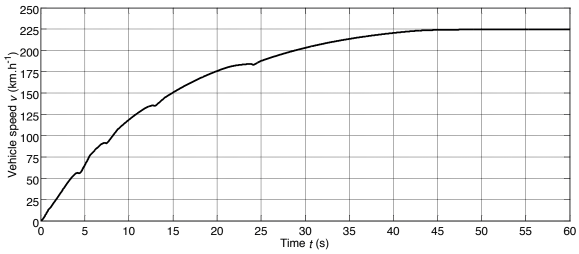


*Fig. 9 Progress of the vehicle speed (Source: authors)*

The acceleration of the modelled car to maximum speed of 225 km.h$^{-1}$ was achieved in 45 s.

## 4. Conclusion

Mathematical modelling and computer aided simulation of technical system virtual prototype behaviour is an important technique that influences the efficiency of the machine design process. It is a procedure, which allows to improve the machine design considerably, including the unconventional transmissions in plenty of applications [7] – [11]. This method requires the knowledge that enables to abstract the technical system into a mathematical model with reasonable level of simplification. Once the correct simulation model is built, there are wide possibilities of parameter changes without excessive demand on working and calculation time.

## References


[1] BRUMERCIK, F.: Transport Applications of Discrete Event System Models, *Logi: Scientific J. on Transport and Logistics*, vol. 3, No. 2- 2012, pp. 14-20, ISSN 1804-3216.

[2] BRUMERCIK, F.: Discrete Event Simulation of Logistic and Transport Systems, *Logi: Scientific J. on Transport and Logistics,* vol. 2, No.1- 2011, pp. 5-10, ISSN 1804-3216

[3] BRUMERCIK, F., LUKAC, M.: Vehicle Simulation Possibilities, *Logi: Scientific J. on Transport and Logistics*, vol. 3, No. 1- 2012, pp. 45-52, ISSN 1804-3216.

[4] KUCERA, L., LUKAC, M., JURAK, L., BRUMERCIK, F.: Hydromechanical Automatic Transmission, *Communications - Scientific Letters of the University of Zilina*, vol. 11, No. 2, 2009, pp. 33-35, ISSN 1335-4205.

[5] BRUMERCIK, F.: Simulation of an Unconventional Vehicle Transmission, *Logi: Scientific J. on Transport and Logistics*, vol. 3, No. 1- 2012, pp. 36-44, ISSN 1804-3216.

[6] BRUMERCIK, F., KOCUR, R., PAZICAN, M., LUKAC, M.: Differential Hydro-mechanical Transmissions with Hydrostatic Units*, Communications - Scientific Letters of the University of Zilina,* vol. 7, No. 1, 2005, pp. 49-53, ISSN 1335-4205.

[7] KAMPF, R., LIZBETIN, J., LIZBETINOVA, L: Requirements of a Transport System User, *Communications - Scientific Letters of the University of Zilina*, ISSN 1335-4205, vol. 14, No. 4, 2012, pp. 106-108.

[8] BUKOVA, B., BRUMERCIKOVA, E.: *The Role of Innovation in Transport Company,* LOGI 2010: 11th Intern. Scientific Conference, Harmony Club Hotel, Pardubice, Brno: Tribun EU, 2010. ISBN 978-80-7399-205-7.

[9] DROZDZIEL, P., KRZYWONOS, L.: The Estimation of the Reliability of the First Daily Diesel Engine Start-up During its Operation in the Vehicle, *Eksploatacja i Niezawodnosc – Maintenance and Reliability* 1(41), 2009, pp. 4-10, ISSN 1507-2711.

[10] WU, D., YAO, J., LI, H., QIAN, B.: Control Strategy for Hydro-mechanical Differential Turning System of Tracked Vehicles, *Nongye Gongcheng Xuebao / Transactions of the Chinese Society of Agricultural Engineering,* vol. 28, No. 8, 2012, pp. 78-83, ISSN 1002-6819.
[11] WANG, G., ZHU, S., SHI, L., TAO, H., VANTHINH, N.: Experimental Optimization on Shift Control of Hydraulic Mechanical Continuously Variable Transmission for Tractor, *Nongye Gongcheng Xuebao / Transactions of the Chinese Society of Agricultural Engineering*, vol. 29, No. 18, pp. 51-59, 2013, ISSN 1002-6819.

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# METHODOLOGY FOR ASSESSING THE QUALITY OF RAIL CONNECTIONS ON THE NETWORK

*The role of the EU transport system is to provide a high degree of mobility where necessary, to increase its performance in terms of speed, comfort, and safety. Achieving a consistent, integrated, and efficient transport system currently requires connections linking all transport modes. The most important criteria from the point of view of passengers are the reachability of the destination and frequency. This paper assesses the quality of rail services by considering the supply of connections on the network. It proposes a methodology for evaluating the constructed timetable in passenger traffic for the assessment of the achievability of tariff points. We also present some results of a case study of a Slovakian railway network.*

***Keywords:*** *Connection, relation, transfers, speed, quality, network.*

## 1. Introduction

The EU pays systematic attention to the quality of passenger transport [1], [2] and [3]. Quality is perceived differently by users and transportation service providers or organizers of transport as well as by society. The needs and expectations of customers are met by establishing procedures under the provisions of the Regulation of the European Parliament and Council Regulation (EC) No. 1371/2007 on rail passengers' rights and obligations [4].

The cornerstone of transport services is to provide travel opportunities by creating links and connections. Often, after the introduction of the new timetable under discussion whether it is better or worse, each approach is evaluated in a subjective manner. The authors solved some partially problematic of rail passenger quality services [5], [6], [7], [8], [9] and [10]. At present, there is no methodology for assessing train timetables from the transportation point of view as a whole. We evaluate specific trains and connections in the stations only, but not the quality of the connection from point A to point B.

The aim of this paper is to introduce a new methodology for the assessment of timetables in terms of passenger traffic focused on connectivity and linking. From the passenger's point of view, it is necessary to assess the availability of travelling opportunities between selected points on the rail network. The travel offer from A to B is in principle affected by travel time, number of transfers (changing the transport means), and number of travel opportunities. Connectivity and linking also affect several factors. This is an outcome for setting of draft criteria for connection evaluation.

Introduced study is designed in purview of the set up a tool for an objective evaluation of the quality of public transport service. Specifically, the aspects of availability and time of the transport services in selected geographical area are closed to the Standard EN 13816 [3].

## 2. Selecting a set of tariff points for evaluation

The aim of the proposed methodology is the comprehensive evaluation of the whole timetable in terms of train passenger services. An ideal case is to evaluate all existing relations between all tariff points for passenger transport on the railway network. If the rail network contains $n$ tariff points for passenger transportation, then the number of sessions to be examined is $m$:

$$m=n^2 \tag{1}$$

For the assessment of connection quality between stations and stops, it is necessary to select a set of representative tariff points which ensures quality assessment on a network-wide scale. For the selection of stations and stops for this sample, it is appropriate to identify specific process steps. Following the individual steps of the proposed procedure, we select tariff points according to the following evaluation criteria:

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- Demographic and geographic criteria (population criterion, meaning places of importance in public administration and local government),
- Criterion of railway geography (location and importance of stations on the rail network - crossroads, junction stations),
- Criterion of tourist destinations (the inclusion of stations with significant potential inflows of passengers).

## 3. Proposed procedure of connection assessment

The proposed methodology aims to comprehensively cover the possibility of achieving any pair of tariff points by passenger trains on a selected rail network in order to assess the quality of the travel opportunities in this area by using selected indicators [11] and [9].

The methodology is based on the evaluation of defined criteria for connectivity between the selected tariff points on the network. Based on the methodology, we evaluate a particular connection. It is necessary to determine whether the connection is evaluated during the working day or at the weekend. It is also possible to evaluate on a selected working day, Saturday, or Sunday. Consequently, we evaluate the summarizing indicators for services in terms of particular relations within the examined networks.

### 3.1 Connection evaluation

For assessing the connectivity and quality of connections in an examined relation (session), we identify the following factors, some of them are introduced in literature [12] and [13]:

- *Number of connections* $N_s$ during the reporting day, direct connections as well connections with changing (transfers).
- *Average waiting time of passenger* $W_i$. This is the time that the passenger has to wait for connection to a point of departure, possibly a transfer point. It is defined as half of the time between the departure of two successive connections:

$$W_i = \frac{(t_{i+1} - t_i)}{2}[h] \quad (2)$$

where:
$t_i$ departure time of train at the boarding station for a rated connection
$t_{i+1}$ departure time of the next train at the boarding station of the next connection

- *Distance route of relation* $L_i$. This is the travel distance by vehicles creating the connection. This criterion is important to calculate transportation speed and the rate of achievement.
- *Type and number of trains* creating the connection. This factor reflects the quality of transport services on the connection. In terms of ZSR, the types of trains are EC - EuroCity, IC - InterCity, Ex - Express trains, R - fast trains, Zr - semi fast trains, and Os - passenger trains.
- *Transportation time* $T_p$. Time between the departure from the boarding station on the route and disembarking the train at the destination railway station (tariff point).
- *Number of transfers* (changing transport means) $N_p$. This is the absolute number of changes of transport vehicles (trains) before reaching the target station.
- *Transfer time* $T_w$. This is the total time that passengers spend waiting for connections at the transfer station (by changing transport means) when using a particular connection:

$$T_w = \sum (t_{i2dep} - t_{i1arr})[\min] \quad (3)$$

where:
$t_{i2dep}$ is the departure time of the connecting train at the transfer station during $i$ changing
$t_{i2arr}$ is the arrival time of the train to the transfer station during i changing

- *Achieving time* $T_D$. This is the time from embarking when the travel trip begins, to the arrival of the train at the destination railway station. It is calculated as the sum of the average waiting time and transportation time:

$$T_D = W_i + T_p[h] \quad (4)$$

- *Transportation speed* $V_P$. This is given as a proportion of the distance travelled and time of transfer:

$$V_P = \frac{L_i}{T_P}[km.h^{-1}] \quad (5)$$

where:
$L_i$ distance route of relation
$T_P$ transportation time

- *Achieving start-stop speed* $V_D$. This is given as a proportion of the length of the relation and achieving time:

$$V_D = \frac{L_i}{T_D}[km.h^{-1}] \quad (6)$$

Transportation speed and achieving speed are important evaluation criteria for the quality of a particular connection relation. They are convenient indicators for comparing public transport link connections with individual transport.

### 3.2 Relation evaluation

After processing connections within single relations, it is necessary to evaluate the relation between tariff points on the

Sample of connection assessment on the Bratislava–Prievidza relation (Friday) Table 1

| Connection Nr. - | Station Bratislava hl.st. dep. [hh:min] | Station Prievidza arr. [hh:min] | Average waiting time $W_i$ [h] | Connect. distance $L_i$ [km] | Transport means | Transport time $T_p$ [h] | Number of transfers $N_p$ | Total changing time $T_w$ [min] | Start-stop achieving time $T_D$ [h] | Travel speed $V_P$ [km.h$^{-1}$] | Start-stop achieving speed $V_D$ [km.h$^{-1}$] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 6:53 | 9:36 | 6.25 | 158 | R, | 2.72 | 0 | 0.00 | 8.97 | 58.16 | 17.62 |
| 2 | 8:03 | 12:20 | 0.58 | 192 | R,Os,Os | 4.28 | 2 | 0.28 | 4.87 | 44.82 | 39.45 |
| 3 | 10:53 | 13:44 | 1.42 | 158 | R | 2.85 | 0 | 0.00 | 4.27 | 55.44 | 37.03 |
| 4 | 11:53 | 16:14 | 0.50 | 207 | R,Os,Os | 4.35 | 2 | 0.92 | 4.85 | 47.59 | 42.68 |
| 5 | 13:33 | 17:15 | 0.83 | 207 | IC,Os,Os | 3.70 | 2 | 0.52 | 4.53 | 55.95 | 45.66 |
| 6 | 14:53 | 17:44 | 0.67 | 158 | R, | 2.85 | 0 | 0.00 | 3.52 | 55.44 | 44.93 |
| 7 | 16:03 | 20:01 | 0.58 | 192 | R,Os | 3.97 | 1 | 0.07 | 4.55 | 48.40 | 42.20 |
| 8 | 18:53 | 21:35 | 1.42 | 158 | R | 2.70 | 0 | 0.00 | 4.12 | 58.52 | 38.38 |
| Average per connection: | | | | | | | 0.88 | 0.22 | 4.96 | 53.04 | 38.49 |

network. For each relation, average values are calculated for all connections: number of transfers, transfer time, transportation speed, and achieving speed. It is also appropriate to verbally assess and justify the results of the calculations. The sample of evaluation of relation is introduced in Table 1.

## 4. Evaluation of the network connection

For assessing connection quality on the network in terms of passengers, the multicriteria analysis (MCA) is suitable. The essence of this method is determining the importance weights of selected quality characteristics and the degree of customer satisfaction with their achievement. To determine the importance weights of quality characteristics, it is preferable to use the Sperling method where the weights of importance and degree of satisfaction are determined by assigning the number of points between 1 and 5. The criterion with the greatest impact is determined by weight 5, which means that the judge is the maximum number of points. The weights of other criteria are determined as a proportion of the weight of the importance of character with maximum impact.

*The satisfaction rate of customers* (passengers) *S* is given as a proportion of the actual value and maximum value of quality [10], [11] and [14]:

$$S = \frac{VN}{MH} \times 100\,[\%] \tag{7}$$

where:
*VN* perceived value of service quality
*MH* maximum value of service quality

*Perceived value of* service quality *VN*:

$$VN = \sum_{i=1}^{n} v_i \times s_{ireal} \tag{8}$$

where:
$s_{i\,real}$ real level of customer satisfaction with i character
$v$ weight of importance of the i character
$n$ quality character

*The maximum value of quality* is calculated according to the formula:

$$MH = \sum_{i=1}^{n} v_i \times s_{i\max} \tag{9}$$

where:
$s_{i\,max}$ maximum degree of customer satisfaction with the i character
$v_i$ weight of importance of the i character
$n$ quality character

For investigating the impact of specific criteria, the statistical regression method can be applied. After determining the satisfaction level, we display the quality characteristics depending on the weight of importance and degree of satisfaction; hence, four quadrants are displayed. On the x-axis, we apply the resulting values reflecting the degree of customer satisfaction with the performance characteristics, and on the y-axis are plotted the resulting values of the weights that identify the importance of character.

## 5. Case Study

The research team elaborates on the case study to verify the proposed methodology. It was applied on connections on

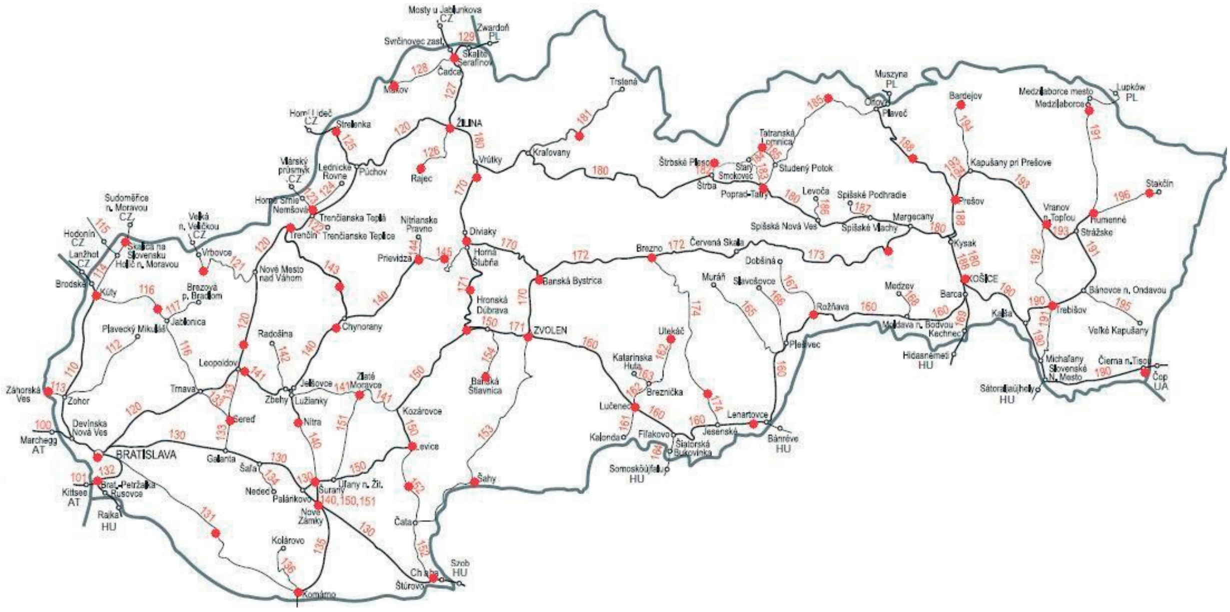


*Fig. 1 Network map of ZSR showing the selected tariff points for assessing the quality of rail connections*

the railway network of Slovak Railways (ZSR). We selected relations from the Bratislava main station to selected tariff points on the ZSR network (see Fig. 1). According to the proposed methodology and selection criteria, we identified 61 tariff points on the ZSR network. For the representative set of stations and stops, we selected first county centres, district towns over 20,000 inhabitants, junctions, and railway stations according to the criteria of geography and subsequently tourism centres so that each of the track lines in a set has at least one tariff point. The selected day of the week for the examination was Friday.

Results of the evaluation of connections on relations from the Bratislava main station according to average transportation speed, start-stop achieving speed, and average number of transfers (changing) Table 2

| From Bratislava to destination | Average travel speed per relation $V_P$ [km.h$^{-1}$] | From Bratislava to destination | Start-stop achieving speed $V_D$ [km.h$^{-1}$] | From Bratislava to destination | Average transfer time $T_w$ [min] |
|---|---|---|---|---|---|
| Trencin | 89.58 | Kosice | 66.62 | Dunajska Streda | 0.00 |
| Sturovo | 89.09 | Presov | 65.33 | Kosice | 0.00 |
| Piestany | 78.34 | Poprad-Tatry | 64.48 | Poprad-Tatry | 0.00 |
| Nove Zamky | 77.71 | Zilina | 62.92 | Zvolen os.st. | 0.00 |
| Kuty | 77.70 | Trencin | 62.39 | Zilina | 0.00 |
| Zilina | 77.45 | Trebisov | 60.41 | Ziar nad Hronom | 0.00 |
| . | | . | | . | |
| . | | . | | . | |
| . | | . | | . | |
| Kremnica | 53.16 | Makov | 34.74 | Brezno | 30.00 |
| Prievidza | 53.04 | Dunajska Streda | 33.86 | Handlova | 32.63 |
| Handlova | 51.96 | Sahy | 33.31 | Strelenka | 33.00 |
| Utekac | 51.68 | Banska Stiavnica | 28.84 | Utekac | 33.80 |
| Zahorska Ves | 48.98 | Zahorska Ves | 23.72 | Bardejov | 39.86 |
| Dunajska Streda | 48.19 | Zlate Moravce | 18.60 | Kremnica | 55.75 |
| Average per relation | 65.56 | Average per relation | 47.34 | Average per relation | 14.37 |

In the timetable for 2013 [15] and under the proposed methodology, we retrieved for each relation all connections. For each connection, we set the value factors of the number of connections during the reporting day, the average waiting time $W_i$ of passengers, the distance route of relation $L_i$, transportation time $T_{pi}$, number of transfers, transfer time $T_{wi}$, achieving time $T_{Di}$, transportation speed $V_{Pi}$, and achieving speed $V_D$.

Subsequently, we evaluated the relations. The most important evaluation criteria for the relations are listed in Table 2 that shows excerption of the start-stop achieving speed, average waiting time per relation, and average travel speed per relation. The listed factors characterises the transport service and are provided as outcome of an objective analyse of the offered connections according to the time table.

On the ZSR network, the highest average speed on modernized track lines from Bratislava to Trencin were direct connections. The start-stop speed was the highest on direct relations too, namely from Bratislava to Kosice, Presov, Zilina, and Nove Zamky. Just as quick are connections to Banska Stiavnica Zahorska Ves, and Zlate Moravce, indicating a slow connection in combination with long waiting times because of the small number of connections. The rate of average transfer time confirms this fact. The longest average waiting times is in the relations Bratislava–Kremnica, Bratislava–Bardejov, and Bratislava–Utekac.

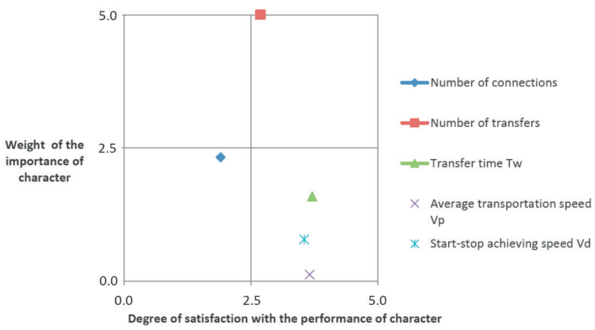


*Fig. 2 The resulting values of quality researched characters*

The set of relations was examined by using MCA and the Sperling methodology to determine the perceived value of quality services *VN*, the maximum value of quality services *MH,* and customer satisfaction rate *S*. As quality characteristics, we set the number of connections, number of transfers, transfer (changing) time, and achieving start-stop speed (see Fig. 2). The quality of the offered connections from Bratislava was rated as 26.99 points (*VN*), the maximum assessment *MH* = 49.05 points, and the customer satisfaction rate was 55.02%. The impact of indicators value was determined based on the statistics of the number of passengers carried on individual relations.

The quality characters depending on weight importance and degree of satisfaction are shown in the chart. On the x-axis, we applied the values of the determined rates of customer satisfaction with performance criteria fulfilment. On the y-axis, we applied the resulting values of the identified weights of the character importance. The weight and degree of satisfaction were set in the range of 1 to 5, where 1 was minimum importance and 5 maximum importance. The output of the case study is shown in Fig. 2. The most important criterion was the number of transfers (weight importance 5.0), which also has a relatively high level of customer satisfaction (importance 2.6). Passengers are least satisfied with the number of connections (1.59). This criterion does not, along with others, have a high weight of importance.

## 6. Conclusion

The issue of connectivity evaluation has not yet been sufficiently elaborated in the literature and is not used in practice where the connections from one station only are rated. This paper introduced the idea of a new evaluation methodology and included a case study on the network connection from the Bratislava main station to defined tariff points.

The proposed methodology covers the possibility of achieving any pair of tariff points in a selected railway network comprehensively. It not only offers an evaluation of the connectivity on a particular relation, but also objectively assesses the availability of connections between two selected tariff points based on quality indicators such as average number of transfers, average waiting time, average transportation speed, and average achieving speed. This enables us to evaluate the quality of the travel opportunities in this area by using selected indicators. Subsequently, using MCA allows us to evaluate the degree of customer satisfaction with selected quality attributes based on their importance. Ultimately, it is possible to examine the statistical dependence of the number of transported rail passengers by examining the quality connection on the network.

This methodology synthesizes knowledge from the theory of passenger transport and provides an evaluation of the connectivity and quality of constructed timetables for the entire rail network or only on selected rail networks.

It should be noted that the character of the current rail network loses due to gradual liberalization. Therefore, the significance of this methodology in the future will increase. The proposed methodology will be helpful for ministries of transport, regional public transport authorities, and other transport ordering bodies as well for integrated transport coordinators. The most important benefit of the proposal is that the evaluation is carried out in terms of the interests of passengers as users of a transport system that requires direct and fast connections. The resulting methodology can be applied in subsequent layouts of transport networks for public transport (Cenek et al., 2002, Kohani, 2013) [16] and [17].

The proposal will contribute to the creation of a competitive transport system that efficiently uses system resources. That is the plan of a Single European Transport Area within the purview of the White Paper "Roadmap to a Single European Transport Area - Towards a competitive and resource efficient transport system". This aims at the realization of an efficient and integrated system of mobility. The importance of the quality, accessibility, and reliability of transport services in the coming years may be even more important.

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References

[1] COM(2011) 144: White paper Roadmap to a Single European Transport Area - Towards a competitive and resource efficient transport system.

[2] EN 15140: Public passenger transport. Basic requirements and recommendations for systems that measure delivered service quality, 2006.

[3] EN 13816: Transportation - Logistics and services - Public passenger transport; Definitions, Determination of the performance goals and measuring of the quality on the service, 2002.

[4] Regulation (EC) No. 1371/2007 of the European Parliament and of the Council of 23 October 2007 on rail passengers' rights and obligations.

[5] ABRAMOVIC, B., BLASKOVIC ZAVADA, J., STEFICAR, S.: *Railway as Backbone for Regional Passenger Transport,* EUROZEL 2011, Zilina : University of Zilina, ISBN 978-80-263-0003-8.

[6] MOJZIS, V. et al.: *Quality of Transport and Transportation Process (in Czech),* Institut Jana Pernera, o.p.s. Pardubice, 2003, 176 p., ISBN 80-86530-09-4.

[7] MOJZIS, V., BULICEK, J.: Transfers in Passenger Public Transport (in Czech), *Doprava*, 2008. vol. 50, No. 5, pp. 13-15, ISSN 0012-5520.

[8] NEDELIAKOVA, E., MAJERCAK, J., NEDELIAK, I.: The Evaluation Methodology of Public Transport Logistic Chain in the Context of Qualitative Approaches to Regional Accessibility (in Slovak), *Pozemne komunikacie a drahy,* vol. 9, No. 1, 2013, pp. 53-58. ISSN 1336-7501.

[9] SULKO, P.: To the Connectivity Issue. *Doprava* a *Logistika,* vol. 7, No. 2.

[10] VONKA, J., DRDLA, P., BINA, L., SIROKY, J.: *Passenger Transport (in Czech),* Pardubice : University of Pardubice, 2001.

[11] SEDLAK, J.: *Methodology Proposal for Rating of Connectivity of Train Passenger Services (in Slovak),* Diploma thesis, University of Zilina, 2013.

[12] BUKOVA, B., NEDELIAKOVA, E., GASPARIK, J.: *Business in Rail Transport (in Slovak),* Bratislava : Iura Edition, 269 p., 2009, ISBN 978-80-8078-248-1.

[13] PECENY, Z.: *Passenger Transport (in Slovak)*, Zilinska univerzita : EDIS, 2000, ISBN 80-7100-781-1.

[14] LALINSKA, J., PECENY, L.: *The Quality of Information in Supply Chain,* LOGI 2012: conference proceedings, Brno : Tribun EU 2012, pp. 236-243, ISBN 978-80-263-0336-7.

[15] *Time Table of Zeleznice Slovenskej republiky 2012/2013 (in Slovak)*, Bratislava, 2012.

[16] CENEK, P., JANACEK, J., JANOSIKOVA, L.: Location of Transportation Districts at Modelling of Transportation Processes in a Region, *Communications - Scientific Letters of the University of Zilina*, No. 1-2, 2002, pp. 5-9.

[17] KOHANI, M.: Designing of Zone Tariff in Integrated Transport Systems. *Communications - Scientific Letters of the University of Zilina*, vol. 15, No. 1, 2013, pp. 29-33, ISSN 1335-4205.

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# LOW LEVEL CLOUDS ANALYSIS RELATING TO SYNOPTIC WEATHER TYPES AT BRATISLAVA AIRPORT

*Low level clouds are one of the most important meteorological phenomena, which can significantly influence every flight phase. In general, clouds are visible indicators of physical processes realized in the atmosphere. They provide information about winds, stability, moisture content and travelling weather systems. Knowledge of cloud base is very important, particularly to a pilot on the descent to an airport flying through a cloud. Cloud base is given as the height of the base of the cloud above a particular level (usually ground level). For aerodrome reports and forecasts the base is the height above the official aerodrome level. For international airports, reports should refer to the approach area; for airports equipped with ILS reference should be to the site of the Middle Marker beacon.*

*This paper deals with analysis of diurnal and annual variations of low level clouds at the Slovak international airport in Bratislava. The results are applicable in aviation weather forecasting and characterizing of dynamic climate of the region.*

***Keywords:*** *Low-level clouds, diurnal variation, annual variation, typical synoptic situation, Bratislava airport.*

## 1. Introduction

Low level clouds are especially stratiform clouds (Stratus and Stratocumulus) in lower troposphere with base height maximally 2 km above ground level. Low level clouds are potentially hazardous to flight operation, but it is quite difficult to define their impacts on operation since they will depend on aircraft type, pilot skills and experience and the navigation aids available en route or at the departure/destination/alternate airport [1].

Low level clouds can extend in horizontal distance of hundreds or thousands kilometers and vertically up to the height of 1 – 2 km. They can be observed in the area of warm and occluded front in central part and in a warm sector of a low pressure area (cyclone). They are also formed at the edges of anticyclone and in the case of high air mass humidity they can even originate in central part of anticyclone.

Low level clouds are usually formed by advection of warm and humid airflow over relatively colder surface. Warm advection is a typical process in warm sectors of cyclones and at the edges of anticyclones with variable duration. In the anticyclones the low level clouds are formed by radiative cooling in subsidence inversion regions below which the clouds are extended. The formation of low level clouds is also influenced by the character of an air mass or front, of which the passage is expected in the particular region, and also by the development of pressure field, to which the air mass or front is connected. The creation of low level clouds generally depends on synoptic conditions and their changes are caused by the presence of a certain weather type [2].

## 2. Data and methods

For statistical processing of daily observations from Bratislava airport, the ten-year-period 2002 – 2011 was considered. As the source of observations, the regular aeronautical meteorological reports (METARs) were used and the hourly terms were taken into account.

The dynamic-climatological weather analysis is based on application of synoptic weather types classification. Each of these types has its characteristic pressure field with defined position of central cyclones and anticyclones, location of frontal zone and probable movement of atmospheric fronts [3]. In this paper the SHMI (Slovak Hydrometeorological Institute) weather types classification is applied. This classification is processed for Central Europe region and determines 28 weather types (Table 1). Using the dynamic – climatological method, it is possible to find physical explanations of the existence of low level clouds in dependence on the occurrence of pressure patterns, air masses an airflow direction in the analyzed region during the presence of typical synoptic situation [4].

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Synoptic weather types determined for the Central Europe area — Table 1

| | |
|---|---|
| Anticyclonic weather types | |
| Wa | Western anticyclonic situation |
| Wal | Western summer anticyclonic situation |
| NWa | North-western anticyclonic situation |
| NEa | North-eastern anticyclonic situation |
| Ea | Eastern anticyclonic situation |
| Sea | South-eastern anticyclonic situation |
| Sa | Southern anticyclonic situation |
| SWa | South-western anticyclonic situation |
| A | Anticyclone over Central Europe |
| Ap1 - 4 | Anticyclone over Central Europe moving in different trajectories |
| Cyclonic weather types | |
| Wc | Western cyclonic situation |
| Wcs | Western cyclonic situation with southern trajectory |
| NWc | North-western cyclonic situation |
| Nc | Northern cyclonic situation |
| NEc | North-eastern cyclonic situation |
| Ec | Eastern cyclonic situation |
| Sec | South-eastern cyclonic situation |
| SWc1 | South-western cyclonic situation without distinct frontal systems |
| SWc2, 3 | South-western cyclonic situations with strong circulation and well-developed frontal systems, |
| B | Trough of low pressure over Central Europe |
| Bp | Trough of low pressure moving across Central Europe |
| Vfz | Frontal zone entry |
| C | Cyclone over Central Europe |
| Cv | Upper cyclone |

In the low level clouds analysis at Bratislava airport I used the definition introduced in Annex 3 – Meteorological Service for International Air Navigation [5], according to which the significant low level cloudiness is the lowest cloud layer in amount of broken or overcast with the base height less than 1000 ft above ground level. In terms of preparation of aviation meteorological forecasts (TAF, TREND) and special aviation meteorological reports (SPECI) the cloud base height is considered and only the data, which reach and exceed the values 100, 200, 500 or 1000 ft in the case of prevailing IFR flights at the airport, were taken into account. Considering this requirement the cloud base values are divided into four equi-long intervals (0 – 200 ft, 300 – 500 ft, 600 – 800 ft, 900 – 1100 ft) and their cumulative frequencies are calculated.

## 3. Statistical analysis of low-level clouds at Bratislava airport

Diurnal and annual variations of low level clouds were processed only for basic weather types. The results are depicted in 3-D isopleth-graphs and demonstrated in Figs. 1 and 2. The values of isolines are displayed in % and derived from absolute frequencies of low level clouds with base height ≤1100 ft.

At Bratislava airport the low level clouds with base height ≤1100 ft occurred in year average of 744 hours. The mutual percentage ratio of anticyclonic and cyclonic weather types is 58:42. This fact means that at Bratislava airport the prevailing low level clouds are of subinversion layered clouds that are typical for anticyclonic circulation. In cyclonic types the characteristic feature is the complete frequency increase in night-time and morning hours in warm half-year which is most likely caused by the radiation cooling after the front passage. The rare daytime occurrence of low level clouds is a result of direct front passage. The diurnal and annual variations for both basic weather types are depicted in Figs. 1 and 2. In the case of several weather types the highest multiplicities of low level clouds with base height less than 1100 ft are recorded in types: SWa, SEa, B, Bp, SEc and SWc3.

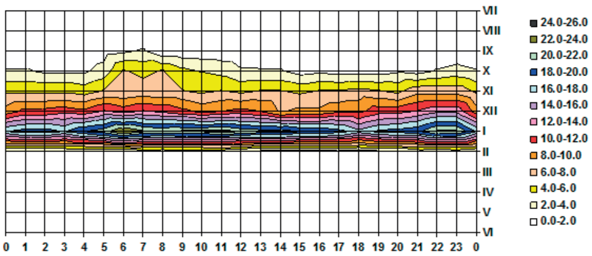


*Fig. 1 Diurnal and annual variations [%] of low level clouds with base height ≤1100 ft in anticyclonic weather types at Bratislava airport (x-axis in hours, y-axis in months)*

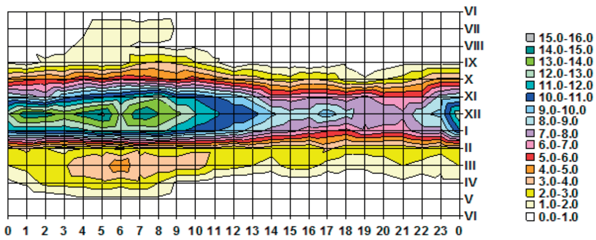


*Fig. 2 Diurnal and annual variations [%] of low level clouds with base height ≤1100 ft in cyclonic weather types at Bratislava airport (x-axis in hours, y-axis in months)*

The average frequency of low level clouds with base height less than 800 ft reaches 622 hours in the year. In anticyclonic types the distinct frequency increasing from November is noticeable, with maximum in January and typical steep decrease in January. Cyclonic types show the similar annual variation. In the case of diurnal variation the anticyclonic types achieve double maximum in the early morning hours, the frequency increase in the midnight hours was recorded in types with south-western and south-eastern airflow. In cyclonic types there is a gradual frequency increase from the midnight hours with the absolute maximum at 05.00. The highest frequencies of low level clouds with base height less than 800 ft are shown in following weather types: A, SWa, B, Bp and SEc.

At Bratislava airport the low level clouds with base height ≤500 ft occurred in year average of 372 hours. In anticyclonic types the daylong occurrence of these clouds is recorded from October to February. In the case of diurnal variation the primary maximum is achieved in the morning hours (04.00 – 09.00) with maximum values in January, the secondary one relates to the midnight hours. In cyclonic types they appear also in warm half-year, the occurrence in the morning hours proves their frontal origin. In spring and summer months the low level clouds with base height less than 500 ft are created after the sunrise in cyclonic types; in anticyclonic ones they are not observed. In diurnal variation the most frequent occurrence of these low level clouds relates to 04.00 and 07.00 with maximum values in December. Considering the weather types the greatest producers of low level clouds with base height ≤500 ft are A, SEa, SWa, Bp, Wcs, SEc, SWc2 and Vfz.

The average frequency of low level clouds with base height less than 200 ft reaches 283 hours in the year. The highest frequencies are shown in winter months with maximum in January when the complete intensification of anticyclonic weather types realizes over the European interior. In this period the most multiple types are A, Wa and types with eastern airflow component. The first two types transport air mass with sufficient humidity. As a result of lower insolation, the air will cool from the surface, which results in stabilization of the air mass and in formation of low level layered clouds. In the case of eastern situations the continental arctic airflow will keep its distinct stability, which leads to formation of subinversion layered clouds. At the edges of anticyclones the low level clouds are predominantly caused by the advection of warm air. In summer season the anticyclonic types do not create conditions for low level clouds formation. In diurnal variation the highest frequencies are shown in time around the sunrise with maximum in January. In winter the low level clouds with base ≤200 ft are also observed in daytime hours, which focuses on their advection character. The repeated increasing of low level clouds frequencies is distinct after the sunset when in autumn and winter months the temperature decrease and following condensation can cause the lowering of cloud base height below 200 ft. In cyclonic weather types the highest frequencies are achieved at the end of the year, but in general, the selected low level clouds are observed in all months. In warm half-year the limited occurrence of low level clouds relates to the early morning hours. That confirms their radiation origin of formation. In diurnal variation the most marked depletion of low level clouds base is shown in the early morning hours with maximum in December. The minimum or zero values are typical for day-time and night-time hours in spring

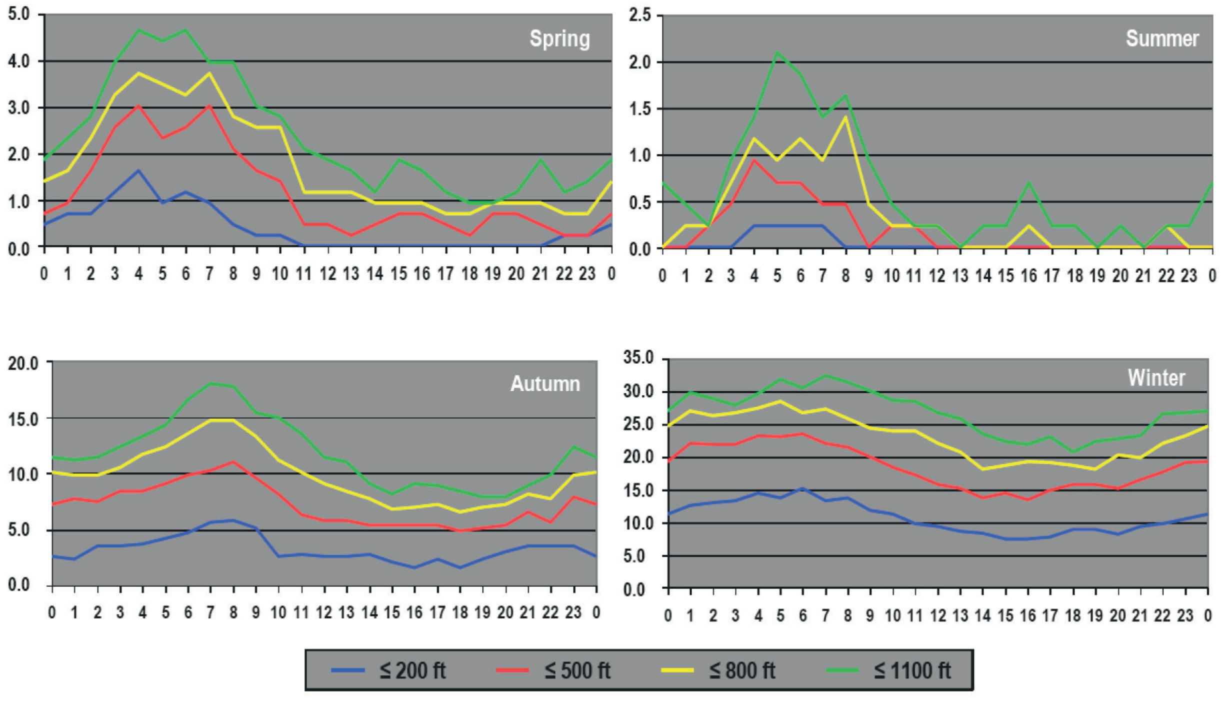


*Fig. 3 Seasonal diurnal variation of low level clouds with different base height at Bratislava airport (x-axis in hours, y-axis in %)*

and summer months. The low level clouds are observed mainly around the sunrise time as a consequence of radiation cooling of surface air layers. The highest frequencies of low level clouds with base height ≤200 ft were recorded in following weather types: A, Ea, SEa, SWa, Bp, SEc, Wc and Wcs.

In terms of effectiveness and optimal seasonal exploitation of an airport there is a possibility to apply information about seasonal occurrence of low level clouds with a certain base height. These results, relating to Bratislava airport, are depicted in Fig. 3. At first sight we can notice striking similarity between the diurnal variation in spring and summer and the diurnal variation in autumn and winter. In spring and summer months the probability curves are of approximately the same shape with difference of their steepness in the early morning hours. In autumn and winter the probability curves show the distinct maximum in the late night and early morning hours (04.00 – 07.00). In diurnal variation the most frequent occurrence of low level clouds is observed in the early morning, two or three hours after the sunrise. Exception can be seen in the winter, when low level clouds are present during the whole night and morning hours. The characteristic depletion of low level clouds frequencies in the morning hours is depicted in a steep slope of the curve in warm half-year and in a slow course in cold months.

The seasonal occurrence of low level clouds in dependence on surface wind direction is shown in Fig. 4. The results demonstrate the significant influence of the main range of Male Karpaty on the low level clouds occurrence at Bratislava airport. In this region the secondary maximum of wind direction relates to NE and E wind, which arises as a consequence of SE wind backing on the windward side. Of course, this is influenced by presence of the weather type throughout the year. The prevailing NW wind achieves its maximum in summer; SE wind is the most frequent in autumn [6]. In terms of air mass transport between Europe and the Atlantic Ocean the maximum frequencies of NE and E wind are typical for the cold months and the minimum is reached in summer.

In spring low-level clouds are associated with increasing amount of cyclonic and anticyclonic weather types with airflow

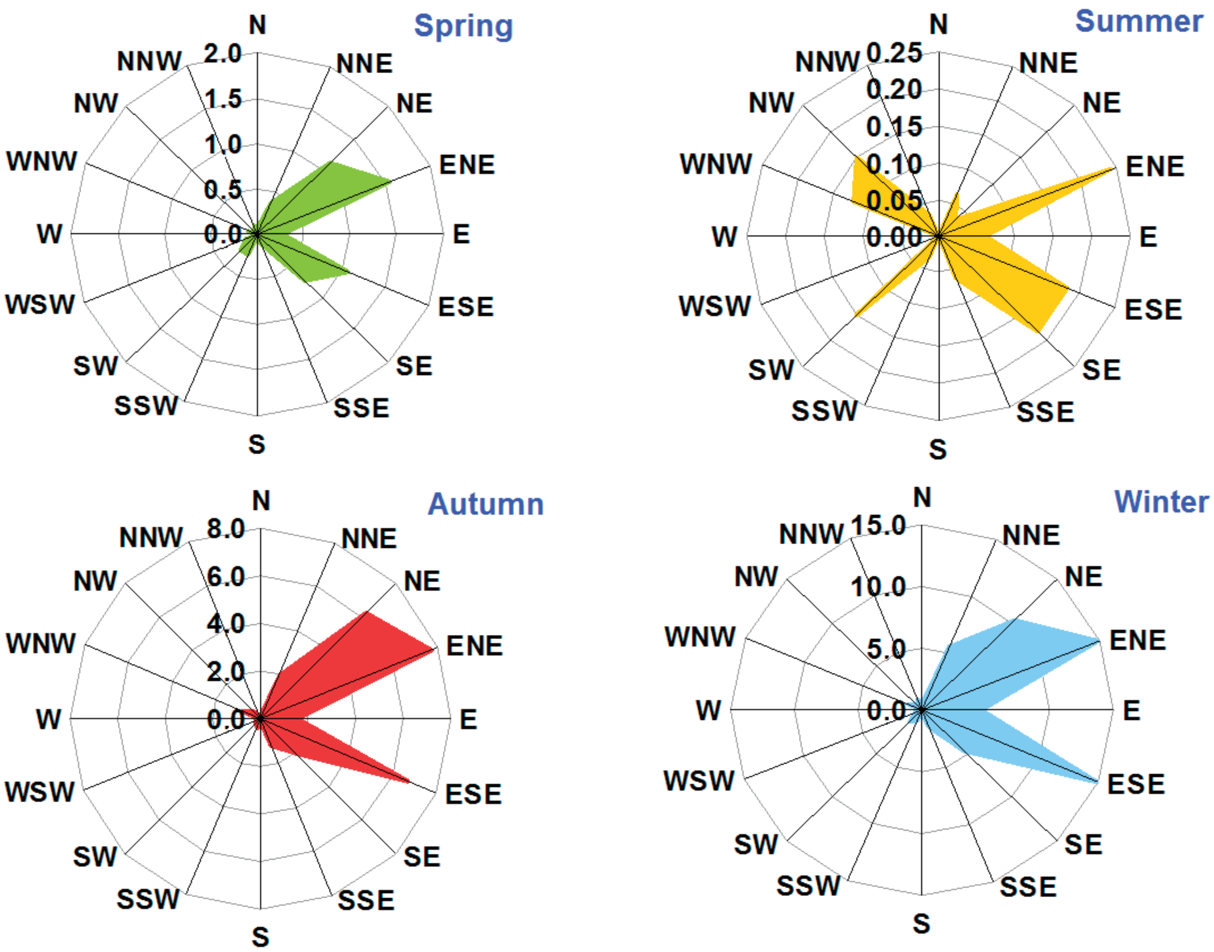


*Fig. 4 Annual variation [%] of low level clouds with base ≤1100 ft depending on surface wind direction at Bratislava airport*

in the N – E sector. This is caused by meridional circulation, which is distinct in this season. More frequent occurrence is also observed in the case of troughs of low pressure, which transport low level frontal clouds from SW. In summer the zonal circulation prevails and reaches its secondary maximum in year. The low level clouds are mostly present in E airflow. However, the large frequencies belong to the cyclonic types with the fronts moving from SW and to the ones with SE airflow. In autumn the maritime airflow decreases and weather types with continental airflow appear. The highest frequencies are typical for anticyclonic weather types and troughs of low pressure with prevailing SW and SE airflow. At the beginning of winter the zonal circulation occurs with typical increasing frequencies of the eastern and western cyclonic weather types [7].

## 4. Conclusion

When cloudbase falls below acceptable values, the pilot can encounter situation where there will not be sufficient time to take action leading to obstacle avoidance. Pilots who are not qualified to use instruments may become disorientated when they are confronted with low cloud. Therefore, the low-level clouds are one of the weather phenomena hazardous to flight operation. Low-level clouds are usually stratiform clouds – Stratus and Stratocumulus. Stratus forms in sheets or layers and occurs when relatively large areas of moist air rise gently in a stable atmosphere. It varies in thickness from a semi-transparent sheet of a few feet to a deck of around 1500 feet. When it forms close to the ground, stratus can mask the surrounding terrain, particularly in mountainous areas. Stratocumulus usually has lumpy appearance that indicates convection within the cloud. But the most significant hazard associated with low-level stratiform cloud is low visibility related to low-lying cloud base.

The occurrences of low level clouds is conditioned by several factors, e.g. time of the sunrise and sunset, elevation angle of the Sun, existence of snow cover, radiation cooling in night-time hours, orographic conditions and characteristic of global atmospheric circulation in a specified region and in particular season. Using the calculation of diurnal and annual variations and by the applying of the dynamic – climatological method it is possible to achieve a certain model of occurrence of low-level clouds at a particular airport during the presence of individual weather types. The results are widely applicable in aviation weather forecasting. Using the data measured and observed at Bratislava airport, the results of research are directly applicable for the airport operations providing valuable prognostic information for air traffic services and ground services.

## References


[1] World Meteorological Organization: *WMO/TD – No. 1390 Aviation Hazards. Education and Training Programme ETR-20*. Secretariat of the World Meteorological Organization. Geneva, Switzerland, 2007.

[2] ZVEREV, A. S.: *Synoptic Meteorology*, Bratislava, ALFA: Praha, SNTL, 1986.

[3] Kolektiv synoptickej a leteckej sluzby HMU: *Catalogue of Typical Weather Situations over CSSR*, Praha: MIR, 1968.

[4] BALLON, L., FORGAC, P., MOLNAR F.: *Weather During the Typical Synoptic Situations over CSSR*, Praha: Hydrometeorologicky ustav, 1964.

[5] Annex 3 – *Meteorological Service for International Air Navigation, Part 4 – Meteorological Observing and Reporting,* Publikacia Leteckej informacnej sluzby SR, Ministerstvo dopravy, post a telekomunikacii SR, druhe vydanie, 2001.

[6] Slovenska akademia vied: *Climate and Bioclimate of Bratislava*, Bratislava, VEDA, 1979.

[7] KROLLOVA, S.: *Diurnal and Annual Variation of Low Level Clouds at Bratislava Airport (in Slovak)*, Intern. Conference at project AIRTN: Increasing safety and quality in civil military air transport, Zilina : Zilinská univerzita, 2011 - ISBN 978-80-554-0364-9, pp. 66-75.

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Anna Tomova – Zdenka Strmiskova *

# EXPLANATORY ANALYSIS OF ANCILLARY REVENUES: CASE STUDY OF THREE EUROPEAN AIRLINES

*This paper quantifies an impact of ancillary revenues on changes of airlines total revenues using the data of three European low-cost airlines during the period from 2006 to 2011. The analysis reveals that ancillary revenues are important in generating total revenues in a low cost airlines group in terms of dynamics and subsequent influence on profit/loss result. The research findings confirmed that ancillary revenues influenced changes of total revenues significantly achieving in prevailing cases double-digit percentage share in the changes of total revenues expressed as a whole. So, quantified impact of ancillary revenues dynamics on dynamic of total revenues is undoubtly important for overall dynamics of airlines total revenues. Our analysis based on quantitative approach of explanatory analysis also clearly identified ancillary revenues as pro-operational profit driver through its positive and not marginal impact on dynamics in total airlines revenues. This disclosure is in line with general assumption of considerable role of ancillary revenues in low cost airlines economics.*

***Keywords:*** *Airlines, ancillary revenues, explanatory analysis, product, quality.*

## 1. Introduction and motivation

Airlines economics is of special nature mainly due to derived demand for air services in passenger and cargo segment which makes it very fragile, risky and volatile. Moreover, airlines compete in fully liberal or gradually liberalizing markets, which lead to higher pressure on airlines costs and revenue management. Changes of airlines revenues are therefore partially externally given, although influence of endogenous drivers such as revenue management, product policy, pricing etc. ought not to be neglected in this context. Just these internal forces of airlines management decide about market success of airlines.

The concept of ancillary revenues is a part of broader product policy and price policy built on applied business model. The topic is intensively researched with regard to sharpening airlines competition as just ancillary revenues stemming from miscellaneous generators in product and price policy may create new sources of revenues and compensate drops in other revenues or cope with increase in costs. In airline industry ancillary revenue is any revenue generated by airlines out of air ticket sale going into airlines operational profit/loss. Ancillary revenues may be miscellaneous – charges for luggage, sales of food and beverage on aircraft board, seat assignment charge etc. – reflecting different approaches of airlines towards product offered to customers. Generally, four main categories of ancillary revenues are defined: a la carte product revenues generated as a part of flight or air travel, commission-based product generated through sales of specific services (hotel accommodation, car leasing etc.), revenues generated by frequent flyer programs (through sale of services by airline partners in frequent flyer programs schemes and revenues from advertisement placed on the aircraft board or on aircraft itself. Mixture of drivers which generate ancillary revenues is very unique within airlines' economics. In the aggregate, airlines implemented unique business models although we can meet in scientific literature some typological archetypes assigning the strong role of ancillary revenues to a low-cost airlines group. A causa de cy we have decided to investigate a role of airlines ancillary revenues in total revenue generation in airline industry in a more detail using methodology of explanatory analysis.

## 2. Methodology and aim

We aimed at confrontation of selected low cost airlines with regard to ancillary revenues generation and its determinative impact on total airlines revenues. Therefore, we worked with three low cost airlines in our analysis, (Ryanair, easyJet, Flybe) traditionally labelled as low cost carriers. As ancillary revenues of the airlines ought to be considered within overall airlines business concept, we exposed the airlines business models to qualitative and quantitative analysis using the works of Klophaus et al. [1], also Lohmann and Koo [2], Daft and Alberts [3] and

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Airlines Business Models Characteristics/Fleet Composition and Network Design Table 1

| | Fleet Composition | | | Network Design | | | |
|---|---|---|---|---|---|---|---|
| | Number of Aircraft Types | HHI Index | The Most Common Aircraft Type in % | Transfer Flights | Network Concept | Number of Destinations | Average Distance of 5 Top Airports to the City Center |
| Ryanair | 1 | 1.00 | 100 | No | point-to-point | 187 | 30 km |
| easyJet | 2 | 0.8517 | 74 | Yes | hub and spoke | 118 | 12 km |
| Flybe | 6 | n. a. | 68 | Yes | hub and spoke | 56 | 12 km |

*Source: Own investigation and computation based on [5], [6], [7].*
*HHI is Herfidahl-Hirschmann Index. n. a. = not available*

Mason and Morrison [4]. Thus, motivated by methodologies of the above-mentioned authors we compiled available qualitative and quantitative descriptive characteristics of business models implemented by the airlines researched. They are gathered in Table 1.

As it can be seen in Table 1, there is no so strict convergence among the airlines investigated when we operate the above-mentioned descriptive characteristics as a whole - the fact strongly opposing the textbook archetypes of low cost business model. Regarding fleet composition and network design only Ryanair gets near theoretical drivers of low-cost carrier letting the others be somewhere in the middle. For instance, Flybe, which was regarded generally as a low-cost carrier, records fleet structure characteristics more typical for full service carriers. Similarly, easyJet and Flybe operate hub and spoke system typical for a full service network carrier offering transfer flights for their passengers – again a feature typical for a clear full services concept of business model. Moreover, Flybe may be noted for its horizontal cooperation – again a fact attributable to full service network business model – as hybridizing airline blending features typical for both theoretical archetypes. Information contained in Table 1 shows yet that every airline business model driver relevant for business model analysis can be described by optional parameters and approaches which can be tackled by different authors differently and thus any conclusion about type of business models applied within airlines is highly influenced by methodology taken. Consequently, one airline may be denoted as low-cost by some authors while others may designate it as hybrid almost with prevailing features of full service network operation. Klophaus et al., for instance, deem that only Ryanair may be without any doubt indicated as a purely low-cost while easyJet is more a hybrid airline with still prevailing low-cost features and Flybe evinces like a more hybrid airline strongly converging by its business concept to full service carriers [1].

We searched the role of ancillary revenues of the airlines as a component present in different (i.e. unique) business models of three different (i.e. unique) airlines more or less coinciding with theoretical (and textbook only) assumption about low cost airline business model. Moreover, ancillary revenues of the airlines may have different structure resulting from different policy depending on the fact whether more bundled or more unbundled product policy is implemented within airline. As Table 2 depicts, there are not so significant differences in main components of ancillary revenues generated by airlines in the sample investigated, however, specific components of ancillary revenues may differ by their generators withal, for instance checked bag charge may contain charge for the 1st baggage or not etc., for the 2nd baggage or not etc.) [8]. Also, Table 2 informs only about main generators of airlines ancillary revenues which cannot fully provide necessary information on innovation in ancillary revenues generation [9].

As importance of ancillary revenues for airlines economics has been mentioned many times in scietific literature we decided to verify the statement by simple explanatory model. Thus, our research aim was to state in a quantitative way impact of ancillary revenue dynamic on dynamics of total airline revenues.

Overview of Main Generators of Airlines Ancillary Revenues Table 2

| | F B on Board | Baggage Checking | Advertisement | Frequent Flyer Programs | Seat Assignment | Credit Card Payment |
|---|---|---|---|---|---|---|
| Ryanair | + | + | + | - | + | - |
| easyJet | + | + | + | + | - | - |
| Flybe | + | + | + | + | + | + |

*Source: Own investigation based on [10], [11], [12]* Input Data for Analysis Table 3

| Year/Airline | Total revenues (of which ancillary revenues in %) | | |
|---|---|---|---|
| | Ryanair (in mil. EUR) | easyJet (in mil. GBP) | Flybe (in mil. GBP) |
| 2006 | 1,693 (15.31) | 1,620 (8.1) | 513 (12.48) |
| 2007 | 2,237 (16.18) | 1,797 (9.53) | 536 (12.23) |
| 2008 | 2,713 (17.99) | 2,363 (15.54) | 572 (12.86) |
| 2009 | 2,941 (20.32) | 2,667 (19.36) | 571 (15.07) |
| 2010 | 2,988 (22.20) | 2,973 (19.22) | 596 (16.61) |
| 2011 | 3,629 (22.09) | 3,452 (25.79) | 615 (16.95) |

*Source: [5], [6], [7]*

To quantify the impact of ancillary revenues on airlines total revenues, we used explanatory analysis in the form of a dynamic additive model and subsequent quantification procedure as explained by Zalai et al. [13] which produced QAR.

QAR is a quantified impact of ancillary revenues generation on dynamics of total airline revenue.

The result of explanatory analysis we obtained is represented by quantified percentage impact of annual change in ancillary revenues on annual change of airlines total revenues tackled as 100 % (QAR) (i.e. change of total revenues in % as an integer) regardless of the specific case. As source data for computation we used annual reports of the airline companies obtaining in this way a dataset covering annual changes of the characteristic analyzed within the period from 2006 to 2011. Main input data in round numbers for analysis are contained in Table 3.

First glance into the input data reveals growing share of ancillary revenues in total revenues, however, not providing strict quantification of their impact on total revenues dynamics, which was exactly our research aim.

## 3. Results

Summarizing, we tried to reveal determinance of changes in ancillary revenues with regard to changes in total revenues and thus obtain an argument about quantitative significance of changes in ancillary revenues towards changes in total airlines revenue. We deem that our methodology enables to reveal more a role of ancillary revenues as pro-profit drivers through its role in increase of total revenues. Applying the standard procedure of explanatory analysis, we have got the research output contained in Table 4.

Although mutually diverse, in bulk the research outputs identify clearly strong determinative impact of changes in ancillary revenues on dynamics of total revenues achieving in majority of cases double-digit score. In all investigated cases our analysis also revealed the ancillary revenue changes as important pro-revenues and thus pro-profit driver. It can be documented, for instance, by Flybe result in 2007 when in spite of generation of loss ancillary revenues ensured 6.8 % of the total increase in revenues by 4.4 % on annual basis. Similarly, another Flybe result from 2009 suggests that change in ancillary revenues acted as crucial driver against overall decrease of total revenues keeping thus only slight drop in total revenues. So as Ryanair result quantifying determinative share of ancillary revenues in change of total revenues in 2010 at 151.9 % means that other components of total revenues operated against significant positive impact of ancillary revenues on the total revenues value.

The outputs also showed that the share of ancillary revenues in total airline revenues need not express fully their impact on total revenues dynamics. That was a main reason to work just with an explanatory determinative analysis. Although having about 10-20 % share in total revenues, ancillary revenues may reverse negative dynamics of other revenues components or, at least, significantly alleviate worsening dynamics of total revenue generation and thus produce more acceptable result for profit/loss statement. The value of determinative impact of change in ancillary revenues on total revenues change exceeded the share of ancillary revenues in total revenues in majority of cases we investigated. This is the most significant result of our invstigation.

Deeper analysis of ancillary revenues as a driver for positive dynamics of total revenues would require work with data in a more detail which would enable to tackle also the role of separate internal components of ancillary revenues. Such approach could answer how these components influence the final shape of dynamics of ancillary revenues and their impact on total revenues as well and quality of air transportation perceived

Explanatory Determinative Share of Ancillary Revenues in Change of Total Revenues Table 4

| | Year | | | | |
|---|---|---|---|---|---|
| | 2007 | 2008 | 2009 | 2010 | 2011 |
| | Ryanair | | | | |
| Annual Change of Total Revenues in % (regarded as 100 % ) | 32,1 | 1,3 | 8,4 | 1,6 | 21,5 |
| Explanatory Determinative Share of Ancillary Revenues of 100 % Change in Total Revenues (QAR) | 20.0 | 29.5 | 54.52 | 151.9 | 21.4 |
| Profit/Loss Recorded (Ancillary Revenues as Pro-Revenue Driver in Profit Generation) | P ✓ | P ✓ | P ✓ | P ✓ | P ✓ |
| | easyJet | | | | |
| Annual Change of Total Revenues in % (regarded as 100 % ) | 11.0 | 31.5 | 12.9 | 11.5 | 16.10 |
| Explanatory Determinative Share of Ancillary Revenues of 100 % Change in Total Revenues (QAR) | 26.3 | 56.2 | 60.9 | 17.9 | 89.0 |
| Profit/Loss Recorded (Ancillary Revenues as Pro-Revenues Driver in Profit Generation) | P ✓ | P ✓ | P ✓ | P ✓ | P ✓ |
| | Flybe | | | | |
| Annual Change of Total Revenues in % (regarded as 100 % ) | 4.6 | 6.8 | -0.33 | 4.4 | 3.3 |
| Explanatory Determinative Share of Ancillary Revenues of 100 % Change in Total Revenues (QAR) | 6.8 | 23.2 | 652,6 | 56.6 | 27.8 |
| Profit/Loss Recorded (Ancillary Revenues as Pro-Revenues Driver in Profit Generation) | L ✓ | P ✓ | P ✓ | P ✓ | P ✓ |

*Source: Own. Results are round numbers.*
*(When in italic, the determinative quantitative effect acted against the final result of change in total revenues achieved; ✓ indicates situations in which ancillary revenues operated as a pro-revenues driver.)*

by customers [10]. Consequently, the shape of product policy towards more sophisticated innovations could be researched more to highlight product/price strategy followed by airlines and its role in the battle of competition in down-stream markets within air transportation industry.

## 4. Conclusions and future research ideas

Our research has confirmed in a quantitative way that low-cost airlines at the time are much more dependent on earning generated out of traditional ticket sales though ancillary revenues streams and the tendency is unambiguous and percieved by passengers as a distinguishing feature of low cost airlines [11] and [13]. Based on case studies of three airlines traditionally ranked among leading European low-cost carriers (Ryanair, easyJet and Flybe) we have provided a quantitative proof about significance of ancillary revenues in total revenues dynamics in the low-cost airline industry using tools of explanatory determinative analysis applied on simple additive revenues model. The fact of increasing role of ancillary revenues has been mentioned verbally many times in numerous scientific literature, however, our approach has focused on achieving quantitative result in a different way not relying only on the 'growing share of ancillary revenues in total revenues' argument. Resulting from our findings, value of determinative impact of change in ancillary revenues on total revenues change exceeded the share of ancillary revenues in total revenues in majority of cases we investigated. Our methodology presented here may be used on a broader list of airlines encompassing also full service network airlines. It can also help to understand more the nature of different ancillary revenues within different product and price policies of airlines. Such approach could contribute to reveal strategies of ancillary revenues applied in airlines – a question that may be different not only among airlines business models but also among world regions as well.

**Acknowledgement**

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## References


[1] KLOPHAUS et al.: Low Cost Carriers Going Hybrid: Evidence from Europe. *J. of Air Transport Management* 23, 2012 ISSN -09696997, pp. 54-58

[2] LOHMANN, G., KOO, T. T. R.: The Airlines Business Model Spectrum. *J. of Air Transport Management*, *7,* 2012, ISSN -09696997, available online http://dx.doi.org/ 10.1016/j.jairtraman.2012.10.005

[3] DAFT, J., ALBERS, S.: *A Conceptual Framework for Measuring Airline Business Model Convergence.* Working Paper 110, 2012, University of Cologne

[4] MASON, K. J., MORRISON, W. G.: Towards a Means of Consistently Comparing Airline Business Models with an Application to the 'Low Cost' Airline Sector. *Research in Transportation Economics* 24, 2008, pp. 75-84

[5] Annual reports of Ryanair

[6] Annual reports of Flybe

[7] Annual Reports of easyJet

[8] BARONE, J. G. et al.: Baggage Fees and Airline Performance: A Case Study of Initial Investor Misperception. *J. of the Transportation Research Forum*, vol. 51, No. 1 (Spring 2012), pp. 5-18 Transportation Research Forum

[9] GARROW, L. A. et al.: Assessment of Product Debundling Trends in the US Airline Industry: Customer Service and Public Policy Implications. *Transportation Research Part A* 46, 2012, ISSN: 0965-8564 p. 255-268

[10] O´ CONNELL, J. F., WILLIAMS, G.: *Passengers' Perceptions of Low Cost Airlines and Full Service Carriers - A Case Study Involving Ryanair, Aer Lingus, Air Asia and Malaysia Airlines*, Air Transport Group, 2008

[11] O´CONNEL, J. F., WARNOCK-SMITH, D.: An Investigation into Preference and Acceptance Levels of Airline Ancillary Revenues. *J. of Air Transport Management* 33, 2013, ISSN -09696997, pp. 12-21

[12] ZALAI, K. et al.: *Financial - Economic Analysis of Enterprise - the 8th edition (in Slovak)*, 2013. ISBN 9788089393800

[13] WITTMER, A., ROWLEY, E.: Customer Value of Purchasable Supplementary Services: The Case of a European Full Network Carrier´s Economy Class. *J. of Air Transport Management,* in press 2013, pp. 1-7.

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# EUROPEAN AUTOMATED CONTAINER TERMINALS

*The establishment of the container as a cargo packaging unit belongs to the most significant developments in maritime transport in the 20th century. Containers started to be used in sea transport due to the reduction of loading time. They also protect cargo against its damage, theft and loss [1]. Containers are transported by specialized cellular container ships that are classified into the generations depending on their size. The role of the container terminals is to handle, load, unload, and transfer containers by special equipment. There is also a yard where containers are stored [2] and [3]. Congested container sea ports have implemented new ways how to increase their throughput. The construction of automated container terminals is one way how to do it.*

***Keywords:*** *Automated container terminal, automated guided vehicles, automated stacking cranes.*

## 1. Introduction

Container terminals are facilities where containers are loaded, unloaded, handled, and transferred by different type of container handling equipment between different means of transport. They are also stored in an open-air storage area for a few days before they are forwarded by sea or land transport to their customers [2].

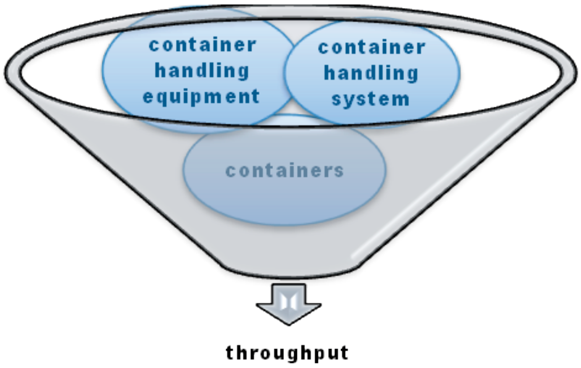


*Fig. 1 The factors that influence the throughput of the container terminals*
*Source: authors*

The throughput belongs to the most important indicators of the container terminals. It may be defined as the number of containers that are transferred by handling equipment for the monitoring period. It depends on the types of:
- container vessels that sail into the terminal,
- containers,
- container handling equipment,
- container handling systems (see Fig. 1).

The various downtimes that decrease the throughput of the terminals arise during handling of containers. They follow from the breakdown rate and technical breaks of container handling equipment, auxiliary operations that are related to the vessels such as anchoring and inspection of vessels controls of the documents or containers [4].

The container sea ports have implemented various ways how to increase their throughput, such as:
- to increase the number of gantry container cranes that serve container ships,
- to increase the number of trolleys of cranes and their travelling velocities,
- to modify spreaders of cranes that may lift at least 2 containers in one operating cycle such as twin lift container spreaders (Fig. 2), double or triple spreaders,

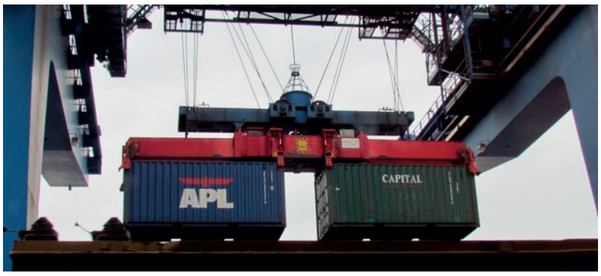


*Fig. 2 Twin-lift spreader*
*Source: authors*

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- to automate handling systems in the container terminals [5] and [6].

## 2. Container handling equipment

Container handling equipment can be divided into two categories:

1. Equipment that moves containers between the vessel and the terminal such as gantry container cranes. These cranes belong to the most widespread equipment in the world container sea ports. They can serve specialized container vessels that anchor at the wharf.
2. Equipment that moves containers within the terminal. Various equipment types are used for handling of containers within the terminal. Straddle carriers, automated guided vehicles or tractors towing trailers transfer containers between the wharf and the container yard. Within the terminal straddle carriers, rubber-tired or rail-mounted gantry cranes can carry out stacking or unstacking of containers. Tractor-trailer systems may be involved in receipt-delivery operations [2].

### 2.1 Gantry container cranes

Gantry container cranes are the most characteristic feature of the container terminals. They transship containers between the container ship and the terminal. The latest cranes have their outreach more than 60 m. They can serve vessels that have more than 22 rows of containers on deck. The time for one operating cycle is about two minutes. They can transfer about 30 containers per hour and some of them can handle more than 30 containers per hour [2]. They have to be equipped with double twin-lift spreaders that can lift four 20´s containers or two 40´s in one operating cycle. The throughput of a crane depends on:

- the number of containers that are handled in one operating cycle,
- the time for one operating cycle,
- the speed of a trolley,
- the position of containers on the container ship.

### 2.2 Straddle carriers

Straddle carriers are the most popular type of container handling equipment. They have a wheeled frame that lifts and transports containers within its framework. They can stack containers up to 3 tiers [2].

### 2.3 Rubber-tired gantry cranes

Rubber-tired gantry cranes run on heavy duty pneumatic-tired wheels. They are container-yard stacking device and are used in the combination with other container handling equipment (tractor-trailer set) for the wharf transfer operation. They handle containers within the block that is parallel to the wharf. They can also move from one block to another. These cranes are used mainly in Asian and American terminals [2].

### 2.4 Rail-mounted gantry cranes

Rail-mounted gantry cranes run on steel wheels over fixed rails. They are similar to rubber-tired gantry cranes in the function. They are used in the combination with tractor-trailer sets for wharf transfer operation. In the container terminals two types of cranes are used. The first type of cranes is used for stacking of containers in the blocks of the container yard that are perpendicular to the wharf. The second type of cranes is used on receipt and delivery operations at rail terminal. They usually have large spans and may stack containers up to 6 tiers. Both cranes are used mainly in automated container terminals [2].

## 3. Automated container terminals

Automated container terminals are defined as terminals with some container handling equipment operating without direct human interaction. In most cases, drivers have been physically removed from the cranes. In some cases drivers remain in the equipment cabins but are not needed for the entire duty cycle [7]. Automated container terminals use automated guided vehicles, automated stacking cranes and rail-mounted gantry cranes in their handling systems.

## 4. Automated container terminals in the European sea ports

### 4.1 Port of Rotterdam and its automated container terminals

The port of Rotterdam (Fig. 3) that is the largest sea port in Europe is the gateway for cargo transported from Asia or America. It is located on the banks of the Nieuwe Mass (one of the distributaries of the Rhine River) and the coasts of the North Sea. It is also the largest container sea port in Europe. About 11.87 mil. TEUs were transferred in the port in 2012 [8] and [9].

The container terminals are located in different parts of the port such as Maasvlakte 1, 2, Eemhaven or Waalhaven. They are divided according to the size of container ships. The latest generation of container ships (Ultra Large Container Ships) or bulk carriers can sail only into the parts Maasvlakte 1 and 2 due to their draught. These parts are located near the estuary of the Nieuwe Mass into the North Sea. On the other hand smaller container ships can also sail into the parts of the port that are located more than 30 km from the North Sea in the city centre. These ships transport containers to the United Kingdom or Scandinavia.

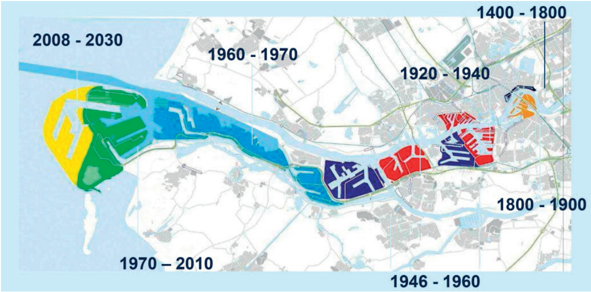


*Fig. 3 The development of the port of Rotterdam*
*Source: port of Rotterdam*

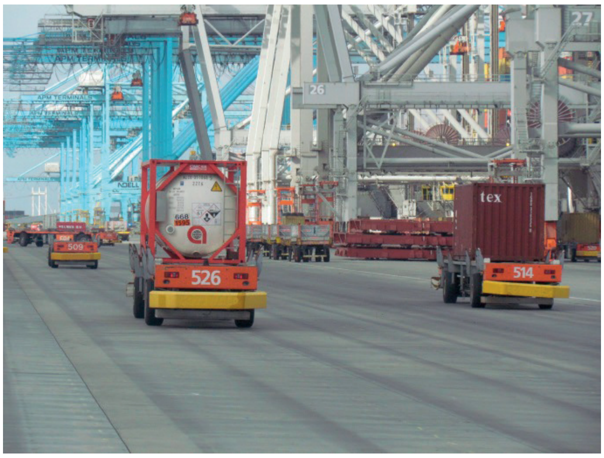

*Fig. 4 Automated guided vehicles in ECT Delta Terminal*
*Source: authors*

Maasvlakte 1 started to be built in the middle of the 1960s. It was the first time that the land was reclaimed from the North Sea for the port. In the 1980s the container terminal operator European Container Terminals (ECT) built its terminal ECT Delta (Fig. 4). It was the first European automated container terminal that started using the system of automated guided vehicles in 1992. The handling system consists of gantry container cranes, automated guided vehicles, automated stacking cranes on rails, straddle carriers and semitrailers. Gantry container cranes tranship containers between the container ship and automated guided vehicles. These vehicles transport containers between the wharf and the container yard that is divided into the blocks according to type of containers and their final destinations, cargo that is loaded into containers. Each block is equipped with one automated stacking crane that transfers containers between automated guided vehicles and this block. It also manipulates containers within the block. Straddle carriers handle containers between the blocks of the container yard and semitrailers. In the terminal there is also a railway station where containers are loaded on the wagons by rail-mounted gantry cranes and are transported to the hinterland [10].

Euromax Terminal Rotterdam (Fig. 5) is another automated terminal in Maasvlakte 1. It started its operation in 2008. Handling system of this terminal is similar to ECT Delta Terminal. Gantry container cranes can also serve the latest generation of container ships with 22 rows of containers on deck. The basic difference is that each block is equipped with two automated stacking cranes. The first crane transfers containers between automated guided vehicle and the block of the container yard, the second crane transships containers between the block of the container yard and semitrailer. In the land side of the terminal there is also a railway station where containers are loaded on the wagons [10].

*Fig. 5 Transfer of containers in Euromax Terminal Rotterdam*
*Source: authors*

Maasvlakte 2 is a new part of the port of Rotterdam. It was the second time in the history of the port that the port spread out its land to the North Sea due to no room for its further development.

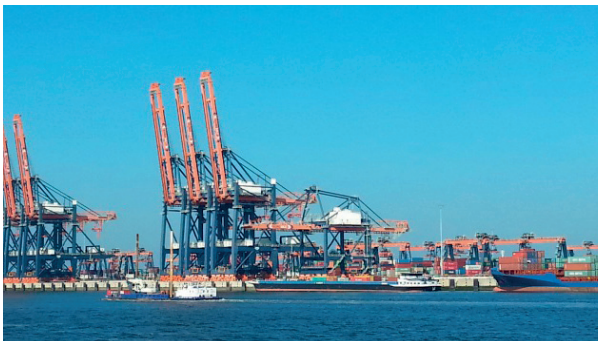

*Fig. 6 Maasvlakte 2*
*Source: authors*

The construction of Maasvlakte 2 (Fig. 6) was started in 2008. About 240 million m³ of sand was required for its construction; most of it came from the North Sea. After opening Maasvlakte 2 in May 2013 the port of Rotterdam widened its land about 20 % (2 000 hectares). New container terminals (APM Terminals and Rotterdam World Gateway) will be opened there in 2014 [9].

## 4.2 Automated container terminals in the European sea ports

The port of Hamburg is the second important container port in Europe. In 2012 it handled about 8.86 mil. TEUs [8]. It is located on the banks of the Elbe River. In the port there are four container terminals, two of them are automated terminals: the Container Terminal Altenwerder (CTA) and the Container Terminal Burchardai (CTB).

At present the Container Terminal Altenwerder is one of the most modern terminals in the world. It was put in operation in 2002. The total costs for its construction were about 650 million EUR, of which 300 million EUR were spent for the construction of quay and infrastructure [11]. It is located in the southern part of Hamburg. Four Post-Panamax ships can anchor at the wharf that is 1 400 m long. The handling system of CTA consists of gantry container cranes, automated guided vehicles, automated stacking cranes on rails and semitrailers. Gantry container cranes that transship containers between the ship and the terminal can serve container vessels Post-Panamax. They have two trolleys. The first trolley (water side trolley) drops containers on the platform that is situated inside of the crane portal. The second trolley (land side trolley) loads containers on automated guided vehicles (Fig. 7) that transport containers to the block of the container yard. Each block is equipped with two automated stacking cranes or rail with the different gauge. The first one transfers containers between automated guided vehicle and the block of the container yard. The second one transfers containers between the block of the container yard and semitrailer. In the land side there is also a railway station where containers are handled by rail mounted gantry cranes between semitrailers and wagons [11] and [12].

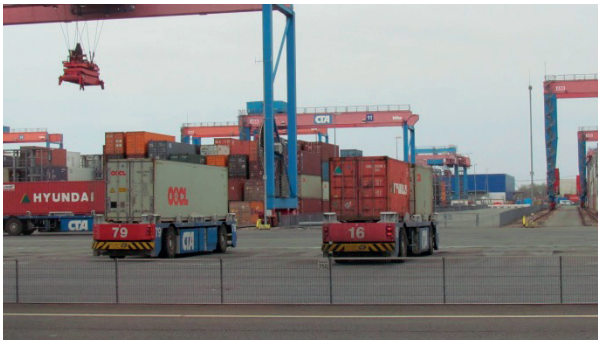


*Fig. 7 Automated guided vehicles in CTA*
*Source: authors*

Container Terminal Burchardkai (Fig. 8) is the oldest and largest container terminal in the port of Hamburg. The first containers were transferred in this terminal in 1968. Ten Post-Panamax container ships can anchor at the wharf that is 2 850 m long. The handling system of the terminal consists of straddle carriers that handle containers between gantry container cranes and the blocks of the container yard. It is one of the oldest systems used in the terminals. At the moment this terminal is being reconstructed. New generation of gantry container cranes will be equipped with double spreaders. They will be able to lift four 20´s containers or two 40´s in one operating cycle. Straddle carriers will handle containers between gantry container cranes and the blocks of the container yard. Each block will be equipped with three automated stacking cranes on rail with the different gauge. Two of them will be smaller, one of them will be bigger. The first smaller automated stacking crane will transfer containers between straddle carriers and the block of the container yard, the second one will transfer containers between the block of the container yard and semitrailers. Bigger automated stacking crane will handle containers within the block. This construction will be completed in 2015 [11] and [12].


*Fig. 8 Container Terminal Burchardkai*
*Source: authors*

## 7. Conclusion

Between 1990 and 2010 the volume of containers that was handled in the container sea ports increased four times. One way how to increase the throughput in the congested container terminals is to automate their handling systems. Rubber tyre gantry cranes, straddle carriers or semitrailers have been replaced by automated handling equipment such as automated guided vehicles or automated stacking cranes on rails. Their movement is managed by the software [13]. In Europe there are only a few automated container terminals. Although the costs of the construction of these terminals are several times higher, their higher throughput, the automation of handling processes, the reduction of port workers including the staff costs have become the most important factors for their constructions.

## References


[1] STOPFORD, M.: *Maritime Economics*. Routledge, Oxon 2009, 816 pp., ISBN 978-0-415-27558-3.

[2] TSINKER, G.: *Port Engineering*. John Wiley and Sons, New Jersey 2004.

[3] AGERSHOU, H.: *Planning and Design of Ports and Marine Terminals*. Thomas Telford Publishing, London 2004, 450 pp., ISBN 978-07277-3498-3.

[4] ZALEZAK, M.: *Technology in Ports and Transshipment Areas, 8 - Container Terminals*. EDIS - the editor of the University of Zilina, 2001, ISBN 80-7100-867-2.

[5] DAVID, A.: *Innovation of Handling Systems in the World Container Ports and Their Terminals*. Proc. of 17th Intern. Conference: Transport Means 2013, Kaunas University of Technology, Lithuania, 2013, pp. 250-253, ISSN 1822-296 X.

[6] SIROKY, J.: *Progressive Systems in Combined Transport*. Pardubice University, 2010, p. 184. ISBN 978-80-86530-60-4.

[7] *Port of Los Angeles Automated Container Terminal Survey*, Oakland 2012.

[8] *Top 50 World Container ports*, online: http://www.worldshipping.org/about-the-industry/global-trade/top-50-world-container-ports, November 2013.

[9] *Port of Rotterdam*, online: http://www.portofrotterdam.com/, 20 November 2013.

[10] *European Container Terminals*, online: http://www.ect.nl, 20 November 2013.

[11] *Container terminal Altenwerder*, online: http://www.svazdopravy.cz/html/cz/ cta.pdf, 20 November 2013.

[12] *Hamburger Hafen und Logistik*, online: www.hhla.de, 20 November 2013.

[13] SOSEDOVA, J., SLESINGER, M., BARIAK, M.: Telematics in Inland Navigation. *Communications - Scientific Letters of the University of Zilina*, vol. 12, No. 3, 2008, EDIS-ZU Zilina, pp. 66-68, ISSN 1335-4205.

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# MICROSCOPIC SIMULATION OF COORDINATED ROUTE IN THE CITY OF ZILINA

*Urban agglomerations are characterized by concentrating a large number of vehicles in a confined space, while it is not possible to increase the range of the road communications. Therefore, it is necessary to achieve better and more efficient use of existing communications. Creation of successful city management means to integrate and optimize the quality of transport. When intersection signal control is used, not only the high degree of safety is ensured, but also permeability of the intersection increases. For better and more effective use of intersections we use a management in real time. We model the program of management by microscopic simulation. In our paper we use simulation of coordination at intersections in the city of Zilina. As modeling tools we use software Aimsun and MATSim which allow microscopic simulation. Finally, in our paper we compare both of the software tools.*

***Keywords:*** *Microscopic simulation of intersections, AIMSUN, MATSim.*

## 1. Introduction

Due to needs of changing mobility demands of population, cities or villages must adapt and create suitable transport infrastructure which will be able to fulfill the demands placed on it and have to introduce measures that will help to make effective of use the transport infrastructure. One of these measures can be reconstruction and building modifications of road communications and a new organization of transport. These activities are logically associated with high financial costs and with certain risk that the new measures will not bring a desired effect. The increase of individual transport, which is more comfortable for its users, especially in time of traffic peak in cities with high intensity of transport flow, has a negative impact on transport quality and environment, emergence of congestions, formation of the exhaust gases, noise, decreasing of road safety, slowing traffic, delay of vehicles at intersections, etc. [1].

Foreign expert studies say that the dynamic management of transport will improve permeability of intersections in the range of 20-30 % compared to the management with fixed signal plans [2].

The issue of management and regulation of urban traffic is one of the most important areas in urban agglomerations. The development of transport has achieved the degree that without thorough revision of management system and regulation, transport collapse would occur in short-time, which would have a negative impact on the other fields of life in city and its inhabitants. Keeping the intensity and safety of vehicles movement along the streets which doesn't endanger the life of the city itself is a task that must be dealt with highest priority, mainly with the help of macroscopic simulation. The base is modeling of vehicles driving within existing communication network, while all parameters of infrastructure and vehicles, including the drivers' behavior are respected [3 and 4].

## 2. Characteristic of the analyzed area

Velka Okruzna Street with its length of about 1.5 km is one of the most important road communications in the city of Zilina. It starts at the junction of streets – Velka Okruzna and 1. Maja and ends at the Murgasova Street. In the past it was an important transport corridor which led traffic from Strecno (today road I/18) to Halkova Street and Rondel and fly-over which roads from Prievidza, Cadca and Bratislava were connected to. Currently Velka Okruzna Street consists of two-lane urban roads and junctions at grade. It is a distributor road of the urban roads category B1 and together with the streets P. O. Hviezdoslava, 1. Maja, Hurbanova, Legionarska and Kalov creates the second ring-road of Zilina. Velka Okruzna Street itself is situated in the central part of the city - see Fig. 1.

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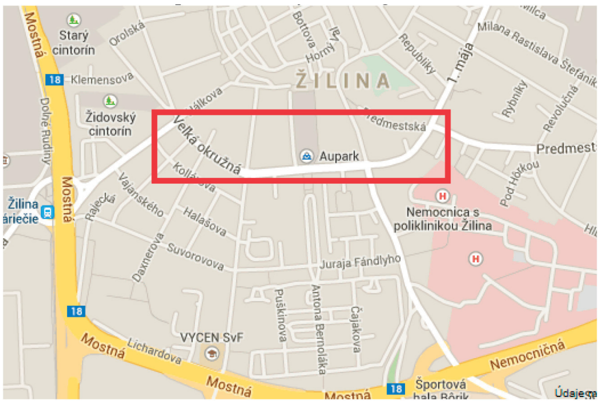


*Fig.1 Situation of Velka Okruzna Street in the city*
*Source: authors using Google maps*

Over 10,000 vehicles pass through this street daily, while an hour traffic volumes come up to 800 veh/hour [5]. In our department within practical exercises in transportation engineering, we regularly carry out the road traffic surveys on these intersections. In the last 10 years the intensity has increased by 7.54 % - at the junction of Velka Okruzna - Komenskeho streets and in average by 14.21 % at the chosen communication. Figure 2 shows the traffic peak intensities of traffic flow at the chosen part of Velka Okruzna street. In addition, almost all public transport lines cross or at least pass through this street.

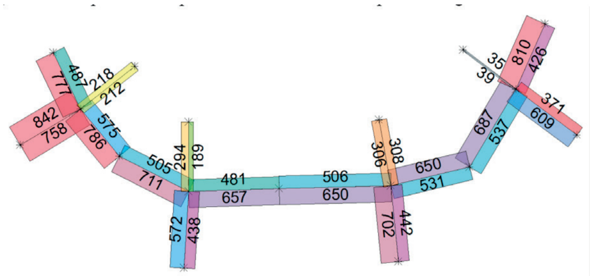


*Fig. 2 Rush-hour rate at the chosen part of Velka Okruzna street*
*Source: authors*

## 3. Modeling of transport at junctions

The advantage of simulation techniques is that they allow insight into existing system without its disruption, as well to repeat the whole simulation process according to needs and modify input data both in real time and in expedited time. With the progress in field of computer technology and with selecting the appropriate tool or software it is possible to model and simulate more and more extensive network. The base of microscopic simulation is to find optimal relation to every single situation and to verify it empirically, which is nearly always complicated. Compared with the conventional calculations, it allows much better approximation to reality and also much easier and better verifiable entering of the input data.

a) Aimsun

Other modeling tool we used was AIMSUN software tool (Advanced Interactive Microscopic Simulator for Urban and Non- Urban Networks) of a Spanish company TSS (Transport Simulation Systems) which is able to reproduce on computer real traffic conditions in any transport network. It is designed especially for testing new control systems.

By simulation in this program it is possible to get a lot of outputs which are divided into groups: statistics for the whole network, statistics for sections and turns, statistics for the chosen road, statistics for matrix source/destination and statistics for public transport. Outputs such as the average intensity, density, mean speed, section speed, travel time, delay time, stop time, number of stops, total traveled distance, total travel time, fuel consumption and quantity of produced emissions are generated for each group. The differences between particular groups are in requirements on input data and in units in which the outputs are calculated [6].

b) MATSim Multi-Agent Transport Simulation

MATSim, standing for Multi- Agent Transport Simulation, is a free transport planning software developed in Germany (Berlin Institute of Technology) and Switzerland (Swiss Federal Institute of Technology Zurich) and is used all around the world including Poland, Singapore, Indonesia, Canada, South Africa, Israel, Japan [7].

MATSim provides a framework for implementing large-scale agent-based transport simulations. The framework consists of several modules which can be combined or used stand-alone. Modules can be replaced by their own implementation to test single aspects of their own work. Currently, MATSim offers both framework for demand-modeling, agent-based mobility simulation (traffic flow simulation), re-planning, and a controller to iteratively run simulations as well as methods to analyze the output generated by the modules.

Key Features of MATSim

- Fast Dynamical and Agent- Based Traffic Simulation: Simulates whole days within minutes,
- Private and Public Traffic: Both private cars and transit traffic can be simulated,
- Supports Large Scenarios: MATSim can simulate millions of agents or huge, detailed networks,
- Versatile Analyses and Simulation Output: E.g. compares simulated data to real- world counting stations,
- Modular Approach: Easily extended with your own algorithms,
- Interactive Visualizer: See what each agent is doing during the simulation,

- Open Source: You get the Java Source Code which runs on all major operating systems,
- Active Development: We add constantly new features and improve current ones [7].

The outputs of simulation by default are graphic and text files which are very useful for initial analysis [7]:

- Score Statistics– as an image or text file- the best, average, the worst results of agent for each iteration
- Leg Travel Distance Statistics – is comparable to the score statistics, but instead of the score, the travel distance is ploted.
- Stopwatch – contains the duration of all actions for every iteration.
- ”Leg“ histogram- depicts the number of agents that arrive, depart or are en route per time unit. Histograms are created for each transport mode and, additionally, for the sum of all transport modes.
- Trip Durations – the number of trips and their durations on a time bin level for each activity pair (work – home, home – shopping, etc.)
- In addition it is possible, in the range of application programming (API – Application Programming Interface) to insert own logic to the model and get other outputs [7].

## 4. Comparison of macroscopic simulations

As we mentioned, we solved coordination on communication Veľká Okružná street with microscopic simulation in two variants: junctions with traffic signal control equipment, junctions without traffic signal control equipment where two different transport-planning modeling softwares Aisum and MATSim were used.

a) Creation of model

We can say that the creation of a transport model in both of the programs consists of two main parts:

- Creation/description of the transport network (nodes, sections, junctions, possible turnings, maximal speed on sections, etc., transport management, etc.)
- Creation/description of the travel demand (the volume of single sections- matrix source/destination, description of public transport routes)

In creation of a transport model in both of the modeling tools, the same inputs were used:

- Map bases, number and widths of driving lanes, intensity and direction of transport in single entrances to junctions (which were obtained from road traffic survey which was made by University of Žilina), characteristics of particular vehicles and junctions signal plans.
- For transport generating in both of the cases, the exponential function was used.

The difference in creation of transport network was that in the modeling program Aismsun the modeling network was created ”,by hand” in a user-friendly drawing editor, whereas it was imported into the MATSim from freely available maps (OpenStreetMap and Geofabrik), specifically from the file OpenStreetMap data for Slovakia [8]. The next difference was in definition of light signalization where Aimsun offers a wide range of possibilities and allows to simulate also adaptive control systems such as SCATS, VS- PLUS, preference for public transport, while the module for modeling of road traffic control equipment in transport networks in MATSim was an unsupported function during carrying out this study (26.07.2013), there was only a basic code which allows only simulation of road traffic control equipment with fixed signal plans [8].

Aimsun outputs Table 1

| Simulation outputs | Value | | The difference | Unit | Relative difference | |
|---|---|---|---|---|---|---|
| | without TLE | with TLE | | | | |
| | | | | | | |
| Delay Time | 35.57 | 108.16 | 72.59 | sec/km | 204.08 | % |
| Density | 8.91 | 15.12 | 6.21 | veh/km | 69.70 | % |
| Flow | 4067.43 | 4088.29 | 20.86 | veh/h | 0.51 | % |
| Harmonic Speed | 35.45 | 20.67 | -14.78 | km/h | -41.69 | % |
| Speed | 41.42 | 25.72 | -15.7 | km/h | -37.9 | % |
| Total Distance Traveled | 2494.07 | 2495.46 | 1.39 | km/h | 0.06 | % |
| Total Travel Time | 68.17 | 11563 | 47.46 | h | 69.62 | % |
| Travel Time | 101.84 | 174.48 | 72.64 | sec/km | 71.33 | % |

Source: authors

MATSim outputs Table 2

| Simulation outputs | Value | | The difference | Unit | Relative difference | |
|---|---|---|---|---|---|---|
| | without TLE | with TLE | | | | |
| Delay Time | 272.32 | 278.07 | 5.75 | sec/km | 2.11 | % |
| Density | 8.32 | 8.34 | 0.02 | veh/km | 0.24 | % |
| Flow | 7014.4 | 7013 | -1.4 | veh/h | -0.02 | % |
| Harmonic Speed | 5.26 | 5.18 | -0.08 | km/h | -1.52 | % |
| Speed | 30.63 | 29.41 | -1.22 | km/h | -3.98 | % |
| Total Distance Traveled | 2347.14 | 2347.12 | -0.02 | km/h | 0 | % |
| Total Travel Time | 241.81 | 246.48 | 4.67 | h | 1.93 | % |
| Travel Time | 370.86 | 378.02 | 7.16 | sec/km | 1.93 | % |

Source: authors

Comparison of outputs of Aimsun – MATSim Table 3

| Simulation outputs | Value | | The difference | Unit | Relative difference | |
|---|---|---|---|---|---|---|
| | Aimsun | MATSim | | | | |
| Delay Time | 108.16 | 278.07 | 169.91 | sec/km | 157.09 | % |
| Density | 15.12 | 8.34 | -6.78 | veh/km | -44.84 | % |
| Flow | 4088.29 | 7013 | 2924.71 | veh/h | 71.54 | % |
| Harmonic Speed | 20.67 | 5.18 | -15.49 | km/h | -74.94 | % |
| Speed | 25.72 | 29.41 | 3.69 | km/h | 14.35 | % |
| Total Distance Traveled | 2495.46 | 2347.12 | -148.34 | km/h | -5.94 | % |
| Total Travel Time | 115.63 | 246.48 | 130.85 | h | 113.16 | % |
| Travel Time | 174.48 | 378.02 | 203.54 | sec/km | 116.66 | % |

Source: authors

b) Outputs of modeling

The following statistics was chosen and compared for our purposes: delay time, density, traffic flow, section speed, mean speed, total distance traveled by all vehicles, total time traveled by all vehicles, travel time.

There are simulations outputs of Aimsun modeling program in Table 1, the simulation outputs of MATSim modeling program are in Table 2. The third table (Table 3) compares simulation outputs in both of the modeling programs.

The results of simulation in Aimsun modeling program (see Table 1) show better statistics for network without traffic lights equipment (TLE), for example, delay time for this network is lower by 72.59 sec/ km, which represents the difference of more than 200% and mean speed of vehicles without traffic lights equipment would be higher by nearly 38%. The reasons for these differences are as follows:

- Junctions are in coordination. For our period of modeling (15:00 – 16:00) they are set to cycle 109 s and in most of the junctions (except junction Velka Okruzna – Komenskeho) there is a four- stroke control.
- Signal plans of junctions (also signal plan of light controlled pedestrian crossing at Dom odborov) are designed to ensure safe pedestrian crossing at every contemplated junction and, therefore, the implementation of signal plans to our model was included with pedestrians which the variant without traffic lights equipment ignores.

The same as in Aimsun modeling program also in MATSim modeling program were simulated and compared variants with or without traffic lights equipment. The outputs of this modeling program showed different values as the outputs of Aimsun modeling program. In Table 2 we can see only slight change between variants with and without traffic lights equipment (2.11% increase of delay time, 3.98% decrease of speed, etc.) and in Table 3 we can see the differences in simulation outputs of both Aimsun and MATSim modeling programs.

The reasons for these differences can be seen in the following factors:

- Setup of MATSim allows setting an adjustable flow capacity and storage capacity factor which is set on the base of empiric results for the whole network. These factors are preset to value 1.0 and the results of simulation are very sensitive to their change. In our paper this factor with the value of 2.0 was used because these settings provide more realistic results, but to capture real-time status further adjustments of this factor would be required.

- The module for modeling traffic lights equipment at transport networks in MATSim- was an unsupported function during carrying out this study on 26 th of July 2013, there was only a basic code which allows only simulation of road traffic control equipment with fixed signal plans.
- Finally, the differences could have been caused by different creation of model of transport network where in modeling program Aimsun the network was created manually, whereas in MATSim it was imported from the maps [7].

## 5. Conclusion

As we mentioned, recently there has been tremendous growth in road transport which has great demands on the accessibility of the city. Constantly increasing traffic results in growth in number of congestions, increasing idle times and environmental damage [9]. Traffic modeling helps to manage all these problems. Traffic modeling doesn´t include only traffic simulation, but it is a wide range of tools ranging from simple application for only one purpose to complex tools which enable to perform complicated analysis of transport networks. Then the outputs can be easily understandable models which can be implemented into the real environment and which provide relevant information. One of the disadvantages of traffic modeling is the fact that a traffic model and simulation don't solve the problem. The outputs of the simulation can only indicate the correct way of solving the problem. Traffic modeling can be used to many operations and there is assumption that the importance of the traffic modeling will be increasing with the increase of transport. In our study traffic modeling confirmed improvement of traffic situation after the coordination of signal controlled junctions in the particular Slovak town and also traffic modeling was shown as a convenient tool in creation process of further transport solutions.

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## References

[1] KALASOVA, A., KUPCULJAKOVA, J.: The Future in the Telematics Applications as Support for Increased Safety. *Transport Problems*, vol. 7, No. 1, pp. 103-110.

[2] JAGELCAK, J.: Equation of the Standard EN 12195-1 Stipulates Unreasonable Demands for Cargo Securing, *Communications - Scientific Letters of the University of Zilina*, vol. 9, No. 4, 2007, pp. 30-33, SCOPUS, ISSN 1335-4205

[3] KUBASAKOVA, I., SULGAN, M.: Using the Intelligent Systems for Transport and Logistics. *LOGI Scientific J. on Transport and Logistics*, No. 1, 2013 Institute of Jan Perner, Pardubice, pp. 86-94, ISSN 1804-3216.

[4] ONDRUS, J., DICOVA, J.: Prediction and Analysis of Motorization Rate Development in Chosen Districts of Slovak Republic, *Archives of Transport System Telematics*, vol. 6, No. 3, 2013, pp. 26-32, ISSN 1899-8208.

[5] *Urban Plan of City of Zilina*, Available at the internet: http://www.zilina.sk/docs/ 2012/ upm_zilina/Obligatory_part_text.pdf; http://www.acea.be (The European Automobile Manufacturers Association).

[6] *TSS – Transport Simulation Systems*. Aimsun 7 Dynamic Simulators User´s Manual May 2012.

[7] http://matsim.org/ on September 2nd, 2013

[8] http://download.geofabrik.de/europe/slovakia.html

[9] SOSEDOVA, J., SLESINGER, M., BARIAK, M.: Telematics in Inland Navigation. *Communications – Scientific Letters of the University of Zilina*, vol. 12, No. 3, pp. 66-68, 2008, ISSN 1335-4205.

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# THE CUSTOMER CONTENTMENT WITH PRODUCTS AND SERVICES IN TELECOMMUNICATIONS SECTOR IN THE SLOVAK REPUBLIC

*Communication is very important for people. Means of communication are constantly increasing and new forms, and ways of communication are developing because of technological innovations. The paper is focused on a part of the marketing research of customers´ contentment and their preferences in order to determine their requirements and preferences in the field of mobile and data services of mobile operators. Results and conclusions of this paper should help mobile operators to identify customers´ needs and allow to customize their service offers. The level of competition in the selected market is relatively low, despite the fact that it is growing nowadays. The first part of the paper focuses on the theoretical basis of customer satisfaction in the telecommunications market and the second part on preferences survey and customers´ contentment in the market and its evaluation results.*

***Keywords:*** *Telecommunications, customer, market, hypothesis.*

## 1. Introduction

In the time of globalisation, internalisation, social networks, information spreading and new ways of communication the ability to make up something new, creative, efficient and unique is a key factor of success [1].

The telecommunications sector is playing an increasingly important role in the development of economy and technological diffusion, and its infrastructure and new telematics services provide a fundamental underpinning for information economies. Service quality can be described as a rationale of differences between expectation and competence along the important quality dimensions. Parasuraman, Zeithaml and Berry identified ten requirements useful for customers' evaluation of the quality of services: reliability, responsiveness, tangibles, communication, credibility, security, competence, courtesy, understanding the customers and service accessibility [2].

Since the 1990s, the telecommunications sector has become a dynamic key area for the economic development of industrialised nations. This is the result of enormous technical progress as well as of the increased number of network operators and the intense competition that has developed. These factors, in turn, are a consequence of the removal of monopoly rights, which were mainly enjoyed by state-owned operators of public telecommunications networks [3]. It is well known that service quality, customer satisfaction and customer value are becoming the most important factors of business success for either manufacturers or service providers. However, many different conclusions have been reached and related studies are rather fragmented, especially with regard to customer value. Furthermore, there are few related studies with service quality, customer satisfaction and customer value and their influences on customers' future behaviours in the telecommunications industry [2]. The Slovak mobile communications market is still relatively young.

Several studies have been conducted with the intent to understand customer satisfaction or loyalty of mobile services customers [2, 3, 4, 5, 6, and 7], Most of these studies emphasize that customer loyalty and analysis of factors affecting it are important for the success of mobile services firms [8].

It has been well known that customer-perceived service quality, customer value and satisfaction have been the most important success factors of business competition for either manufacturers or service providers [7, 9, and 10].

Customer satisfaction generally means customer reaction to the state of fulfilment, and customer judgment of the fulfilled state [11]. It heightens customer loyalty and prevents customer churn, lowers customers´ price sensitivity, reduces the costs of failed marketing and of new customer creation, reduces operating costs due to customer number increases, improves the effectiveness of

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advertising, and enhances business reputation [12]. The main factor determining customer satisfaction is the customers´ own perception of service quality [13]. In earlier studies on mobile telecommunications services, service quality has been measured by call quality, pricing structure, mobile devices, value-added services, convenience in procedures, and customer support [14, 15, and 16].

Telecommunications belong to the sector of notification techniques which provides systemic conditions for the implementation of public communications networks. These networks are used to transfer information between pairs or groups of participants in both directions in a dialog way. Telecommunications services provide transmission of information via telecommunications devices (computer, mobile phone, landline, etc.). The role of telecommunications is to process the signal (in the form of data or speech) and ensure its transmission from the transmitter to the receiver via metallic, optical or wireless lines. Telecommunications service providers may be just institutions and companies defined by law and respecting all legal requirements. *Telecommunications* belong to the sector of notification techniques which provides systemic conditions for the implementation of public communications networks.

## 2. Characteristics of Slovak telecommunication market

In 2012, according to the Statistical Office of the Slovak Republic the total revenues from own services and products in the telecommunications sector accounted for 2,126.1 million €. This amount is 0.62% decrease in sales compared to 2011 and 7.32% decrease compared to 2008.

### 2.1 Mobile operators and competition on the telecommunications market

Mobile operators with the largest market share on the Slovak telecommunications market in 2011 are:

- Slovak Telekom, Inc. (39% market share),
- Orange Slovensko, Inc. (32% market share),
- O2 Telefónica Slovakia, Ltd. (20% market share),
- Others (9 % market share).

### 2.2 Selected features of mobile operators market, key problems and survey aim

The market potential is based on the number of residents who are or may potentially be mobile phone users. It is made up of - 5,114,774 inhabitants of the Slovak Republic. According to the Statistical Office of the Slovak Republic in 2011, the number of active SIM cards of mobile services was 5,983,059; it was 116.4 SIM cards on 100 inhabitantsThere are some features typical for the Slovak mobile operators market:

- low level of competition,
- high volume of sales, periodicity of businesses,
- strong market regulation,
- customers´ sensitivity to price changes,
- lack of flexibility in the field of customers´ requirements.

The fast changes of the environment, economy, and technology etc. or globalization processes have impact on the needs and expectations that new companies must fulfil [14].

With regard to the market characteristics, specifications and current development related to the decrease in the market, it is necessary to obtain *additional information regarding customer preferences.* Because of the extensity of telecommunications market and wide spectrum of provided services, we decided to focus on *the market of mobile operators and data services market.* The survey aims to identify the requirements and preferences of customers and services provided to them. Marketing survey of customers´ preferences on mobile and data telecommunications services market is realized due to lack of information of this kind, such as technical information and those from secondary sources.

*Marketing survey of customers´ preferences, focused on services provided by mobile operators, carried out on the market of mobile and data services within the Slovak republic.*

Marketing research has the character of quantitative, single, descriptive survey pre-test.

This survey helped to identify the requirements and preferences of customers for services provided by mobile operators in the selected market.

Survey realization is associated with the fact that there is a large number of customers and users of services provided by mobile operators in the market in Slovakia, evidenced by the statistics of the number of active SIM cards operators as well as a high degree of market saturation. Although the market capacity exceeds market potential, price of services provided by mobile operators are still relatively high. However, we believe that the use of these services despite this fact will not decrease significantly because it is a relatively popular form of communication among people. The low level of competition in the market has been caused by the strict regulatory actions of the Telecommunications Office of the Slovak Republic. This low level of competition in the selected market does not oblige providers of mobile telephony and data services to monitor and adapt their services to specific customer requirements. There is a slight liberalization in the market. This liberalization is particularly related to free regulatory measures, for example, the allowance of the telephone number transfer to another mobile operator. In recent years, there has been a slight increase in competition, decrease in market prices, reduction of interconnection fees for services and it was also linked to a slight decline in sales of mobile operators. Since the services do not still reflect the actual needs of customers, we think that just tracking customers´ requirements and preferences of the provided services could lead to a competitive advantage and become a key factor for success in the market in the future.

*The survey aim* is based on the selected marketing problem. This aim leads to hypothesis determination and other survey process to reach the selected goal. The aim of this study is to find out the following information:

- information related to *customers´ requirements* - mobile and data services – price, quality and quantity, safety, complexity, comfort, form of service provided, etc.,
- information about *mutual relations and dependencies* between the selected variables,
- information about *preferences among the requirements* of customers of mobile and data services,
- information *regarding the respondents* in demographic terms - gender, age, employment status, monthly income, level of education, place of residence.

For the needs of selected study we determined following hypotheses:

**Hypothesis 1**: The most preferred requirement of customers to mobile and data services in terms of activation time, price and form of provided services is the price.

**Hypothesis 2**: The most preferred form of communication is represented by voice talks regarding these factors: price, availability, reliability and user comfort.

**Hypothesis 3**: There is a relationship between the respondent's work position and daily use of mobile and data services.

## 3. Methodology, data and variables

The base set of respondents is made up of inhabitants of the Slovak republic at the age of 18 and over. The sample was determined by quota sampling based on demographic characteristics – age, place and gender. Through this method a quasi-representative sample of respondents was determined which can be considered representative only on a particular likelihood principle.

The sample size of respondents was determined by free available on-line calculator of the company Creative Research Systems engaged in marketing research, surveys and statistical data processing.

The above calculation indicates the need to address the questionnaire to 384 respondents. This sample was calculated at 95 % confidence (accuracy) interval of estimate and margin of error in the estimate equal to 5. The margin of error reflects the width of the confidence interval which reflects the degree of particular parameter uncertainty. The survey was conducted by electronic questionnaire which was sent to 1000 respondents. The questionnaire included 15 questions. Initial questions focused on determining the age, gender and other demographic characteristics. Respondents in other issues determined the preferred service, communication method, ancillary services, etc

Data processing includes check and correction of erroneous data from the questionnaires, their classification into groups according to the answers of respondents, encoding and preparations for analysis. *The correction* consisted of discarding incorrectly, incompletely filled questionnaires and questionnaires with a large number of errors (if the numbers of incorrect and incomplete responses were greater than half of all responses). In the case of minor errors in individual questions some correction were made by re-contacting the respondent to amend or withdraw incorrect answers from the questionnaire.

Data classification into logical groups according to possible answers of respondents and selected demographic characteristics (age, gender, place of residence etc.) anticipate the **data encryption**. Data were processed, converted into electronic format and encrypted using software MS Excel and IBM SPSS Statistics 20. Encryption means the transformation of all possible answers of respondents into numerical values. Numerical values are an important step in preparing the data for analysis.

**Data analysis** was performed by computers. Statistical data, connection, interdependencies of variables were analysed and designed using the software MS Excel and IBM SPSS Statistics 20. The aim of data analysis is to draw conclusions and outcomes from the data collected in marketing research. Conclusions should contribute to the solution of defined marketing problem. When analysing the data, we base on the following statistical methods and procedures: descriptive and analytical statistics, semantic differential with3-level bipolar range, monotonic analysis of variance (MONANOVA, CONJOINT) etc.

To confirm or deny hypothesis 1, we used CONJOINT analysis which is one of the most widely used quantitative methods in marketing survey. It allows to measure customer preferences for the selected combination of service parameters to ascertain how changes in these parameters affect purchasing behaviour and decision-making of customers. To confirm or deny hypothesis 2, i.e., the determination of respondents´ most preferred form of communication, we used the method of *semantic differential* with the help of 3-level bipolar scale in the questionnaire.

This method is similar to rating scales and the process of its design works on the basis of opposites. The respondents select particular score on bipolar scale that best describes their attitude. The advantage of this method is an output in the form of transparent chart. This chart allows comparison of opinions and attitudes of respondents [17].

Pearson Chi - square test of independence tests the null hypothesis $H_0$ which expresses the independence of variables.

This method is part of a two-dimensional inductive statistics. If the p - value is lower than the chosen significance level (traditionally 5% = 0.05), the null hypothesis is denied. Chosen significance level reflects the likelihood of an error if we deny the null hypothesis, which is in fact true. That is, if we find that the relationship between the selected variables exists, but, in fact, there is no relationship between them [18, 19 and 20].

When analysing the data obtained in a marketing survey, we used the processes of inductive statistics despite the fact that the quota sampling of respondents does not meet the prerequisites of randomness. It is possible to consider it as a representative selection only under a certain level of likelihood. The project duration was seven months.

## 4. Outcomes and conclusions of customers´ preferences in the market of mobile and data services survey

**H1:**

In the case of provided mobile and data services, following parameters related to customers´ requirements were set:

- activation time,
- price and form of service providing.

We based on the assumption that all consumers want by purchasing services to maximize their usefulness. *Respondents mostly perceived the change in price* because the estimated benefits of the service at 51-75€ per month are the lowest. The result is that *respondents prefer blanket price to prepaid cards,* in the terms of form of provided mobile and data services. According to the values of estimated usefulness, respondents prefer lower price of provided service to a higher one. We also found out that respondents prefer a faster activation of mobile and data services to a slower one.

In the next step of the analysis we estimated the importance of individual factors of provided mobile and data service. This allows us to determine the importance of individual criteria and the order of preferences of respondents for individual requirements while the estimated overall importance of each parameter is:

- form – 14.782,
- price – 61.149,
- activation time – 24.069.

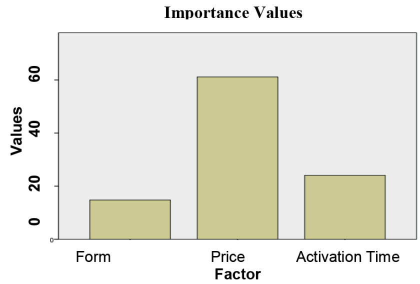


*Fig. 1 Order of respondents´ preferences according to importance*
*Source: Self processed*

The previous chart (Fig. 1) represents the order of preferences of the respondents in terms of the combination of their requirements on the price, form of the provided service and its activation. *The most preferred parameter (requirement) is clearly the price followed by activation time of service and the last place is occupied by the form of service provided.* Hypothesis 1 was confirmed.

H 2:

Table 1 shows average values of respondents´ answers from the scale in questionnaire.

Comparison of individual ways of communication according to respondents — Table 1

| | Voice calls | SMS | MMS | Roaming | Data and internet communication |
|---|---|---|---|---|---|
| Costingness | -0.800 | -0.240 | -1.240 | -1.580 | -0.560 |
| Service reliability | 0.360 | 0.040 | -0.980 | -0.340 | -0.080 |
| Service availability | -0.020 | 0.400 | -0.600 | 0 | -0.520 |
| User comfort | -0.180 | -0.580 | -0.760 | -0.340 | -0.740 |

*Source: Self processed*

Ideal form of communication according to respondents — Table 2

| | Ideal form of communication |
|---|---|
| Costingness | 2.990 |
| Service reliability | 2.620 |
| Service availability | 2.940 |
| User comfort | 2.750 |

*Source: Self processed*

Ideal form of communication according to respondents based on selected criteria is mainly the low-cost communications (Table 2). Another important factor is the availability.

**Legend:**

| | |
|---|---|
| *Red line – voice communication* | *Dark blue line – SMS* |
| *Black line – Roaming* | *Light blue line – MMS* |
| *Green line – Ideal communication* | *Yellow line – Internet* |

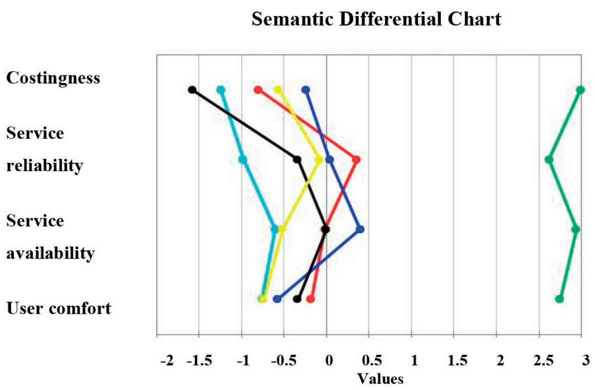


*Fig. 2 Semantic differentials of selected communication forms and the ideal way*

*Source: Self processed*

From the chart of semantic differential (Fig. 2) it is obvious that in term of the *costingness,* the SMS communication is closest to the ideal form of communication according to the answers of respondents. In terms of *reliability* the voice communication meets the ideal. In case of availability of services the SMS communication is best evaluated by respondents. Voice calls meet the ideal form of communication in terms of *user comfort*.

For accurate representation of the distances of selected real forms of communication from the ideal form we use D-statistics procedures. This method quantitatively compares the distance between ideal and real perceptions of respondents´ requests.

Results of D-statistics reflect the differences (distance) between the real and ideal perceptions of communication ways by respondents. The highest obtained value D means that the way of communication is most different from the ideal way (it has the greatest distance), while the lowest calculated value of D reflects the smallest difference between reality and ideal. The result of D-statistics is the SMS communication which represents the smallest difference between reality and ideal - 5.88. Based on calculated values we can consider **SMS communication as the most ideal form according to respondents**. Hypothesis 2 was denied.

**H 3:**

Null hypothesis ($H_0$) claims that there is no relationship between selected variables. On the other hand, hypothesis $H_1$ declares the relationship existence between occupation of respondents and time of mobile and data services usage (Table 3).

Existence of relationship between selected variables Table 3

| | Value | Df | Asymp. Sig. (2-sided) |
|---|---|---|---|
| Pearson Chi-Square | 235.624a | 20 | .000 |
| Likelihood Ratio | 250.707 | 20 | .000 |
| Linear-by-Linear Association | 68.950 | 1 | .000 |
| N of Valid Cases | 400 | | |

Source: Self processed

Existence of independence between selected variables Table 4

| | Value | Asymp. Std. Errora | Approx. Tb | Approx. Sig | |
|---|---|---|---|---|---|
| Nominal by nominal | Phi | .768 | | | .000 |
| | Cramer´s V | .384 | | | .000 |
| | Contingency Coefficient | .609 | | | .000 |
| Ordinal by Ordinal | Kendall´s tau-b | .402 | .027 | 13.441 | 0.000 |
| | Kendall´s tau-c | .323 | .024 | 13.441 | 0.000 |
| | Spearman Correlation | .492 | .031 | 11.226 | .000° |
| Interval by Interval | Pearson´s R | .416 | .036 | 9.118 | .000° |
| N of Valid Cases | | 400 | | | |

Source: Self processed

The resulting p -value of the test is less than 0.05.This means that it is possible to deny the null hypothesis and **confirm the existence of a relationship between occupations of the respondents and their daily time use of the services provided by mobile operators**. Hypothesis 3 was confirmed.

We proved by the analysis *that entrepreneurs and employees use daily more mobile services than unemployed, students and pensioners.* In terms of frequency of the service usage, these segments are more attractive: entrepreneurs and employees (Table 4).

## 5. Conclusion

The survey result confirmed that customers in the Slovak market mostly prefer the price, then the service activation time and the form of provided service. Hypothesis 1 was confirmed. The customers´ most preferred combination of selected requirements on mobile and data services is the service to 25 € per month, activated from 2 to 6 hours, and provided for blanket price. The preferences order for other combinations regarding the selected criteria cannot be created clearly. This fact was the objective of CONJOINT analysis where the order of respondents´ preferences is sorted by: price, activation time, and the less preferred criteria - form of provided service.

Hypothesis 2 was denied. This results from the smallest distance between the ideal and the real form of communication according to these factors: costingness, availability, reliability and user comfort of the service. The SMS communication is followed by the second most ideal form - voice calls, then data, internet and roaming communication. The last place is, according to the distance between reality and ideal, occupied by the MMS communication.

Last hypothesis ($H_3$) was confirmed and there is an existence of a relationship between occupations of the respondents and their daily time use of the services provided by mobile operators. Evaluation of the above results leads us to the following conclusions: As we expected, the low level of competition in the Slovak market of mobile operators and service providers does not force towards improvement of services and lower prices. Customers´ requirements are easily identifiable and, therefore, the businesses in this area should pay attention not only to massive advertising campaigns but also to satisfaction survey and customers´ requirements.

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## References

[1] SOVIAR, J., VODAK, J.: Value Network as Part of New Trends in Communication, *Communications - Scientific Letters of the University of Zilina*, (2), 2012. ISSN: 1335-4205.

[2] WANG, Y. S., LIAO, Y. W.: The Conceptualization and Measurement of Commerce user Satisfaction. *Computers in Human Behavior*, 2(1), p. 381-398, 2007.

[3] GERPOTT, T. J., RAMS, W., SCHINDLER, A.: Customer Retention, Loyalty, and Satisfaction in the German Mobile Cellular Telecommunications Market. *Telecommunications Policy* 25, pp. 249-269.

[4] KIM, D. J., FERRIN, D. L., RAO, H. R.: Trust and Satisfaction, Two Stepping Stones for Successful e-commerce Relationships: A Longitudinal Exploration. *Information Systems Research,* 20 (2), p. 237.257, 2009.

[5] LAI, T. L.: Service Quality and Perceived Value´s Impact on Satisfaction, International and Usage of Short Message Service (SMS). *Information Systems Frontiers* 6(4), pp. 353-368, 2004.

[6] LIM, H., H., WANG, Y. S.: An Examination of the Determinants of Customer Loyalty in Mobile Commerce Contexts. *Information and Management*, 43 (3), pp. 271-282, 2006.

[7] ZEITHAML, V. A., BERRY, L. PARASURAMAN, A.: The Behavioral Consequences of Service Quality. *J. of Marketing*, 60 (2), pp. 31-46, 1996.

[8] DENG, Z., LU, Y., WEI, K., K., ZHANG, J. Understanding Customer Satisfaction and Loyalty: An Empirical Study of Mobile Instant Messages in China. *Intern. J. of Information Management,* 30, 2010, p.p. 289-300.

[9] BOLTON, R., DREW, J. H.: A Multistage Model of Customers´ Assessment of Service Quality and Value, *J. of Consumer Research,* 17, pp. 375-384, 1991.

[10] VALASKOVA, M., KRIZANOVA, A.: The Passenger Satisfaction in the Regional Integrated Public Transport System, *Promet-Traffic and Transportation*, vol. 20, No. 6, 2008, pp. 401-404, Zagreb : Fakultet prometnih znanosti, ISSN 0353-5320.

[11] OLIVER, R.: *Satisfaction, a Behavioural Perspective on the Consumer,* New York: McGraw-Hill, 1997.

[12] FORNELL, C., JOHNSON, M. D., ANDERSON, E. W., CHA, J., BRYANT, B. E.: The American Customer Satisfaction Index. Nature, Purpose, and Findings, *J. of Marketing*, 60 (7), 1996.

[13] ZEITHAML, V. A., BINTER, M. J.: *Service Marketing*. New York: The McGraw-Hill Companies, 1996.
[14] COREJOVA, M., ROSTASOVA, M., CHRENKOVA, A.: *Knowledge Biography – Tool for Researching the Knowledge Dynamics.* Global Engineering Education Conference, 2012.
[15] KIM, H.: The Churn Analysis and Determinants of Customer Loyalty in Korean Mobile Phone. *Korean Information Society Review*, pp. 1-18, 2000.
[16] LEE, J., LEE, J. FREICK, L.: The Impact of Switching Costs on the Customer Satisfaction-loyalty Link: Mobile Phone Service in *France. J. of Services Marketing*, 15(1), pp. 35-48, 2001.
[17] JOHNAROVA, R.: *Marketing of Heritage and Arts*. Praha, pp. 116-117, 2008.
[18] RIMARCIK, M.: Statistics for Practice, Bratislava, p. 71, 2007.
[19] TUREL, O., SERENKO, A.: Satisfaction with Mobile Service in Canada: An Empirical Investigation, *Telecommunications Policy*, 30 (5-6), pp. 314-331, 2006.
[20] WANG, Y., LO, H. P.: Service Quality, Customer Satisfaction and behaviour Intentions: *Evidence from China´s Telecommunications Industry*, 1999.

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Marian Sulgan – Jarmila Sosedova *

# PROCUREMENT OF MATERIALS AND COMPONENTS FOR MANUFACTURING ACTIVITY

*Contribution provides insight into various forms of procurement of material inputs in production companies in the Slovak Republic. Compares the traditional approach with modern systems and highlights the main features of each system with respect to logistics activities.*
***Keywords:*** *Material procurement, inbound logistics, purchase, Just-in-Time, Just-in Sequence.*

## 1. Introduction

With increasing demand for provision of goods and services from external sources, the procurement of these sources has an important role. Procurement may be defined as a purchase of materials and services from external organizations in order to support all operations in the plant - from production to marketing, sales and logistics. Instead of general term "procurement", sometimes also terms such as purchase, supply management, etc. are used. However, they always include the following activities: selection of suppliers, negotiation of price, delivery terms and conditions, payment conditions, etc. If the plant creates a long term relation with key suppliers - partners, the importance of procurement and its possible contribution in terms of profitability will increase.

Basically, there are two different approaches to manage the enterprise procurement. There are systems which work under so-called "push principle" and systems using a "pull principle".

In the system of "Make to stock" the movement of material and information is based on a long-term forecasting demand. Reverse thrust principle means that the movement of the material is carried out only if the following stage of the supply chain is required and, therefore, the system is often called "Make to Order" system.

Supply chains often use both principles, the push principle at the beginning and the pull principle at the last stages of the supply chain.

The main reasons are clear - a growing trend towards wider adaptation and the fact that the value of the product throughout its movement is reflected in the cost calculation. The place where the system changes to the push pull system is called the point of separation.

The article compares the three most widely used forms of procurement:

- Form described as a traditional approach to public procurement because it is based on the push principle - it is an older approach,
- Just in Time procurement,
- Just in Sequence procurement.

Although the last two systems work on the principle of thrust, the differences in their organization and operation are great.

## 2. Description of procurement systems in use today

Company logistics as a subsystem of the company can be divided into the following areas (sub-systems):

a) basic areas of logistics:
  - purchase (acquisition) logistics,
  - production logistics,
  - distribution logistics,

b) cross-sectional areas of logistics:
  - transport logistics,
  - logistics information,
  - storage logistics,
  - it also includes flow of finances, which is in the opposite direction to the direction of material flow and is essential for the functioning of the entire logistics chain and for providing the company's existence [1].

The scope of activities of basic types of logistics is shown in Fig. 1.

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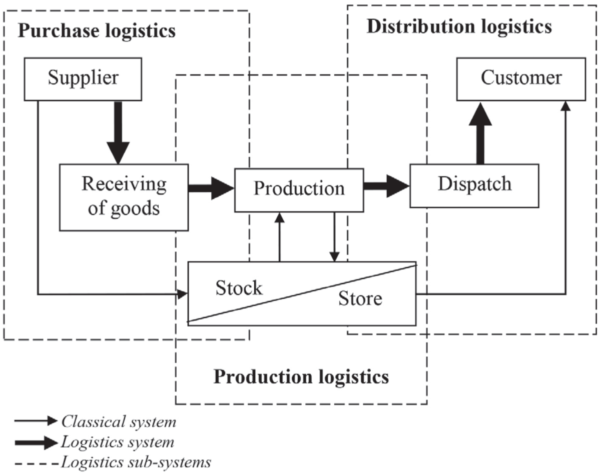


*Fig. 1 Basic types of logistics*

Purchase (acquisition) logistics means a complex of logistics tasks and measures in preparation and execution of purchase of all material items that are necessary for provision of respective production or other activity of the company. It deals with all activities connected with material flow of raw materials, auxiliary materials and production materials, purchased parts from the purchase market for the input store or directly for production.

Areas of purchase logistics cover the following logistics tasks:

- Make or Buy – strategy (together with production and purchase),
- purchase adjusted to production (determination of outgoing types, time and place),
- minimization of transport costs,
- data concerning packaging, binding, quality control, etc.

The most important role of purchase logistics is procurement of all raw materials, components, intermediate products and other supplies for production activities.

Each of the forms of procurement is found in several alternatives. Therefore, choosing the best alternative is very important.

## 3. Traditional procurement

Traditional procurement works in a "Push" principle, which is based on a long term forecasting demand. In this system, it is necessary to store a large number of stocks. There are two basic inventory management systems under traditional procurement [2]:

- Fixed order quantity of inventory held in the system,
- Fixed limited inputs of inventories in the system.

Quantity of material in each supply is constant, the interval between deliveries varies depending on the actual material consumption. The order is executed when the stock reaches a predetermined minimum level, the so-called Order point. Stocks in the system must be constantly monitored. This causes higher requirements on technical and information support of inventory management. Order quantity can be determined by optimizing the total cost function. Optimized ordering is labeled „Economic order quantity".

The system also examines the time interval. The requirement is adjusted to achieve the required level of stock. This procedure is used for a large number of items from the same supplier.

## 4. Just in Time procurement

It is the most widespread logistics technology in the field of supply, production and distribution. It satisfies the requirements on delivery of particular material, parts and components in production or on distribution of finished products (goods) in the distribution segment by its supply JIT (Just in Time); it means accurately and in compliance with the deadlines according to a need of withdrawing segment. This system supplies small amounts and in the latest possible moment, so the supplies are very frequent. The customer is a dominating article of this chain, to which the supplier has to adapt in such a way that in supplies it creates such manipulation units that will smoothly pass through all points of handling operations in a subsequent flow. The aim of JIT strategy is to produce in line with demand through simplification and rationalization of material flows. Deliveries must be synchronized with the production.

A task of JIT is to eliminate any losses [2]. The final ideal state is production without keeping stocks. This concept also includes a method of quality detection as well as the planning of production and material flows, in particular:

- choice of means of transport,
- placement decision,
- relations with suppliers.

The method is considered a tool for decreasing stocks and providing early supply to the plant. The plants using this method concentrate particularly on elimination of time downtimes. The objective is to be closer to the customer and to react faster on changes in needs. The real benefits are based on shortening the entire production cycle. Saving time during the whole cycle results in acceleration of capital turnover, increases performance and flexibility and satisfies the consumer. The location of suppliers closer to the factory (the place of consumption) usually means a reduction in distribution costs. If the rapid reduction of stock is not simultaneously accompanied with the saving of time in a production process, it may cause serious threat to the plant. To adapt to the needs of customers, the suppliers currently use synchronized strategies within JIT system when there is only minimal safety stock for the case, e.g., of unexpected delay of transport or emancipation strategies when the plant produces several supplies to the store, from where they are dispatched according to customer needs in JIT mode.

The advantage of this system is propinquity of the supplier and the customer. On the contrary, this strategy may be limited in the case of not very long transfer distance, border controls and freight forwarding equipage, in the case of not complex composite assortment, in-adaptable structures of suppliers production or unsolved problem of connection in the material flow (not aligning means of transports, unsuitable way of unloading, ineffective quantitative and qualitative control upon receiving goods, long follow-up inter-operational handling) or in information flows (in not smooth transmission of information). The first four above mentioned factors may be eliminated by accepting the emancipation strategy in the form of inserted common warehouse operated by a contractual freight forwarding agency, which in this case also ensures the receiving of supplies sent by the supplier to the warehouse on the basis of appeal to the customer (e.g. storage operations and their evidence, supplies from the warehouse for consumption according to direct appeals in JIT mode). Moreover, this warehouse also provides information services and handles formalities connected with supply transport.

If several suppliers are involved in the subsystem of transit storage supplies, the freight forwarder also performs completion or compilation of items within supply from the warehouse, according to the order required by the customer. Importance of freight forwarders´ involvement in storage systems increases in current trend of distribution channels influenced by global logistics. In general, it is possible to say that JIT system operates in 4 basic fields:

- improvement of stocks turnover,
- better customer service,
- reduction of storage area,
- improvement of response time.

The implementation of JIT system may also cause decrease of distribution costs, decrease of transportation costs, improvement of products quality from the suppliers and reduction of number of carrier haulers and suppliers [3]. Within JIT system, importance of transport as a segment of logistics increases and high requirements are put on it:

- shorter and more reliable time of transportation,
- more sophisticated communication,
- smaller number of carrier haulers with long-term relations,
- effective design of vehicles and equipment for material handling,
- high-quality decision-making models regarding the use of transport vehicles (own, public, contractual).

However, JIT has also some negatives. The emphasis on creating the best conditions for smooth production with minimal stocks may lead to deterioration of conditions for the customer and limitations of the sub-suppliers. On the other hand, the companies with several suppliers may become too dependent. Similarly, JIT system makes high demands on organization of transport process (correct timing of supply, reliability of means of transport, etc.). It is very difficult to implement JIT system, because it requires significant costs to ensure effective operation of the entire system. The most important benefits of the system can be seen only after certain time of its operation. The process of material system includes a sub-system of material availability, material appeal, storage, material preparation, visual management and information system.

Extended JIT system with sequential order is called JIS (Just in Sequence), which is described in the next section.

## 5. Just in Sequence procurement

As already indicated, JIS is a modification of a JIT system. However, this adjustment is very important, so the system is currently marked as a separate - JIS - which is used mainly in automotive industry. Most supply companies for automakers in Slovakia use the JIS system. Suppliers adapt their own production plans so that they can deliver their products at the right time, in the right quantity, at the right place and in a certain order – the sequence.

The need for such a system was caused by increasing variability of input material items (operating units and modules), as well as because of the need of adaptation to the final product according to customer requirements. Within the JIS, it is possible to adjust production to the required specifications according to the customer - that is to modify the specification of individual components and modules. Information is transformed into the production plan, which must be adapted to current ranking cars on the production line. Information for the supplier is generated automatically as a sequence of pulses, which are also automatically sent normally through electronic data interchange [4].

The sequence determines the order in which the modules must be delivered - they are usually shipped several hours before installation into the product. In view of the normal operation of supply, it is possible to perform the shifting process in two basic forms:

- the supplier delivers components under the JIT system in a location near the final assembly of the final product, the components are from this place gradually moved into the assembly line,
- the supplier supplies components directly to the working position on the assembly line.

In the first case, the providers are called third-party logistics providers. They provide services and perform sequential warehouse operations. Products are distributed in the right order and at the right time. Products are loaded on suitable pallets and transported to the assembly line.

In the second case, the supplier places the components into special containers or pallets in compliance with the desired sequence, and such containers are loaded into a vehicle with respect to the order of their unloading. According to the scheduled time the supplier delivers components and a vehicle stops at a particular location that is closest to the assembly line. From there, the containers are moved to the assembly point on the production line. The same car will be venturing empty containers back to the supplier.

## 6. Comparison of procurement forms with respect to the logistics activities

Table 1 shows the differences between various forms of acquisition with regard to the selected logistics criteria. We can see that the warehouse facility prefers decline in inventories (JIT, JIS). The result is a lower probability of generating unproductive inventory. It also appears that the amount by the optimum sequence will significantly reduce inventory. This is the way of maintaining inventory levels (the system maintains inventory levels continuously). Although the system with fixed time constraint is less demanding for the management, maintenance has the potential surplus stock and is vulnerable to supply shortages [5].

In the field of material handling there is an important criterion called "the number of touch points." These points are necessary to ensure the desired order of material inputs into production (it covers all handling activities and all equipment procurement).

Criteria such as accuracy and frequency of the provision of supplies and the distance between the supplier and the customer are very important in the logistics area, especially for demand-driven systems (JIT, JIS).

Accuracy is very necessary for the provision of services under JIT and JIS. Therefore, the entire process must be supported by an efficient information system. It is preferred to use systems based on a modular structure which allows individual processes (modules) to be effectively altered, replaced, moved, or to create entirely new processes. JIS system has relatively high demands on the quality of the information system.

In the purchase, we can see that the traditional form of procurement prefers a multi-sourcing model where the price is the key criterion for vendor selection. Conversely, JIT and JIS systems prefer to focus on one of the selected supplier. The supplier must provide high quality products because the organization of re-delivery is too expensive.

## 7. Conclusion

The paper deals with the characteristics and differences in the forms of contracts that are currently applied in Slovakia. Supply was evaluated in terms of managing logistics and purchasing activities. Differences were examined through a set of selection criteria within the main logistics activities. The main differences concern the storage and inventory management (inventory levels) and transport (frequency and accuracy). Also, logistics, information and communication require some changes (compatibility information systems, increased reaction time, etc.). The procurement differs mainly in the area of supplier selection, the ordering, the control activity and invoicing.


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Some of the differences between forms of procurement — Table 1

| Purchasing activity | Traditional approach | Just-in-time | Just-in-sequence |
|---|---|---|---|
| **Choosing supplier** | Two or more suppliers, key choosing criterion is price | Often only one supplier who has to be able to ensure frequent and accurate deliveries | Often only one supplier who has to be able to assure deliveries in required sequence |
| **Changes in orders** | Delivery time and quality are often changed at the last moment | Delivery time and quality are fixed, quantity can be adjusted within predetermined range according to the current need | Delivery time and quality are fixed, in case of unexpected situation the order of parts has to be changed according to the new sequence |
| **Supplier evaluating** | Quality evaluation, delivery deviations up to 10% are accepted | Deviations are not accepted, price is fixed and it is based on clear calculation | |
| **Invoicing** | Payment after each delivery | Invoices are gathered, payment usually once a month | |

Source: authors

**References**

[1] KUBASAKOVA, I: Just in Time Versus Just in Sequence. *Transportation and Communications*: the Internet magazine 2012. ISSN 1336-7676, pp. 250-256.

[2] KALASOVA, A., KRCHOVA, Z.: *Analysis of Road Traffic Accident Rate in the Slovak Republic and Possibilities of its Reduction Through Telematic Applications.* Transport Systems Telematics. Conference, Katowice, 2010. ISBN 978-3-642-16471-2, pp. 463-468.

[3] DAVID, A.: *Project Support Inland Waterway Transport and Logistics in the Danube Corridor.* Conference New Trends in Water Transport, Zilina, 2012. ISBN 978-80-554-0553-7.

[4] STOPKA, O.: *Trends in Security Storage Halls.* 6th Intern. Conference CMDTUR 2012, Zilina. EDIS - Publishing University of Zilina 2012, pp. 309-315, ISBN-978-80-554-0512-4.

[5] KAMPF, R., LIZBETIN, J., LIZBETINOVA, L.: Requirements of a Transport System User. *Communications - Scientific Letters of the University of Zilina*, No. 4, 2012, pp. 106-108. ISSN 1335-4205.

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Ivana Andriskova - Mariana Strenitzerova *

# THE DIAGNOSTIC SUPPORT TOOL - QUALITY FUNCTION DEPLOYMENT AND ITS IMPLEMENTATION POSSIBILITES TO URBAN PUBLIC TRANSPORT QUALITY MANAGEMENT

*This paper deals with the diagnostic support and its implementation possibilities to urban public transport quality management in the city of Zilina. It describes the Quality Function Deployment method with its own House of Quality tool along with its building. The complex building of the House of Quality was made in order to identify the key drivers needed to be improved for higher customers' satisfaction with the service quality.*

***Keywords:*** *Quality Function Deployment, Diagnostic Support Tool, Urban Public Transport.*

## 1. Introduction

For majority of people, the urban public transport is a part of their everyday lives. And is there anybody at all who has never used urban public means of transport to get from Point A to Point B?

Nowadays the number of people preferring individual car transport is increasing and this fact results into serious problem needed to be solved by the service operators. It is important to outline the main reasons why individual car transport is preferred and to become more responsive to customers' needs. In the city of Zilina there is one service operator – Dopravny podnik mesta Zilina, s. r. o. (DPMZ) whose customers decline in quantity each year. Urban public transport quality management offers several methods and techniques of the service improvement. Quality management diagnostic support is one of them. The aim of this paper is to find the necessary key information exploitable as a basic input for service operator decisions. This information is obtained by the implementation of the selected diagnostic support tool - Quality Function Deployment - generally used in quality management.

## 2. Theoretical Basis

### 2.1. Fundamentals of Diagnostics

Diagnostics has its primary basics in Pain and Remedy management. The pain is the reason why the system is being brought to the decision crossroad called *Bifurcation point* - the position with two possible ways to set out for.

A toothache is a very suitable and clear example for illustrating this. Everybody in their lives has suffered from the toothache. The toothache is accompanied by the pain and it represents the bifurcation point:

a) *one will not see the dentist* = one takes the risk for the pain may be worse, moreover the inflammation could accrue and this could lead to death (the worst scenario),
b) *one will see the dentist* = one would be cured of the pain, moreover the information about preceding the tooth decay can be given [1].

This is the main principle the diagnostics originates from. However, the diagnostics helps to identify the weak spot, it also hints at unused opportunities. The diagnostics helps to:

- tackle arisen problems (the toothache),
- precede adverse situations (the tooth decay).

Quality management diagnostic support offers the extensity tools which can be used in the process of planning the service quality, its implementation or even in the process of its evaluation. Diagnostic support tools help to find and choose the information needed most for repressing the adverse situation along with detecting the way of its effective solving.

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## 2.2. Current Situation Analysis

In the city of Zilina DPMZ has been providing the urban public transport service since November 1st, 1993. The service is provided for inhabitants in order to meet the everyday transport needs (commuting to work, school etc.) and represents very important social-economic component which the environment consist of. To comply with the customers' requirements the quality of service has to be enhanced. The object of the current situation analysis is DPMZ quality management system and its ability to match the customers' needs and preferences.

In the Slovak Republic the framework for urban public transport field goes from the European norm 13816:2002. The Slovak version has the same identification numbers and it is named: *Transportation. Logistics and services. Public passenger transport. Service quality definition, targeting and measurement* [2]. According to this framework the service quality is divided into eight categories and each category of the service quality is specified to details - in fact, these eight categories cover 103 service attributes however, the customers do not rate the service according to as many criteria as the norm suggests [3].

Except for the European norm (which is basic and the most important framework) the bearer quality management frame of urban public transport implies also the ISO certification and audit even though the audit has already been a part of the diagnostic support. The quality management diagnostic support tools are used by service operators less often and assimilation rate differs

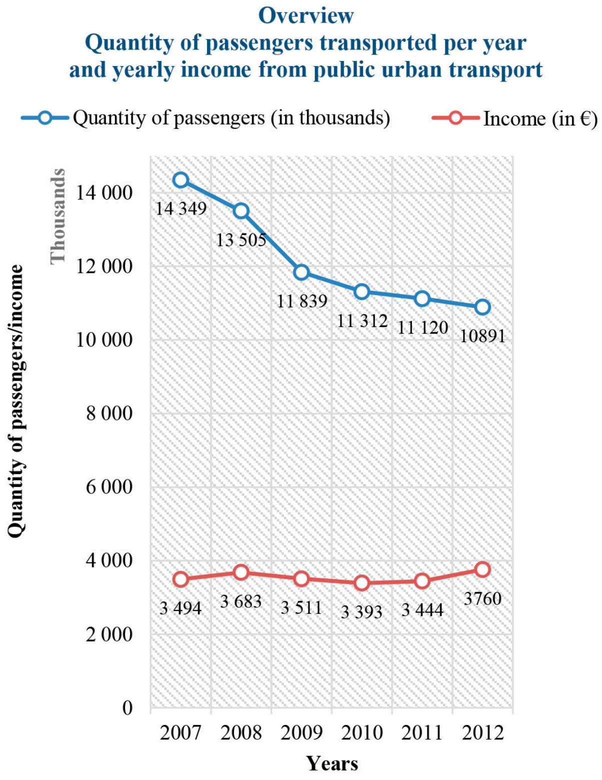



*Fig. 1 Overview - The Quantity of Passengers and Yearly Income (Source: compiled by the authors on the base of DPMZ annual reports)*

Urban Public Transport Quality Management Overview — Table 1

***Urban Public Transport Quality Management***

| | | |
|---|---|---|
| **Basic framework** | | |
| EN 13816 | ✔ | ✔ |
| ISO certification | ↑ increasing tendency | ✘ |
| Internal guidelines (amendment to EN) | **individually** (at the discretion of service operator) | ✔ |
| **Diagnostic support tools** | | |
| Audit | ↑ increasing tendency | ✘ |
| Benchmarking | **low rate** (mostly in big cities in Europe) | ✘ |
| Other tools | **individually** (depends on faced problem) | ✘ |
| | ***Service operators generally*** | ***DPMZ*** |

Source: Authors

from one service operator to another. Overview in Table 1 shows the assimilation rate comparison between service operators in general and the service operator in Zilina DPMZ separately. The information was gained thanks to internal information given by some service operators and accomplished secondary research.

The most reliable indicator showing whether the current quality management system in DPMZ is adequate to customers' requirements or not, is the quantity of passengers transported per year. Information being annually published in DPMZ annual reports experiences the decline. During the last six years (2007-2012) the quantity of passengers transported/year decreased by 3 200 000, however the yearly income from the urban public transport remains at the same level each year (Fig. 1) – this is caused by increasing transport ticket prices.

The quality management system in DPMZ is not sufficient for the market needs and, therefore, the service operator should pay more attention to customers. In the deciding process *the reducing passenger numbers* symbolize a *bifurcation point*. For both sakes (the operator and customers) it is necessary to upgrade the quality management system with the diagnostic support tools focused on customers and their requirements. Higher transport ticket prices along with higher quality of services - but still adequate to the ticket price - would affect the customers' willingness to pay.

## 3. The Research Methodology

The main objective, rising from the current situation analysis, is to obtain more effective quality management system in DPMZ which would lead to higher customers´ trust. This could be achieved by selecting an appropriate diagnostic support tool. When selecting a tool the major purpose to have in mind should be following:

- stabilisation of the quantity of passengers,
- improving the quality service provided,
- enhancing the customers' satisfaction.

## 4. Quality Function Deployment

### 4.1. Selecting the Tool

The technique of mind map was used for selecting an appropriate diagnostic support tool. It helps to detect the structure graphically and linked relations which are important to see.

Complying with the major purpose (mentioned above) the selected method is Quality Function Deployment (QFD) with its specific tool named *The House of Quality* because:

- it is based on customers' requirements,
- it is commonly used in the planning phase of the service quality, but has its own justification in cases the service is already provided but it has some weak spots and the service operator faces the loss of customers,
- DPMŽ has no experiences with the diagnostic support tools and the QFD method used in the planning process of quality seems to be applicable,
- the successful building of the House of Quality would result into meeting the major purpose in order to improve the current quality management system in DPMZ accompanied with a higher customers trust.

### 4.2. Building the House of Quality

The House of Quality is a very complex diagnostic support tool. It combines multiple sub-analyses which differ from each other in difficulty of processing, in types of data input (primary research/secondary research) and in the total time needed for their successful building (Fig. 2).

As the range of this paper does not allow describing each step in detail, only the final results are presented.

The essential and most important step was to identify customers' requirements they have when thinking about quality of urban public transport. It was done by applying the Critical to Quality method which comes from the Voice of Customers. As mentioned in the section *2.2 Current Situation Analysis* the European norm consists of 103 quality service attributes, even though customers use their own characterization – they are not so specific in certain cases and some of the attributes are described widely. It means that one customer requirement can include more than one service attribute determined by the European norm. This information is considerable for a service operator as it helps to focus on necessary service attributes.

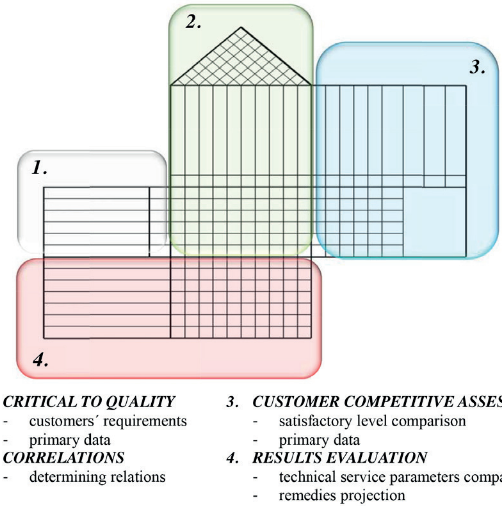



*Fig. 2 Different approaches in the House of Quality (Source: Authors)*

Customers identified *fifteen key requirements* which represent *drivers of satisfaction* when talking about delivered service quality.

After identifying drivers of satisfaction and their significance (weight) the technical service parameters which affect the fulfilment of requirements were assigned to each, for example:

| Customary requirement | is affected | by the technical service parameter |
|---|---|---|
| Timetable keeping | ↔ | Ø delay in seconds |

The correlations among each chosen requirement and each service parameter could be done afterwards. When rating the service quality, *four key technical service parameters* affect customers most. They play a major part in deciding about using the urban public transport or individual car transport. If the customer rates them with high satisfactory score, he prefers the urban public transport. If the score is low, he turns his preferences to individual transport. These are the *most important technical service parameters:*

1. *Ø number of line connection/hour,*
2. *Ø time waiting for the next line connection in minutes,*
3. *Ø delay in seconds,*
4. *Tariff in €/km.*

The second primary research deals with *Customer competitive assessment*. The customers´ 15 drivers of satisfaction were compared to the service quality delivered in other four Slovak cities. Thanks to this rating we are able to see the customer satisfaction score with each requirement even in each city, to define overall satisfaction and calculate total quality service perceived by customers in each city separately.

Drivers of satisfaction score

Table 2

| SATISFIED WITH | Score | DISSATISFIED WITH | Score |
|---|---|---|---|
| Timetable keeping | 2.90 | Frequency off peak | 2.49 |
| Frequency in rush hours | 2.84 | Bus driver driving skills | 2.49 |
| Barrier-free access | 2.81 | Functioning ticket machines on bus stops | 2.45 |
| Travel time | 2.78 | Ticket office opening hours | 2.41 |
| Reliability | 2.77 | Bus indoor temperature adequacy | 2.38 |
| Bus cleanliness | 2.68 | Staff behaviour | 2.19 |
| Bus stop condition | 2.68 | Price | 1.96 |
| Lines continuity | 2.54 | | |
| strongly agree (4.00 – 3.26) | agree (3.25 – 2.51) | disagree (2.50 – 1.76) | strongly disagree (1.75 – 1.00) |

*Source: Authors*

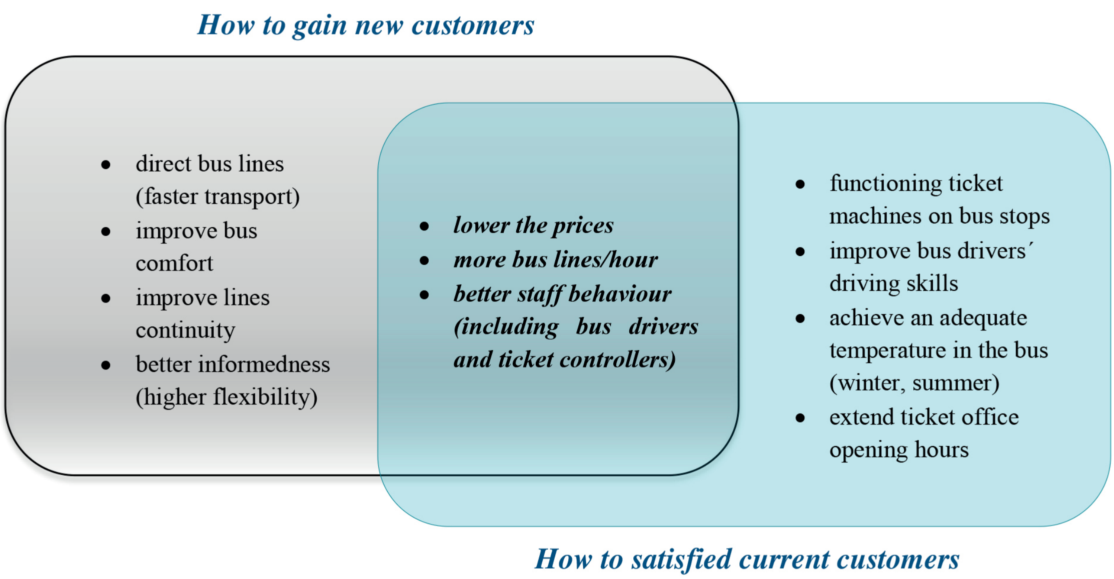



*Fig. 3 How to achieve higher score of customers' satisfaction (Source: Authors)*

Zilina took the fourth place. Complete order of cities according to descending level of satisfaction is as follows:

1. Banska Bystrica – the most satisfied customers,
2. Bratislava,
3. Kosice,
4. Zilina,
5. Povazska Bystrica – the least satisfied customers.

When rating the customer satisfaction level with chosen requirements in Zilina, almost half of them – exactly 7 – cause the customers dissatisfaction. Likert-type scale rate ranged from strongly disagree, disagree, agree and strongly agree. Table 2 shows the overall situation.

The result is noticeable to the service operator because the pros of using urban public transport are almost equal to its cons in general, even though each requirement has its own weight and importance – however, the weight of some service attributes is crucial as the quantity of passengers tends to decline (Fig. 1). The service delivered does not match the sought service quality and this leads to preferring the individual car transport. Each of rated requirements is important for current customers but some of them are significant for people preferring individual car transport only. The research has detected the factors important when deciding whether to choose urban public transport or individual car transport. Upcoming Figure 3 detects the improving service possibilities for routine commuters and for people preferring cars. The conjunction of two parts is in the middle of the figure. These factors are important for both categories. However, the current customers' satisfaction would also increase after improving the factors significant to customers preferring the individual car transport.

## 4.3. Staff Behaviour

The staff behaviour was chosen as the most deep-going factor of the service quality (except for the price). This driver of satisfaction indicates very low score not only in Zilina but in each compared city. Staff behaviour has the lowest average score among all 15 drivers of satisfaction.

When projecting such a complex service as urban public transport is, we often unwittingly focus on technical service parameters while forgetting that the service is provided by people to people (by operator staff to passengers). This means both sides have their own participation in the service quality. The routine commuters cannot avoid getting in touch with operator staff – including bus drivers, ticket controllers, ticket office sellers. Behaviour is rated very anxiously and affects service quality in a less visible and psychological but in even more significant way. Staff behaviour quality elements consisting of staff skill, knowledge and attitude toward the customer may be:

- The staff behaves nicely and correctly.
- The staff answers questions correctly.

The staff represents the operator and the company culture. Employee behaviour and relationship quality impact on customers research shows that service orientation (the operator views interactions with customers as an opportunity to please them, providing a prompt service, having a reputation for good service, is being committed to service customers) affects relationship satisfaction and trust, and that the latter influences satisfaction and commitment (loyalty). In turn, satisfaction, trust and commitment have a positive impact on positive behavioural intentions, trust a negative one on activism (switching to a competitor if customer experiences problem with the service, complaining to external agencies, complaining to other customers), and commitment a positive one on perceived switching costs [4]. This may be a reason why staff behaviour is a significant service attribute to routine commuters and also the ones who had switched to individual car transport.

However, it is hard to generalize as every driver of satisfaction can be also influenced by parameters which are not part of The House of Quality such as traffic situation or transport infrastructure in the city etc. It is found that traffic quality can be an important goal on the one hand. On the other hand, traffic quality can be used to influence many decisions of road management and planning and, thereby, to reach other goals [5]. These correlations can be objectives of further research.

## 4.4. The House of Quality

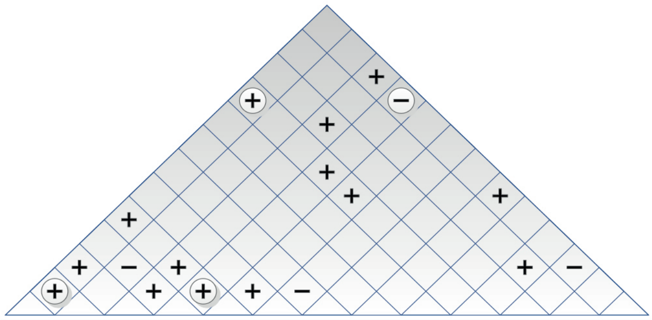
Figure 3 shows completely processed House of Quality. More detailed description of each sub-analysis along with research results is disclosed in the section above.

## 5. Conclusions

The Technical Competitive Assessment is the last part of the House of Quality and we were only allowed to obtain data information from DPMZ thanks to the internal operator assessment. Following remedies projection is a continuous but self-dependent part of research.

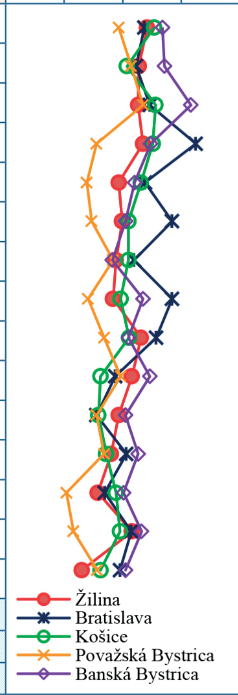
The selected diagnostic support tool meets the major purpose it was chosen for. The several sub-analyses were found very useful for detecting and seeing all the factors along with key factors needed to be improved by the service operator. Thanks to uncovering the customers' requirements, identifying the correlations hidden between customers' requirements and technical service parameters and competitors comparison, it is easy to know the critical service possibilities of improving. After identifying the bifurcation point in the analysis part, the information coming from the House of Quality helps to tackle arisen problem and to precede adverse situations. Just the same thing as the fundamentals of diagnostics say.

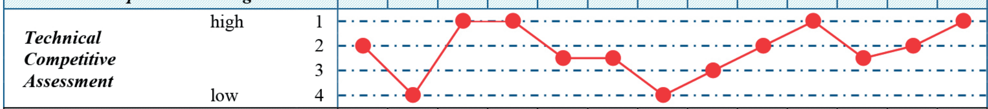
| Correlations: | |
|---|---|
| + | positive |
| − | negative |
| ⊕ | strong positive |
| ⊖ | strong negative |
| **Direction of parameter improvement:** | |
| ↓ | minimized |
| ↑ | maximized |
| ◇ | target |
| **Relationship:** | |
| ● | strong (9) |
| ◉ | moderate (3) |
| ▽ | weak (1) |



***Technical Service Parameters***

| *Customers´ Requirements* | W | Ø delay in seconds ↓ | number of bus stops / line ↓ | numbers of vehicle inspection / month ◇ | Ø number of line connection / hour ↑ | Ø waiting time for line in minutes ↓ | bus stop equipment in % ↑ | ticket office opening hours ◇ | barrier free access buses in % ↑ | number of bus maintenance / day ◇ | bus driver practise ↑ | buses with heating and air conditioning in % ↑ | psychological trainings ◇ | tariff in €/km ↓ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Timetable keeping | 9 | ● | ◉ | ▽ | | | | | | | ◉ | | ▽ | |
| Travel time | 3 | ◉ | ● | ▽ | ◉ | ● | | | | | ▽ | | | |
| Reliability | 1 | ◉ | | ● | | ▽ | | | | | ▽ | | | ▽ |
| Frequency in rush hours | 9 | | | | ● | ◉ | | | | | | | | ◉ |
| Frequency off peak | 3 | | | | ● | ◉ | | | | | | | | ◉ |
| Lines continuity | 9 | ◉ | ▽ | | ◉ | ● | | | | | ▽ | | | |
| Functioning ticket machines | 9 | | | | | | ● | | | | | | | |
| Ticket office opening hours | 1 | | | | | | | ● | | | | | | |
| Barrier-free access | 3 | ▽ | | ▽ | | | | | ● | | ▽ | | | |
| Bus cleanliness | 3 | | | | ▽ | | | | | ● | | | | |
| Bus driver driving skills | 3 | ▽ | | | | ▽ | | | | | ● | | ▽ | |
| Bus indoor temperature adequacy | 3 | | | ● | | | | | | | | ● | | |
| Staff behaviour | 3 | | | | | | | | | | | ● | | |
| Bus stop condition | 1 | | | | | | ● | | | | | | | |
| Price | 9 | | | ▽ | ◉ | | | | ▽ | | | ▽ | | ● |
| ***Total*** | | 126 | 45 | 60 | 174 | 148 | 90 | 9 | 36 | 27 | 70 | 63 | 12 | 118 |
| ***Relative weight in %*** | | 13 | 5 | 6 | 18 | 15 | 9 | 1 | 5 | 2 | 7 | 6 | 1 | 12 |
| ***Technical Importance Rating*** | | 8 | 3 | 4 | 10 | 9 | 6 | 1 | 3 | 2 | 5 | 4 | 1 | 7 |




| ***Target*** | |
|---|---|
| Ø delay in seconds | 0 ± 59 second |
| number of bus stops / line | < 8 |
| numbers of vehicle inspection / month | 1 inspection /month |
| Ø number of line connection / hour | RH: 5 – 6 comm. / h OP: 3 – 4 conn./ h |
| Ø waiting time for line in minutes | RH: 5 min. OP: 10 min. |
| bus stop equipment in % | >85 % - machine 100% - time table |
| ticket office opening hours | 7.00 – 20.00 h |
| barrier free access buses in % | > 80% |
| number of bus maintenance / day | 1 maintenance / day |
| bus driver practise | > 3 years |
| buses with heating and air conditioning in % | 100% - heating 50% - air cond. |
| psychological trainings | once / year |
| tariff in €/km | < 0.40 € / km |

*Fig. 4 Complete House of Quality (Source: Authors)*

The result highlights the importance of staff and cost-friendly public transport service. The research conclusion was released to DPMZ in order to trap the service attributes with low score of satisfaction. DPMZ decided to use a questionnaire survey research considering mainly the staff behaviour which seems to be a good step from bifurcation point as it could uptick the customers' loyalty in a longer time period. The higher interest in communication with customers would strengthen the customers' satisfaction and impacts on increasing numbers of people who decided for urban public transport in their everyday lives.

**Acknowledgements**

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## References

[1] HAUSER, S.: *Crisis Management in a Turbulent Environment (in Czech)*. Opava, 2007. Online available: <http://www.slu.cz/math/cz/knihovna/ucebni-texty/Krizove-rizeni-v-turbulentnimprostredi/Krizove-rizeni-v-turbulentnim-prostredi.pdf>

[2] KENDRA M.: *Measuring the Service Quality of Public Transport Services (in Slovak)*. 2009. Online available: <http://fpedas.uniza.sk/zdal/images/stories/clanky_pdf/ cislo_03_09/08_kendra.pdf>

[3] STN EN 13 816 *Transportation. Logistics and Services. Public Passenger Transport. Service Quality Definition, Targeting and Measurement.*

[4] BEATSON, A. T., LINGS, I., GUDERGAN, S.: *Employee behaviour and Relationship Quality: Impact on Customers*. 2008. Online available: < http://eprints.qut.edu.au/20535/1/c20535.pdf>.

[5] KOREN, C.: Traffic Quality and its Management in Urban Areas. Zilina. 1999. *Communications - Scientific Letters of the University of Zilina.* Online available: <http://www.uniza.sk/komunikacie/archiv/1999/ 4/4_1999en.pdf> ISSN 1335-4205.

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COMMUNICATIONS

Tomas Kalina - Anezka Grobarcikova *

# LNG AS ALTERNATIVE FUEL FOR EUROPEAN TRANSPORT SYSTEM

*This paper gives basic information about Liquefied Natural Gas as a greener alternative to other fossil fuels. It focuses on basic properties of LNG, which are fundamental to understanding LNG correctly and then possibly use it as a fuel for ships, trucks, etc. Furthermore, it focuses on essential parts of a process chain of LNG transport, which is liquefaction, transport of LNG itself and regasification. Closer look is given to the usage of far less preferred alternative for transport, which is inland navigation.*

***Keywords:*** *Energy consumption, fossil fuels, liquefied natural gas, terminals, transport.*

## 1. Introduction

Despite the innovating transport technologies around the globe, transport sector is the fastest growing consumer of energy and producer of greenhouse gases in the European Union. Moreover, this trend is expected to continue in next years. Energy security is one of the key conditions of smooth functioning of state and nowadays only few European countries are energy self-sufficient. Denmark, Norway, the Netherlands, Russian Federation and United Kingdom produce more energy than they can consume [1]. Countries in Central and Eastern Europe are absolutely dependent on imported oil and gas from other suppliers.

According to White Paper [2] (Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system) European Commission calls for breaking the oil dependence of transport and sets a target of 60% greenhouse gas emissions reduction from transport by 2050. Furthermore, it sets goals for the different modes of transport. In order to reach these goals a big share of alternative fuels is required. Alternative fuels can significantly contribute to improve European air quality and to reduce the existing oil dependency. As alternative fuels are generally considered any materials or substances that can be used as fuels other than conventional fuels. Well-known alternative fuels include natural gas and bio-methane, liquefied petroleum gas, biofuels, electricity and hydrogen. Proved reserves of natural gas made a very high potential for a significant contribution as an alternative fuel for the European transport sector. This opens the doors to LNG, common acronym for Liquefied Natural Gas as the only way to transportation of this form of fossil fuel to distant destinations.

## 2. World demand of Natural gas and LNG trade

Globally, natural gas accounted for 23.9% of primary energy consumption in 2012. It is the third largest source of energy after oil and coal. To be precise, in 2012 the world consumed 3.0 billion tons of natural gas, compared to 4.1 billion tons of oil and 3.7 billion tons of coal [1]. Natural gas consumption increased by 2.2 per cent compared to previous year.

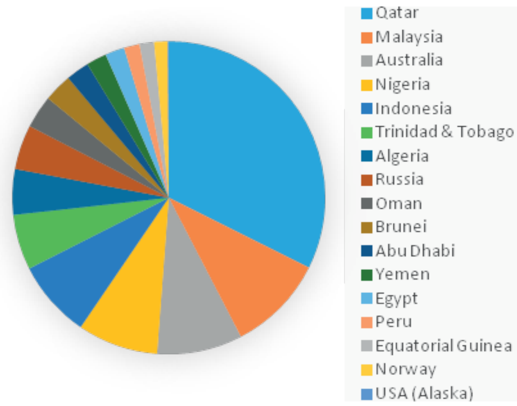


*Fig. 1 LNG export [3]*

During the same year, natural gas prices rose in Europe and Asia, but fell in North America, where rising US natural gas output

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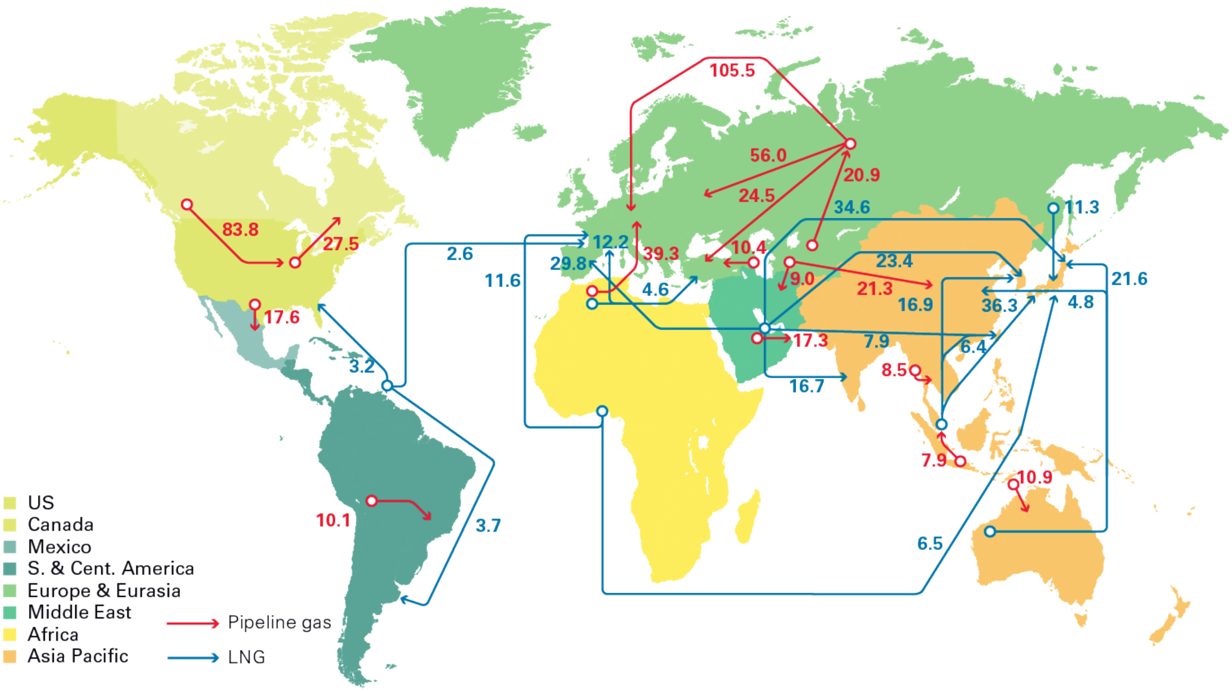


*Fig. 2 Major gas trade movements of 2012 in billion cubic metres [1]*

pushed gas prices to record discounts against both crude oil and international gas prices. Production grew by 1.9 per cent, with the United States remaining the world's largest producer. Norway, Qatar, and Saudi Arabia also saw significant production increases, while Russia had the world's largest decline in volumetric terms. Qatar remained the largest world exporter with a share of over 32.1 per cent of global LNG exports, see Fig. 1.

Increased export volumes were recorded also in Australia, Malaysia, Nigeria and the United Arab Emirates, while shipments from Algeria, Egypt and Indonesia contracted. LNG shipments fell for the first time, due to falling imports in Europe and the limited global liquefaction capacity expansion recorded during the year. Now LNG share of global gas trade represents 31.7%, [3] and [4]. Figure 2 shows major gas trade movements in 2012.

The outlook for LNG trade is positive in view of following facts: new gas finds worldwide (Cyprus, Israel and the United Republic of Tanzania), the decline in nuclear power use, promotion of LNG in Asia region, attractiveness of gas as a greener alternative to other fossil fuels. One study projects [5] that by 2030 Norway and Russian Federation will be driving global exports of LNG, moreover they will lead the fourth wave of LNG export. The first wave is taking place at the present time and is led by Qatar, the second wave is projected to occur in 2014 with Australia and the Asia Pacific. The third wave is expected to occur around 2020 and it will be driven by West Africa.

## 3. Basic properties of LNG

Chemical and physical properties are fundamental to understanding LNG and then safely use it as a fossil fuel. The presented properties made LNG a good source of energy but, on the other hand, they can also make LNG a hazardous material. These properties influence how we assess and manage safety risks. Moreover, to accurately understand and predict LNG behaviour, we must clearly distinguish its properties as a liquid from its properties as a gas or vapour.

When natural gas is cooled to approximately -162°C at atmospheric pressure, it condenses to a liquid and becomes liquefied natural gas – LNG [6]. This low temperature makes LNG a cryogenic liquid. Generally, substances which are -100°C are considered cryogenic and involve special technologies for handling. The cryogenic temperature means it will freeze any tissue (plant or animal) upon contact and can cause other materials to become brittle and lose their strength or functionality. This is why the selection of materials used to contain LNG is so important. To remain a liquid, LNG must be kept in specially designed containers which function like thermos bottles – they keep the cold in and the heat out. Natural gas in liquid form takes up about 1/600th of the volume of natural gas in its gaseous equivalent so that is the economical reason to transport LNG.

LNG is odourless, colourless, non-corrosive, and non-toxic. Common smell of natural gas is caused by an odorising substance which is added to natural gas before it is sent into the distribution grid. This is due to detection of gas leaks [7].

There are five key liquid and gas properties for LNG, which are listed on Material Safety Data Sheets [6]: chemical composition, boiling point, density and specific gravity, flammability, ignition and flame temperatures. More about these properties is discussed below.

### 3.1 Chemical Composition

There are three major fossil fuels - coal, oil, and natural gas. Fossil fuels have been created by organic material deposited and buried in the earth millions of years ago. Crude oil and natural gas constitute types of fossil fuel known as hydrocarbons, chemicals whose molecules consist exclusively of collections of hydrogen and carbon atoms. Natural gas is a mixture of methane, ethane, propane and butane with small amounts of heavier hydrocarbons and some impurities, notably nitrogen and complex sulphur compounds and water, carbon dioxide and hydrogen sulphide which may exist in the feed gas but are removed before liquefaction [7]. The chemical composition of natural gas is a function of the gas source and type of processing. Methane is by far the major component, approximately over 85% of volume.

Table 1 displays the average chemical compositions of the LNG reported by the different receiving terminals.

Average chemical composition of the LNG by selected countries

Table 1

| Origin | Nitrogen | Methane | Ethane | Propane | Butane + |
|---|---|---|---|---|---|
| | N2% | C1% | C2% | C3% | C4+ % |
| Algeria | 0.65 | 90.15 | 7.9 | 0.4 | 0.5 |
| Egypt | 0.02 | 96.28 | 3.04 | 0.43 | 0.23 |
| Libya | 0.59 | 82.57 | 12.62 | 3.56 | 0.65 |
| Nigeria | 0.03 | 91.7 | 5.52 | 2.17 | 0.58 |
| Norway | 0.46 | 92.03 | 5.75 | 1.31 | 0.45 |
| Qatar | 0.27 | 90.91 | 6.43 | 1.66 | 0.74 |
| Russia | 0.07 | 92.53 | 4.47 | 1.97 | 0.95 |
| USA | 0.17 | 99.71 | 0.09 | 0.03 | 0.01 |
| Yemen | 0.02 | 93.17 | 5.93 | 0.77 | 0.12 |

*(Source: GIIGNL - The Lng Industry) [3]*

The chemical composition of the natural gas and the properties of its hydrocarbon components determine how LNG behaves, affect our predictions about its behaviours, and influence how we assess and manage safety risks. LNG is often confused with liquefied petroleum gas (LPG), which in turn is often incorrectly identified as propane. In fact, LPG is a mixture of mainly propane and butane gases that exist in a liquid state at ambient temperatures when under moderate pressure. LPG's differing composition and physical properties compared to LNG make its behaviour different as well. The propane and butane in LPG have different chemical compositions from methane. Propane and butane can be stored and transported as a mixture, or separately. Both are gases at normal room temperature and atmospheric pressure, like methane, readily vaporising. Propane liquefies much more easily than LNG (at -43°C vs. -162°C) so it is substantially easier to compress and carry in a portable tank. In fact, LPG is stored as a liquid under pressure at room temperatures, whereas LNG is stored as a liquid only at very low temperatures and ambient pressure.

### 3.2 Boiling Point

Boiling point is the temperature at which a liquid boils or at which it converts rapidly from a liquid to a vapour or gas at atmospheric pressure. The boiling point of LNG varies with its basic composition, but it is typically -162°C [6]. After transportation LNG is converted back into natural gas for distribution to industrial and residential consumers. The LNG regasification process warms the LNG and converts it back into its gaseous form.

### 3.3 Density and Specific Gravity

Density of LNG varies with its actual composition. It ranges between 430 kg/m$^3$ to 470 kg/m$^3$ [6]. It is less than a half of the density of water. The specific gravity of a liquid is the ratio of density of that liquid to density of water at 15.6°C. LNG specific gravity is one half of water specific gravity. In case of spillage LNG floats on water and vaporises very fast. Vapours at low temperatures are heavier than air and make visible white cloud. The cloud is white because the water in the air is frozen by cold vapours. The cloud disperses quite quickly because vapour of methane is heated and at the temperature of about minus 100°C it has the same weight as air. At higher temperature vapour becomes lighter than air.

### 3.4 Flammability

The main hazard of LNG is flammability of liquid gas vapours, but it is the same property which makes natural gas desirable as an energy source. To be clear, natural gas is flammable but the liquid form of natural gas - LNG is not because of the lack of oxygen in the liquid. Several factors are required to start a fire from LNG vapours. In particular, the fuel and the oxygen have to be in a specific range of proportions to form a flammable mixture. This is called Flammable Range and it is the range of a concentration of a gas or vapour that will burn if an ignition source is introduced [8]. For LNG lower flammability limit (LFL) is 5% by volume and upper flammability limit (UFL) is 15% by volume. When vapour concentration exceeds its UFL, it cannot burn because too little oxygen is present. This situation exists in storage tanks or vessels where the vapour concentration is approximately 100% methane. Any small leak of LNG vapour from a tank in a well-ventilated area is likely to rapidly mix and quickly dissipate to lower than 5% methane in air. Because of the rapid mixing, only a small area near the leak would have the necessary concentration to allow the fuel to ignite. All LNG terminals use several types of equipment on and around the storage tanks and piping throughout the facility to detect any unlikely leakages and combustible gas mixtures [6].

### 3.5 Ignition and Flame Temperatures

The auto-ignition temperature is the lowest temperature at which a gas or vapour will spontaneously ignite in a normal atmosphere without an external source of ignition, such as a flame or spark. In an air-fuel mixture of about 10% methane in air, the auto ignition temperature is approximately 540°C. The precise auto-ignition temperature of natural gas depends on its composition. If the concentration of heavier hydrocarbons in LNG increases, the auto ignition temperature decreases.

In addition to ignition from exposure to heat, the vapours from LNG can be ignited immediately from the energy in a spark, open flame, or static electricity when they are within the flammable limits. LNG burns quickly and is a better heat source than other fuels (e.g. gasoline). The methane in LNG has a flame temperature of 1330°C. As mentioned before, LNG burns quickly, at a rate of about 12.5 $m^2$/minute, in comparison with gasoline's burn rate of 4 $m^2$/minute. The combustion of LNG produces mainly carbon dioxide and water vapour. The radiant heat of an LNG fire is a frequent safety concern of government regulators and officials, and the public [6] and [7].

## 4. The LNG Process Chain

The global LNG business can be described as a process chain or value chain containing four main components [9]: Extraction, Liquefaction, LNG Transport and Regasification. Firstly, it is extraction and production. Plentiful source of gas is needed at a price competitive with other energy source, such as oil. Although there are plenty of reserves, they are in the wrong place and multi-billion dollar investment projects are needed to ship the gas to market. As consequence, investors are locked into a very inflexible long-term commitment, so political stability and future pricing worries weigh heavily on their minds, often leading to delays [10].

For this particular reason, the country must develop a sufficient market with a pipeline network capable of distributing the gas to domestic and commercial customers. The largest component of the total cost of the LNG value chain is usually the liquefaction plant while the production, shipping, and regasification components account for nearly equal portions of the remainder. In this paper we look closely to Liquefaction, LNG Transport and Regasification which are most significant for European transport system.

### 4.1 Liquefaction

Extraction of the natural gas from the earth's surface represents the first step along the process chain of LNG production. This is followed by liquefaction, which basically means the cleaning of the natural gas in the liquefaction plants (Fig. 3). A liquefaction plant represents one or more 'trains' which liquefy the gas. A train is a compressor, usually driven by a gas turbine [10].

*Fig. 3 LNG Liquefaction Plant [3]*

At the end of 2012 there were 89 liquefaction trains in operation in 18 exporting countries in the world [3]. The aggregate nominal capacity of all liquefaction plants reached 282 mmtpa (Million Metric Tonne Per Annum), to be compared with a worldwide LNG consumption of 236 mmtpa. Snohvit in Norway is the only liquefaction plant in Europe. Regrettably the plant owner decided to shelve their plans for a second train due to insufficient gas reserves. Nevertheless, in the Mediterranean region there are other possibilities for export of liquefied gas to Europe – in Egypt, Algeria and Libya and also another in Nigeria, Equatorial Guinea and Trinidad & Tobago. Feedgas supply for exports in Egypt has been reduced mainly because of rising domestic demand. On average, the liquefaction plants at Idku and Damietta operated at around 40% of the nameplate capacity. In Algeria, production was constrained mainly due to feedgas shortages. Due to civil war in Libya the plant remained shut down in 2012. Common situation happened also in Nigeria were various sabotage actions on feedgas pipelines led to force majeure on deliveries at the end of 2012. From Middle East region there are potential imports through the Suez Canal from Abu Dhabi, Oman, Qatar and Yemen.

### 4.2 LNG Transportation

LNG transport involves four operations. Firstly, the natural gas is transported by pipeline from the gas field to the plant. Secondly, the LPG and condensates are separated out and the methane gas is liquefied and stored ready for sea transport. Thirdly, the liquid gas is loaded onto ships for transport to its destination. Finally, the receiving terminal unloads the cargo, stores it and regasifies it [10].

LNG transportation safety could be assessed from two views. On the one hand, there is danger of explosion and subsequent fire. On the other hand, it is the environmental aspect [8]. LNG is transported at low pressure. Because of its low temperature, the gas is transported in double-wall tanks with vacuum perlite insulation. Perfect insulation protects contents from heat and pressure, even if the container gets into fire and loses vacuum. There are known cases where cars transporting the LNG were burnt due to a malfunction of electrical installations, but the tank remained intact. Tanks are designed according to the regulations so they withstand even external fire. There had been no accident relative to explosion or fire in the content of LNG tankers.

In contrast to oil tankers, there are no recorded maritime disasters of LNG tankers. In the world there are currently about 378 tankers in the operation [3]. Compared with diesel and petrol, LNG is significantly safer, but it does not mean that LNG transport is completely safe. It may occur that large LNG amounts can escape from the ship into water. If the liquefied gas, which has a temperature of about -163° C, suddenly appears in a warmer ambient temperature, the liquefied natural gas will quickly change over to gas. A massive release of energy during this transition may cause an explosion.

Ignition of liquefied natural gas needs evaporation in a significant heat input and, consequently, it is possible to ignite its mixture with air, but only in a narrow range of concentrations from 5 to 15% at 280°C ignition, which is a considerably higher value than in the case of gasoline or diesel. Prevention of such cases is associated not only with designing ships for LPG transport but also employing skilled crews, trained specifically for such shipments [11].

Neither from the environmental considerations represents LNG transport an increased risk. In case of a tanker accident, gas does not accumulate in the water, therefore there is no direct damage to the water. Damage results from the possible leakage of chemicals or oils, which are necessary for the operation of the vessel, not directly from the cargo content of the LNG tanker. From the point of safety, LNG tankers are comparable with any other cargo ships.

The much worse problem in LNG transportation is lack of experienced crew to operate the complicated cargo handling system of LNG carriers. The estimations show that LNG ship owners need about 2300 deck officers, 1200 engineers, 1200 steam engineers and about 4500 ratings. Ships need experienced and well educated crew who can easily determine how LNG behaves in order to properly assess and manage safety risks [8].

### 4.3 Regasification

The last step in the LNG process chain involves the import terminals which are marine or floating facilities. LNG carriers deliver the LNG to a marine terminal (Fig. 4) where the LNG is stored before undergoing regasification which converts the LNG back into its gaseous form.

*Fig. 4 Regasification terminal in Barcelona [3]*

At the end of 2012 93 LNG regasification terminals were in operation worldwide [3], including 11 floating facilities. The combined nominal send-out capacity of the facilities reached 668 mmtpa, with 406 tanks, total storage capacity was close to 46 106 million $m^3$ of LNG. Based on an annual LNG consumption of 236.3 mmtpa, the global average utilization rate of receiving installations decreased to 36%. While the utilization rate of Asian terminals remained stable (around 46%), the European rate decreased to 31%. In the Americas, the average terminal utilization rate was around 10% but only 2% in U.S terminals. In Europe regasification plants are situated in Belgium, France, Greece, Italy, Netherlands, Portugal, Spain, Turkey and United Kingdom. Total storage capacity in liquid represents 8 644 500 $m^3$. In May 2012 the construction of the new LNG terminal in Dunkirk (France) began, which, with 9.4 mmtpa regasification unit, is expected to be the largest terminal in Continental Europe. Under construction is another terminal in Poland, Swinoujscie, with expected start-up in the second half of 2014. Furthermore, in 2013 a new terminal in Livorno, Italy was expected to launch with 2.7 mmtpa regasification capacity.

## 5. Natural gas for European transport system

Nowadays many EU countries adapt to the general trend of replacing fossil fuels such as coal, lignite and oil well by environmentally more friendly natural gas. The majority share of the consumed gas in Europe comes from the United Kingdom, France, Germany and Italy [1].

The imports of Russian gas to Europe represent about 26% of the total consumption of EU countries. For Central and Eastern Europe, Russian gas is 87% of total imports. For example, Slovakia, Estonia, Latvia, Finland and Lithuania depend on 100% import from Russia. The primary effort of the EU is to maintain access to Algerian natural gas reserves, which could reduce dependence on Russia. Algeria's economy is heavily dependent on exports of hydrocarbons (oil and natural gas) – which make up 97% of exports, contributing 30% of GDP and finance 65% of the budget. EU imports 62.7% of Algerian exports, which is 58% of total EU natural gas imports [11].

The weakest link in the process chain of gas path from source to final consumer is a long haul. Current technology for natural gas transport allows long distances through pipelines or tankers in liquefied form. A wide branched European network of pipelines is preferred within the continental gas transport. In the recent past, it was annexed to the undersea pipeline connecting with the sites of customers in North Africa. Most gas from Algeria and Nigeria to Europe is transported in compressed form (CNG, PNG) by sea tankers into offshore terminals, followed by distribution pipelines, marine, rail and road tankers. Transhipment and storage capacity of most of these terminals is already at its limits. The solution is either construction of the new ones or substantial increase in inland traffic flows. An appropriate alternative also could be to carry LNG.

The use of inland waterways for LNG transportation is particularly relevant for landlocked countries of Central and Eastern Europe. The network of inland waterways of the European Union consists of approximately 37 000 km navigable rivers and canals. Interlinking the Danube to the Main and the Rhine by trans-European waterway connects the Black and North Sea with a direct connection to the network of waterways in western France, Luxembourg, Switzerland, Germany and the Netherlands. This waterway has become one of the infrastructural priorities of European transport projects taken within the European transport policy. The crucial goal of this priority is a full navigability of this important waterway so that the vessels could transport group of products from the North Sea to the Black Sea with the minimum weight of 3,000 tons during one turn. Overall, the EU has earmarked for this task the amount of 1,889 million € and from it 180 million € for the route Vienna – Bratislava. A significant amount is expected to use on the Lower Danube for removing ford sections with regard to the transport of heavy bulk items and also items containing dangerous cargo. An equally important activity for the Central European region in this direction is the effort to link the Danube with the North and Baltic Sea by canals and the Elbe and Oder rivers. Czech, Slovak and Austrian investors promote the implementation of the Danube-Oder–Elbe Canal project in the trans-EU and the European Agreement on Main Inland Waterways of International Importance (AGN). The aim of this project is to connect the link in the waterway network which could lead to maximization of the gains from trade for countries of the region, including the extension of facilities for transportation of commodities, such as LNG.

Vessels for LNG transportation by inland waterways have a capacity of 2000 - 4000 $m^3$, equivalent to 1.2 to 2.4 million $m^3$ of natural gas. Restrictions in the transport are associated with a sufficient bridges clearance on the waterway. Given the low density of LNG (0.45 $t/m^3$), draft of the vessel is negligible [11].

It opens the door to possible recovery of the recently neglected mixed river-sea technology. This system is based on the elimination of boundaries between the sea and river, which leads to elimination of transhipment from marine vessels onto river vessels and back. The removal of just one transhipment brings significant economic and time savings. In this case there is no need to build any pumping equipment and the ship can navigate from dispatch (liquefying terminal) to a port of destination.

Based on research results we can say that the river-sea transport technology can reduce transport costs by 10 – 15% in comparison with separate technologies – "inland" and "maritime navigation". Positive effects of the formers technology appear in connection with the logistic technological scheme "door to door" [12].

## 6. Conclusion

The outlook for LNG is positive in view of new investments in building supporting infrastructure for LNG trade. In comparison with other fossil fuels, LNG is not as dangerous as people think and it becomes a significant energy source in European region. Therefore, one of the most recent contentious issues is to ensure its stable supply.

One of the options for Europe is an extensive network of inland waterways that offer relatively inexpensive, efficient, clean and reliable mode of transport. Countries with well-developed river and canal networks could envisage the development of LNG transportation to end users via inland waterways and, consequently, creating a virtual network of pipelines, which avoids congestion and allows the LNG supply to urban areas where geographical, demographic or environmental specificities are not suitable for the traditional laying of pipelines. One of the main problems nowadays is lack of experienced crew to operate the complicated cargo handling system. It is essential to educated not only officers, but also public about positive effects of usage of LNG as alternative fossil fuel.

## References


[1] BP. *BP Statistical Review of World Energy June 201*. [online]. London: BP, 2013. Available on: <*bp.com/statisticalreview*>

[2] EUROPEAN COMMISSION. *WHITE PAPER: Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system.* [online]. Brussels: European Commission, 2013.

[3] *GIIGNL. The Lng Industry.* [online]. Paris*: GIIGNL, 2013.* 46 p. Available on: <http://www.giignl.org/sites/default/files/publication/giignl_the_lng_industry_2012.pdf>

[4] UNCTAD. Review of maritime transport 2013. 2013. Geneva: UNCTAD, 2013. 204 p. ISBN: 978-9211128727.

[5] UNCTAD. Review of maritime transport 2012. 2012. Geneva: UNCTAD, 2012. 196 p. ISBN: 978 – 9211128604.

[6] *GIIGNL. Basic Properties of LNG.* [online]. Available on: < http://www.giignl.org/about-lng/lng-basics >

[7] TABAK, J.: *Natural Gas and Hydrogen.* New York: Facts on File, 2009. ISBN-13: 978-0816070848.

[8] STAROSTA, A.: Safety of Cargo Handling and Transport Liquefied Natural Gas by Sea. Dangerous Properties of LNG and Actual Situation of LNG Fleet. *TransNav, the Intern. J. on Marine Navigation and Safety of Sea Transportation*. vol. 1, No. 4, 2007, pp. 427-431. ISSN 2083-6473.

[9] *GIIGNL. The LNG Process Chain.* [online]. Available on: < http://www.giignl.org/about-lng/lng-basics >

[10] STOPFORD, M.: *Maritime Economics*. London: Routledge, 2009, 840 p. ISBN: 978-0415275583.

[11] KLEPOCH, J., ZARNAY, P.: Vessels for River-Sea Shipping Technologies. *Communications – Scientific Letters of the University of Zilina,* vol. 3, No. 1, 2001, pp. 103-112. ISSN 1335-4205.

[12] KALINA, T., PIALA, P.: River-Sea Technology in Transport of Energy Products. *TransNav, Intern. J. on Marine Navigation and Safety of Sea Transportation,* vol. 6, No. 4. 2012, pp. 469-473. ISSN 2083-6473.

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# ASSESSMENT OF INTERCHANGEABILITY OF POSTAL SERVICES IN TERMS OF VALUE ADDED

*This paper is focused on the issues of interchangeability of postal services. It presents the main terms related to the issues, the relevant legislation on postal services and describes the different aspects of the assessment of postal services interchangeability. It focuses mainly on the assessment of interchangeability of postal services in terms of value added. The aim of the article is to apply the method of determining the added value in assessing the interchangeability of postal services. The paper refers to a particular application of the proposed procedure and quantitative output of interchangeability evaluation of the postal services.*

***Keywords:*** *Value added, interchangeable postal services, use value, liberalization.*

## 1. Introduction

Recently, the term "liberalisation" has become widespread in the postal sector. The main issues in the liberalisation process are the need to guarantee the universal service and finding a new way of financing the universal service. Last legislation in the postal sector in the Slovak Republic requires the use of a compensation fund to ensure funding the forced costs from providing the universal service. Contributors to the compensation fund are all the providers of interchangeable postal services. The main problem of this legislation is a decision and, thus the answer to the question when it comes to interchangeable service [1], [2] and [3].

## 2. Assessment of interchangeability

According to § 4, Section 1, of the Postal Services Act, interchangeable postal service is a postal service that can be considered from the user's point of view to be the service that belongs to the range of a universal service by being interchangeable to a sufficient degree with the universal service [4] and [5]. Simply, we can say that the interchangeable service is a service provided by a postal service provider which is not the universal service provider and the service is similar to the service from the range of universal services. These services may be similar/interchangeable from different perspectives. According to the act, assessment of interchangeability is conducted from the following perspectives:

- *content of postal service,*
- *purpose and usage of postal service,*
- *price of postal services,*
- *added value of postal service.*

From some perspectives, the assessment of interchangeability is quite obvious, such as the price of postal service. Therefore, the explicit aspects are considered as first when assessing the interchangeability. The assessment based on the value added approach is used just in the case when the postal service is considered as interchangeable from all other perspectives [6] and [7].

### 2.1 Assessment of interchangeability from the value added perspective

Value added can generally be assessed on the basis of evaluation of customer value. The notion of value is neither absolute nor objective. It is always subjective because every customer has individual values, depending on his/her needs. In essence, the customer value is divided into three categories: exchange value (represented by price), use value (represented by total utility) and emotional value [8].

*The exchange value* is the value expressed in the price which the postal company is willing to provide the postal service for and a postal customer is willing to pay for it. The exchange value is created in the market at the point where supply meets the

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demand – postal operators and their customers, while both of these entities are willing to proceed an exchange for this price.

*The use value* (or *value-in-use*) refers to a value that a postal service generates for a specific owner under a specific use.

*Emotional value* is represented by the *individual satisfaction* (complacency), emotional and intangible aspects (*money* – customers hardly spend their money, *time* - the value of time is considered to be higher than the value of money), *effort* - the customer must put a physical effort to obtain a postal service, *psychological stress* - involves the need to deal with the postal service provider, waiting for the provision of services, filling out forms, the need to understand the new procedures, the need to adapt to new things and situations.

As it was previously mentioned, the emotional value is very subjective, because each customer is different. For this reason, we will take into account, while quantifying the value added, particularly the use value expressed in the total utility (TU) and the exchange value expressed in the service price (P).

### 2.2 Quantification of value added

Customer value added = proportion of *total utility* of postal services and *prices/tariffs* for postal service:

$$VA = TU/P \qquad (1)$$

VA - value added
TU - total utility
P - price

*The total utility* is a set of benefits that the customer expects from the postal service. *Price* represents a financial value that the customer must expend in relation to evaluating, obtaining and using the postal services [1].

### 2.3 Basic factors of customer utility

Factors of utility for the customers primarily include:

- *warranty* (content and scope of warranty result in gaining the customer trust to the postal company and the postal services offered by the company);
- *reliability* in the provision of postal services (a low number of complaints, the postal company's good image in the eyes of customers);
- *speed* of providing the postal service ( D + x );
- *quality* of provided services attributed to the postal company based on the quality certificates, e.g. ISO 2000, etc.;
- *accurate and timely information* (provided to the customer before, during and after the provision of postal service);
- **customer care and respect** (professional and dignified customers treatment while providing the postal services, in terms of trust, courtesy, etc.);
- **convenience** (the simplicity of postal service provision - spatial and temporal availability of postal services, ease of mailing conditions, etc.).

### 2.4 Procedure for assessment of the use value

Assessment of the use value may be determined by using a variety of theoretical methods and procedures. As a procedure for assessment of the use value, which can be applied in testing the interchangeability of postal services, we will describe a procedure that follows the next steps:

A. Establishing evaluation criteria,
B. Establishing criteria weights,
C. Evaluating alternatives,
D. Aggregating partial use values,
E. Selecting the best alternative.

### A. Establishing evaluation criteria

For the development of criteria arising from the foundations of utility theory and the logic of mathematical model, basic requirements of criteria such as *relevance, integrity, independence, discrimination and compensation* must be met. Relevance can be understood as a significance of the various criteria and from the completeness perspective, all relevant criteria have to be taken into account. We must also ensure that the criteria in their remarks do not affect each other (correlating characters must be assigned to the superior characters), which will be ensured by the requirement for independence. Discrimination says that the criteria manifestation of the various alternatives have to be reflected in different results. Compensation means the linking of criteria, so that "better" one in the first criterion must compensate "worse" one in the second criterion.

For the development of evaluation criteria in terms of postal services, it is needed to be aware of these essential requirements:

- criteria cannot be determined in general, but only in relation to the issue of interchangeability of postal services;
- criteria must be derived from superior (strategic) objectives - fulfilling the Postal Services Act;
- criteria shall be divided as long as they can be clearly determined.

### B. Establishing criteria weights

After the establishment of evaluation criteria, which have been determined on the basis of the above requirements, we can specify the weights for the criteria. Criteria weights are characterized by the following:

- they assess the importance of each criterion of interchangeability of postal service,
- since there are too many criteria for the direct assignment of weights, they can be *arranged in a target hierarchy*, and then *group-weighted*,
- sum of the factors of one group = 1,
- absolute weight of one character (absolute partial utility) is calculated as *the multiplication of specific weights of the degree* (relative partial utility) *and all superior specific weights*,
- predicted *costs of the postal service* can be directly evaluation criterion and their value can represent the *use value*, as a final ranked dimension is *the profit*.

## C. Evaluating alternatives

In doing so, it is an assessment of interchangeability of postal services depending on how far the developed characters relevant for the decision are. We must realize that the quantitative and qualitative variables must be transformed into numerical values with the same dimension in all evaluation criteria.

## D. Aggregating partial use values

- Aggregating the use values must meet the following requirements:
- total utility of each postal service can be derived from the weighted partial utilities,
- numerical values (scores) are multiplied by the criteria weights and the results are summed,
- sometimes it is preferable to use multiplication instead of addition, it is thus possible to evaluate the postal services with low scores in some respects, while a low score for addition connections can be significantly compensated by large numbers,
- K.O. criterion is taken into account when the final result is equal to zero.

## E. Selecting the best alternative

After the realization of all the previous steps for assessing the use value, we can proceed to the final step, which definitely evaluates the best alternative from the group of assessed postal products and services. This part of the evaluation process allows us to use the total use values of the assessed postal products and services to derive the *final ranking of examined alternatives.*

Due to the subjective assessment and weighting of criteria, and as a result of not always theoretically explainable transformation of characteristics to the numerical values, *"control of assurance"* should be proceeded.

Method of *"equivalency test"* compares the different criteria which have diverse results, and submits the abstract, weighted use values back to the specific characteristics of characters [1].

# 3. Example on the assessment of the use value

For a better understanding how to decide on the interchangeability of the two services based on the assessment of the added value, we will give an example, which is provided (see Table 1). This will be an evaluation of the interchangeability of a postal service provided by alternative postal operator and a postal service from the scope of universal services provided by the Slovak Post - the universal service provider. From the content perspective, the service is interchangeable with the service "1st Class Parcel" provided by the Slovak Post. We will be considering the interchangeability of these two services in terms of added value.

## A. Establishing evaluation criteria

In this case, we established the following evaluation criteria:

1. Ensuring the safety of postal items.
2. Appropriate conduct of employees.
3. Meeting the agreed conditions (speed of delivery of the item).
4. Process simplicity of the service.
5. Spatial and temporal availability of post offices and mailboxes.
6. Wait time.
7. Availability of information about the products and services.
8. Complaint handling.
9. Additional services.

We assigned the different quality levels to the specific criteria. We used the levels that are common in practice and that are characteristic for a given criterion such as ensuring the safety [9]:

- no guarantee against loss,
- guarantee up to the level of the difference,
- guarantee up to the price level,
- guarantee up to the multiplied price.

## B. Establishing criteria weights

Then we identified the weights of each criterion according to a survey on customer satisfaction with the Slovak Post conducted in 2008. Those criteria that were not included in the survey were linked with the weights based on the expert estimation. Of course, the researcher could use the results of his own survey.

We assigned percentages to the qualitative levels of individual criteria according to their relevance to the customer so that the sum of the percentage of options for each criterion is equal to one hundred per cent.

We have to take into account the different opinions among ordinary customers who use postal services in a small volume (retail customers) and the customers who regularly use postal services in a large volume (corporate customers). These two groups of customers assign different weights to each criterion. For this reason, we divided the weights into two groups:

- retail customers - SU (small user),
- corporate customers - LU (large user).

Calculation of the total utility of selected postal services for the purposes of evaluation of interchangeability of postal services (concept)

Table 1

| 1st Class Parcel - Day definite | Weights - SU | Weights - LU | conv. SU | conv. LU | SP | AO | Utility SP | Utility AO |
|---|---|---|---|---|---|---|---|---|
| 1. Ensuring the safety of postal items | 91.3 | 92.3 | 13.4 | 13.0 | | | | |
| *No guarantee against loss* | 10.0 | 8.0 | 1.34 | 1.04 | 1 | | 1.19 | 0.00 |
| *Guarantee up to the level of the difference* | 20.0 | 20.0 | 2.68 | 2.60 | | | 0.00 | 0.00 |
| *Guarantee up to the price level* | 30.0 | 32.0 | 4.03 | 4.16 | | 1 | 0.00 | 4.09 |
| *Guarantee up to the multiplied price* | 40.0 | 40.0 | 5.37 | 5.20 | | | 0.00 | 0.00 |
| 2. Appropriate conduct of employees | 89 | 88.8 | 13.1 | 12.5 | | | | |
| *Without independent evaluation* | 10.0 | 13.0 | 1.31 | 1.63 | | 1 | 0.00 | 1.47 |
| *With independent evaluation* | 40.0 | 40.0 | 5.23 | 5.01 | | | 0.00 | 0.00 |
| *With published independent evaluation* | 50.0 | 47.0 | 6.54 | 5.88 | 1 | | 6.21 | 0.00 |
| 3. Meeting the agreed conditions (speed of delivery of the item) | 87.9 | 89.3 | 12.9 | 12.6 | | | | |
| *Without independent evaluation* | 10.0 | 7.0 | 1.29 | 0.88 | | | 0.00 | 0.00 |
| *With independent evaluation* | 40.0 | 40.0 | 5.17 | 5.03 | 1 | | 5.10 | 0.00 |
| *With published independent evaluation* | 50.0 | 53.0 | 6.46 | 6.67 | | | 0.00 | 0.00 |
| 4. Process simplicity of the service | 83.8 | 84.9 | 12.3 | 12.0 | | | | |
| *averagely up to 1 minute* | 50 | 60 | 6.16 | 7.18 | | | 0.00 | 0.00 |
| *averagely up to 2 minutes* | 30 | 30 | 3.70 | 3.59 | 1 | | 3.64 | 0.00 |
| *averagely over 2 minutes* | 20 | 10 | 2.46 | 1.20 | | 1 | 0.00 | 1.83 |
| 5. Spatial and timely availability of post offices and mailboxes | 82.3 | 82.6 | 12.1 | 11.6 | | | | |
| *Spatial availability (branch network) 40% points* | *40.0* | *40.0* | | | | | | |
| *501+* | 50.0 | 35.0 | 2.42 | 1.63 | 1 | | 2.02 | 0.00 |
| *101-500* | 30.0 | 30.0 | 1.45 | 1.40 | | | 0.00 | 0.00 |
| *11-100* | 15.0 | 25.0 | 0.73 | 1.16 | | 1 | 0.00 | 0.94 |
| *0-10* | 5.0 | 10.0 | 0.24 | 0.47 | | | 0.00 | 0.00 |
| *Timely availability 60% points* | *60.0* | *60.0* | | | | | | |
| *18 - 24* | 40.0 | 50.0 | 2.90 | 3.49 | | 1 | 0.00 | 3.20 |
| *12 - 18* | 30.0 | 30.0 | 2.18 | 2.10 | | | 0.00 | 0.00 |
| *6 - 12* | 25.0 | 10.0 | 1.81 | 0.70 | 1 | | 1.26 | 0.00 |
| *0 - 6* | 5.0 | 10.0 | 0.36 | 0.70 | | | 0.00 | 0.00 |
| 6. Wait time | 86 | 86.7 | 12.6 | 12.2 | | | | |
| *Wait time at the branch 50% points* | *50.0* | *50.0* | | | | | | |
| 0 - 3 min. | 50 | 40 | 3.16 | 2.44 | | | 0.00 | 0.00 |
| 3 - 6 min. | 30 | 30 | 1.90 | 1.83 | | | 0.00 | 0.00 |
| 6 - 9 min. | 15 | 20 | 0.95 | 1.22 | 1 | | 1.08 | 0.00 |
| 9+ min. | 5 | 10 | 0.32 | 0.61 | | | 0.00 | 0.00 |
| *Wait time for the courier 50% points* | *50.0* | *50.0* | | | | | | |
| 0 - 1 hod. | 50 | 40 | 3.16 | 2.44 | | | 0.00 | 0.00 |
| 1 - 2 hod. | 30 | 30 | 1.90 | 1.83 | | 1 | 0.00 | 1.86 |
| 2 - 3 hod. | 15 | 20 | 0.95 | 1.22 | | | 0.00 | 0.00 |
| 3+ hod. | 5 | 10 | 0.32 | 0.61 | | | 0.00 | 0.00 |
| 7. Availability of information about the products and services | 60 | 60 | 8.8 | 8.5 | | | | |
| *physically at the branch* | 60 | 10 | 5.29 | 0.85 | 1 | 1 | 3.07 | 3.07 |
| *by phone* | 10 | 20 | 0.88 | 1.69 | 1 | 1 | 1.29 | 1.29 |
| *by Internet* | 30 | 70 | 2.65 | 5.92 | 1 | 1 | 4.28 | 4.28 |
| 8. Handling of complaints | 30 | 40 | 4.4 | 5.6 | | | | |
| *Guarantee of complaint handling within the period at least 5 days shorter than the statutory deadline* | 80 | 80 | 3.53 | 4.51 | | | 0.00 | 0.00 |
| *Free information about the complaint* | 20 | 20 | 0.88 | 1.13 | | | 0.00 | 0.00 |
| 9. Additional services | 70 | 85.0 | 10.3 | 12.0 | | | | |
| *cash on delivery* | 25 | 36 | 2.57 | 4.31 | 1 | 1 | 3.44 | 3.44 |
| *insurance* | 14 | 25 | 1.44 | 2.99 | 1 | 1 | 2.22 | 2.22 |
| *fragile* | 2 | 1 | 0.21 | 0.12 | 1 | | 0.16 | 0.00 |
| *bulky* | 1 | 1 | 0.10 | 0.12 | 1 | | 0.11 | 0.00 |
| *telephone notice* | 9 | 1 | 0.93 | 0.12 | 1 | 1 | 0.52 | 0.52 |
| *reply service* | 1 | 1 | 0.10 | 0.12 | 1 | | 0.11 | 0.00 |
| *Cancellation of sent consignment* | 1 | 1 | 0.10 | 0.12 | 1 | | 0.11 | 0.00 |
| *Cancellation of delivered consignment* | 1 | 1 | 0.10 | 0.12 | 1 | | 0.11 | 0.00 |
| *not to impose* | 1 | 1 | 0.10 | 0.12 | 1 | | 0.11 | 0.00 |
| *store X days* | 5 | 1 | 0.51 | 0.12 | 1 | | 0.32 | 0.00 |
| *not to deliver* | 1 | 1 | 0.10 | 0.12 | 1 | | 0.11 | 0.00 |
| *not to return* | 1 | 1 | 0.10 | 0.12 | 1 | | 0.11 | 0.00 |
| *Poste restante* | 3 | 1 | 0.31 | 0.12 | 1 | 1 | 0.21 | 0.21 |
| *change of address* | 1 | 1 | 0.10 | 0.12 | 1 | 1 | 0.11 | 0.11 |
| *back to* | 1 | 1 | 0.10 | 0.12 | 1 | | 0.11 | 0.00 |
| *exclusion substitute the consignee* | 3 | 1 | 0.31 | 0.12 | 1 | | 0.21 | 0.00 |
| *extension of the time limit for delivery* | 3 | 1 | 0.31 | 0.12 | 1 | | 0.21 | 0.00 |
| *time forwarding* | 1 | 1 | 0.10 | 0.12 | 1 | | 0.11 | 0.00 |
| *delivery to another address for the recipient's request* | 1 | 1 | 0.10 | 0.12 | 1 | 1 | 0.11 | 0.11 |
| *mandate* | 2 | 1 | 0.21 | 0.12 | 1 | 1 | 0.16 | 0.16 |
| *denial of receipt of the shipment* | 1 | 1 | 0.10 | 0.12 | 1 | | 0.11 | 0.00 |
| *repeated delivery to the recipient's request* | 2 | 1 | 0.21 | 0.12 | 1 | 1 | 0.16 | 0.16 |
| *provide information about the lodging of shipment* | 2 | 1 | 0.21 | 0.12 | 1 | 1 | 0.16 | 0.16 |
| *provide information about the delivery of an item* | 4 | 1 | 0.41 | 0.12 | 1 | 1 | 0.27 | 0.27 |
| *provide information on Tracking* | 1 | 1 | 0.10 | 0.12 | 1 | 1 | 0.11 | 0.11 |
| *depreciation posting receipts* | 2 | 1 | 0.21 | 0.12 | 1 | | 0.16 | 0.00 |
| *confirmation of the consignment* | 5 | 8 | 0.51 | 0.96 | 1 | 1 | 0.74 | 0.74 |
| *packaging* | 1 | 1 | 0.10 | 0.12 | | 1 | 0.00 | 0.11 |
| *non-standard pick-up and delivery* | 3 | 1 | 0.31 | 0.12 | | 1 | 0.00 | 0.21 |
| *Go Green* | 1 | 2 | 0.10 | 0.24 | | 1 | 0.00 | 0.17 |
| *payment, billing options* | 1 | 3 | 0.10 | 0.36 | | 1 | 0.00 | 0.23 |
| Total | 680.3 | 709.6 | 100.0 | 100.0 | | | 39.56 | 30.99 |

Derived data (survey on customer satisfaction with Slovak Post, 2008)

Weights based on the expert estimation

### C. Evaluating alternatives

The next step is a numerical expression of the for the individual criteria and their options. First, it is necessary to convert the individual criteria on an equal basis. This is achieved as follows:

$$conv.\,SU/LU = \frac{x}{\sum x} \times 100\% \qquad (2)$$

*conv. SU/LU* – weights converted on an equal basis
*x* – weights of the individual criteria

It is also necessary to quantify the weights for the various options of criteria. We will obtain the result by the following calculation:

$$Y = \frac{y}{conv.\,SU/LU} \times 100\% \qquad (3)$$

*conv. SU/LU* – criterion weight
*y* – significance of a given option of a given criterion expressed as a percentage
*Y* – converted weight of a given option of criterion

### D. Aggregating partial use values

To determine the individual use values, we must first determine which options of the individual criteria are met by the postal operators. One of these operators is the universal service provider and the other is the postal operator whose service is being assessed whether it is interchangeable or not. In our case, the Slovak Post represents the only universal service provider and unnamed company represents an alternative provider of postal services. We assigned a value of one to the option which was met by a given enterprise.

Consequently, the value of utility (U) for a given criterion and a given postal company is calculated as a sum of arithmetic averages of the converted weights of a given option of criterion for retail and corporate customers (the calculation is not presented in Table 1).

$$U = \sum \frac{Y_{SU} + Y_{LU}}{2} \qquad (4)$$

$Y_{SU}, Y_{LU}$ – converted weight of a given option of criterion
*U* – utility of the specific criterion

Final value of total utility (TU) of the compared services will be quantified as a sum of the utilities of single criteria.

$$TU = \sum U \qquad (5)$$

*U* – utility of the specific criterion
*TU* – total utility

### E. Selecting the best alternative

In our case, the total utility of the service "1st Class Parcel" provided by the Slovak Post is 39.56 points. For similar service provided by the alternative operator, the total utility is 30.99 points.

Based on the result, it would be logical to choose the service "1st Class Parcel" provided by the Slovak Post.

## 4. Conclusions

To quantify the value added of services, we need to divide the total utility (Table 1 row "Total"), according to the above equation for calculating value added (1), by the price and then assess the interchangeability.

This division is necessary especially in cases when the total value of utility of alternative operator exceeds several times the value of the total utility of the universal service provider. In our case it is not necessary, since our results show that the value of the total utility of assessed postal service of alternative postal operator is even smaller than value of the total utility of the postal service from the area of universal services.

In our case, it is clear that it is the interchangeable service because the total utility of the service provided by the universal service provider is higher than the total utility of the similar service provided by the assessed company. So we cannot state that the assessed postal service of alternative operator has a significantly higher value added comparing to the service provided by the Slovak Post.

By the example of calculating the total utility of postal services and its interpretation, we have demonstrated the application of the method of determining the added value in assessing the interchangeability of postal services and thus we achieved the main objective. However, the results of the total utilities of services are not always so clear. In that case, it is necessary to calculate the value added. There may also be a problem when the value added of the service provided by the assessed postal company is higher than a value added of a similar service provided by the universal service provider. In that case, it would be necessary to decide how much the added values have to differ to become irredeemable services. There are several decision options. The exact value of the ratio or the difference for the calculated values added of compared postal companies would have to be determined by a regulatory authority for the postal sector in a given country.

This methodology quantifying the value added is intended primarily for postal sector regulator, which is the main authority in the evaluation of interchangeability of postal services as well as for postal operators themselves. The proposed solution also paves the way for a more detailed specification of the monitored criteria or more accurate determining the proportional characteristics of utility perceived by customer according to type of customer.

This procedure may also serve as a guide for solving the issues of the quantification and comparison of value added in services in general.

## References


[1] UNIVERSITY OF ZILINA: *Solution of Problematic with Interchangeable Pservices, Including the Development of Methodologies for Assessing the Interchangeable Postal Services (in Slovak)*, project, No. 117, 2011.

[2] ACHIMSKY, K., ROSTASOVA, M., ACHIMSKA, V., HNATOVA, Z., KOLAROVSZKI, P.: *Research of Using Alternative Financing Mechanisms of the Universal Postal Service in Slovakia after the Abolition of the Postal Reservation (in Slovak)*, 2007.

[3] CERP: *Working Group Economics PT Universal Service and its Financing*, 2008.

[4] Act No. 507/2001 *Coll of. on Postal Services, as Amended (in Slovak)*, 2001.

[5] Act No. 324/2011 *Coll of. on Postal Services and on Amendments to Certain Laws (in Slovak)*, 2011.

[6] PRU: *Postal license No. 589/001/2004 (in Slovak)*, 2004.

[7] WIK-Consult GmbH: *The Role of Regulators in a More Competitive Postal Market.* Final Report. [online database] September 2011 [cit. 29. September 2013] Available at: http://ec.europa.eu/internal_market/post/doc/studies/2009-wik_regulators.pdf

[8] Economic portal EuroEkonóm.sk: *The Value and Value Perceived by Customer (in Slovak).* The Paper, [online database], September 2011 [cit. 30. September 2013] Available at: http://www.euroekonom.sk/obchod/predaj/hodnota-a-hodnota-vnimana-zakaznikom/

[9] HRNCIAR, M., GANOVA, J., MIKUSOVA, A.: *Survey of Customer Satisfaction of the Slovak Post*, project, 2008.

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# ECONOMICALLY OPTIMAL ROAD SUBNETWORK

*The paper deals with the following situation: An area is served by a transportation network, usually the road one. The current quality of the network is not satisfactory for the owner (e.g. a company or public administration), but the reconstruction or recovery of the whole network is not feasible for the economic reasons. Managers, who are responsible for the network, make decisions how to reduce the network and then to reconstruct or recover it meeting certain conditions and minimizing costs. The condition is formulated by means of the set W of important pairs of sources and sinks of transport flows and by the number q ≥ 1 representing the maximal acceptable elongation rate of routes between nodes (vertices) from the set W.*

*Such a problem can be met e.g. in rural road network reduction for winter maintenance, choice of tram or trolleybus network as a subnetwork of the bus one etc.*

*The paper describes the mathematical support for that decision making. The mathematical model of the problem is presented. Then a depth-first search type exact method is proposed and verified. Afterwards, a heuristics is described and verified as well. Finally, linear programming version of the problem is added.*

*The results were applied to urban bus network of Slovak town Piestany.*

***Keywords:*** *Road, network, subnetwork, optimization.*

## 1. Introduction

The paper describes the results of research focused on mathematical support for the following managerial decision-making problem: For the given road network, select a subnetwork that would be enough to fulfill a mission and whose adaptation or reconstruction would require minimal resources. One can mention several examples.

### 1.1 Rural Roads Network

As can be seen from the road map, in the Czech Republic (and certainly somewhere else), one can find many regions where the average distance between neighboring villages is about 2 km and there are direct roads from each village to other 3-6 villages – see e.g. areas around Cheb, Kolín, Telc etc. Such a network is too long for the regular maintenance, mainly in the winter time. The problem is to reduce it and to determine a suitable subnetwork. It is desirable not to increase the length of routes for strong vehicle flows at all, or to do it only partially.

### 1.2 Urban Trolleybus or Tram Network

The usual development of public transport in medium towns begins by the phase of bus transport and then, after many years, the idea of partial electrification arises. The problem is how to choose a trolleybus or tram subnetwork of the bus network. Naturally, the electrified subnetwork has to serve to the strongest passenger flows and not to force them to travel on much longer routes than before. The partial change of bus to trolleybus networks took place e.g. in Slovak towns Zilina (1994), Banska Bystrica (1989), in Czech towns Chomutov (1995), Opava (1952).

### 1.3 Urban Bus Transport Intensification

In the past, in several Czech and Slovak towns with 30-60 thousands inhabitants, the bus urban transport was of 'extensive' type. I.e., on almost every street ran a bus line, but the intervals between successive buses were very long, ½-1 hour or even more. Further, the city administration ought to build and maintain many stop shelters, adapted for long waiting passengers. Some town hall managers were displeased

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with it. They decided to intensify the system by reducing the network, but with the condition that the travel time extends for more than 15% for no significant passenger flow. Such an arrangement saves time for passengers and money for the town hall, since the system needs less stops with smaller and cheaper stop shelters - see [1].

### 1.4 Other Transport Networks

Other transport networks, e.g. rural railways, continental waterways, mountain ski tows and cableways, may be subject of reduction because of small demand or necessity of expensive modernization. However, it is desirable not to increase the length of routes for strong passenger (or freight) flows at all, or to do it only partially.

### 1.5 Common Features of the Decision Problems

All four abovementioned decision problems have several common features:

- A network, i.e. a non-oriented graph, is given.
- Each edge of the network has a 'length' in a general sense - for example, it may be the actual length, the time of transit, the cost of construction or maintenance, etc. The notion of 'length' is extended to the set of routes as the sum of lengths of the edges forming the route.
- A 'demand flow' is given for each pair of vertices. Several of the pairs are considered important, e.g. the ones with high flow between them.

The decision problem is to find a subnetwork of minimal 'length' where no important pair of vertices has a distance (= the 'length' of the shortest path) exceeding $q.d$, where $q \geq 1$ is the given number and $d$ is the distance of the pair on the original network.

### 1.6 Optimal Subgraph Problem in Bibliography

The decision problem formulated in 1.5 belongs to the family of network design problems (NDP's). One can look at it from several perspectives. The civil engineering will ask how to construct them. The geographical one focuses attention on the accessibility of network, i.e. the distance of the origin of the trip to the closest entrance and the distance of the closest exit to the destination. The transport viewpoint observes transport time, reliability, costs etc. The mathematical questions are what model to create or choose and what method to use.

The "classic" NDP [2] can be formulated as follows: Given a transport network and a transport demand on it, the problem is to improve current links (= edges) or to add new ones minimizing the total (and usually generalized) travel costs of all demand elements. A NDP is said discrete [3] if it is focused on the link addition to an existing transport network. A NDP is said continuous [4 and 5] if it touches the improvement of current links. A particular case of public transport system is dealt in [3], [6] present the bimodal bus&car discrete urban road network design problem of bi-objective type: lane addition to the existing streets, new street constructions, converting some two-way streets to one-way streets, lane allocation for two-way streets, and the allocation of some street lanes for exclusive bus lanes are the studied measures focused on maximization of both consumer surplus, and maximization of the demand share of the bus mode.

Geographically, a typical feature of modern transport systems is the growth of networks [7]. However, it brings not only many positive effects, but also some negative ones. For instance, [8] draw attention to the rise in trip length and travel time in the metropolitan area of Madrid. On the other hand, [9] show that there are measures against this negative development.

Until now, there was presented the "main stream" in the theory of NDP dealing with the growth of networks, improving current links or adding new ones. However, that doesn't apply in some weak demand areas, e.g. in remote regions. There, one can see the opposite phenomenon - the need to reduce the existing network, e.g. for economic reasons or for the reasons mentioned in 1.1 – 1.4. And that is the main topic which is dealt below using the abbreviation NDP-R (Network Design Problem - Reduction). Of course this may increase the risk of network vulnerabilities, as pointed out by [10].

To find an article oriented directly to the NDP-R is difficult, they are rare. One can mention the paper by [11]. It starts with possible, i.e. not yet existing, network. The problem is to select a subnetwork to be really constructed minimizing the total construction and transportation costs.

It is obvious that, in general, the NDP-R can be solved by the models and techniques described in the papers mentioned above, provided that the constraints and objective function remain unchanged. However, the following problem does not fall into this category.

Suppose an area is covered by a transportation network. This coverage is thought ideal in terms of meeting transport demand. However, it is too expensive to operate the entire network. Therefore, it is necessary to reduce it to the cheapest subnetwork "sufficient to fulfill the original purpose". The last condition is formulated by means of the set $W$ of important pairs of sources and sinks of transport flows and by the number $q \geq 1$ (e.g. q = 1.2) representing the maximal acceptable lengthening rate of routes between nodes (vertices) from the set $W$.

In the sequel, there are presented graph-theoretical models and methods applicable to this particular problem of transport subnetwork optimization. Hence graphs are used in mathematical context and networks concern transport.

In the graph theory, a large family of problems related to construction of extremal (max or min) subgraphs with the given properties has been studied for decades. E.g., the first known algorithm designing the shortest spanning tree was published in 1926 [12]. The further development of spanning tree theory is described in [13].

Typical representatives of the family are the following problems starting with the given graph $G = (V, E, c)$ where $c(e) \geq 0$ is a "cost" or "weight" (e.g. length or passing time or toll) of the edge $e \in E$:

- find the maximum planar subgraph [14],
- given integer $\lambda > 0$, find a $\lambda$-edge connected spanning subgraph with the minimum sum of edge weights [15 and 16] and also [17] where $c(e) \equiv 1$ and [18] where $\lambda = 2$,
- given integer $k > 0$, find a $k$-vertex subgraph with the maximum sum of edge weights [19],
- given integers $k > 0$, $\lambda > 0$, find a $k$-vertex $\lambda$-edge connected subgraph with the minimum sum of edge weights [20 and 21],
- given integer $d > 0$, find a subgraph with vertex degree not exceeding $d$ with the maximum sum of edge weights [22],
- given integer $d > 0$, find a subgraph with vertex degree not less than $d$ with the minimum sum of edge weights [22],
- given a subgraph $H$ of $G$, find the minimum weight-sum subgraph isomorphic to $H$ [23],

Other family members differ a bit from the ones mentioned above. E.g., [23] have weighted vertices instead of edges. Their second problem is to find the minimum weight-sum subgraph isomorphic to the given graph $H$. Or [24] considers $c(e)$ as the probability of defect (= break of service) and the problem is to eliminate $k$ edges in order to maximize the connection reliability. On the other hand, [25] study a finite set of graphs $G_1, ..., G_n$ and their problem is to find the maximum common subgraph, while [26] seek the maximum acyclic subgraph of a digraph.

## 2. Optimization Problem

All the examples 1.1 – 1.4 may lead to the following mathematical **problems:**

### 2.1 Subnetwork for Complete Flow Matrix

In this case one can suppose that for each pair of nodes $(v, w)$ a flow from $v$ to $w$ may exist.

Let $G = (V, E, d)$ be a connected undirected finite graph without loops with the length $d(e)$ for each $e \in E$. Let $d(p) = d(v_0, e_1, v_1, e_2, v_2, ..., v_{n-1}, e_n\ v_n) = d(e_1) + ... + d(e_n)$ be the length of the path $p$ and let $d(v, w)$ be the distance between the vertices $v$ and $w$ on the graph $G$, i.e., the length of the shortest path from $v$ to $w$.

Let $q \geq 1$ be a real number called the upper bound of the length extension ratio.

*The problem* is to find a graph $G' = (V, E', d')$ such that

C1: $E' \subset E$, $d'(e) = d(e)$ for each $e \in E'$, $d'(v, w)$ is the vertex distance on the graph $G'$.

C2: $d'(v, w) \leq q d(v, w)$ for each pair $(v, w) \in V \times V$

C3: $\sum_{e \in E'} d(e) \rightarrow \min$

### 2.2 Subnetwork for Important Flows

In this case one can suppose that there exists a set $W$ of selected pairs of vertices $(v, w)$ with important flow from $v$ to $w$.

Let $G = (V, E, d)$, $d(e)$, $d(p)$, $d(v, w)$ and $q$ have the same meaning as in 2.1

Let $\emptyset \neq W \subset V \times V$ where each $(v, u) \in W$ represents "important flow direction" from the vertex $v$ to the vertex $u$ (the other flows are so small that they are neglected in the problem)

*The problem* is to find a graph $G' = (V, E', d')$ such that

C1: $E' \subset E$, $d'(e) = d(e)$ for each $e \in E'$, $d'(v, w)$ is the vertex distance on the graph $G'$.

C2: $d'(v, w) \leq q d(v, w)$ for each pair $(v, w) \in W$

C3: $d(E') = \sum_{e \in E'} d(e) \rightarrow \min$

It is easy to see that 2.1 is a particular case of 2.2, one only needs to replace the set $W$ by the set $V$. Any method solving 2.1 is suitable for 2.2 as well.

### 2.3 Other Similar Problems

It is possible to modify the basic problem 2.1 in a way different from 2.2.

- One can change the role of the constraint on the length extension ratio and the objective of the total length of the subnetwork and look for a subnetwork with a limited length minimizing the maximum of the length extension ratio.
- One can replace the previous min-max objective by the weighted sum where the coefficients are proportional to the flows.

## 3. Exact Methods of Solution

It is known [3] that the discrete network design problem has been recognized as one of the most difficult yet challenging problems in transport. As shown in [27], both problems 2.1 and 2.2 are NP-hard. Therefore, even in the case of Problems 2.1 and 2.2, the exact solution can be expected only for small instances of them – say, until 25 vertices.

In the chapters 3 and 5, two basically different exact methods are described. In the chapter 6, it is shown that these methods are usable for different networks with 20 vertices and sometimes even with 30 ones. In the chapter 4 an original heuristics is presented. All these methods are compared in the Table 1.

At the beginning, it is good to predict whether the resulting set $E'$ will have the number of elements $|E'|$ closer to $|E|$ or to 0. In the first case it is better to use the following decreasing method. In the second case the increasing one is better. If the prediction is not possible then one can start with any one of the methods (the authors prefer the decreasing one). Both these methods are of the "depth first search" type.

### 3.1 Decreasing Exact Method for the Problem 2.1

First, the ordering of the set $E = \{e_1, e_2, ..., e_n\}$, $n = |E|$ is chosen. The computing experiments show that it can affect the duration of computations (see later).

Start with $E' = E$. Obviously the constraint C2 is valid and the record is $d(E') = d(E)$. Then subsequently inspect the sets $E' = E - \{e_1\}$, $E - \{e_1, e_2\}$, $E - \{e_1, e_2, e_3\}$ until the first moment when the constraint C2 fails, say, for $E' = E - \{e_1, e_2, ..., e_{k-1}, e_k\}$. Then the set $E' = E - \{e_1, e_2, ..., e_{k-1}\}$ is a temporary solution with the record $d(E')$. If $k = 1$ then the procedure stops since the optimal solution is obviously $E' = E$. If $k > 1$. Then the backtracking is done omitting $e_k$ and replacing it by $e_{k+1}$ etc.

### 3.2 Increasing Exact Method for the Problem 2.1

Start with $E' = \emptyset$. Obviously the constraint C2 is not valid. Then the sets $E' = \{e_1\}$, $\{e_1, e_2\}$, $\{e_1, e_2, e_3\}$ are subsequently inspected until the first moment when the constraint C2 is fulfilled, say, for $E' = \{e_1, e_2, ..., e_k\}$ with the record $d(E')$. If $k = n$ then stop since the optimal solution is obviously $E' = E$. If $k < n$ then backtrack, omit $e_k$ and replace it by $e_{k+1}$ etc.

## 4. Heuristic Method of Solution

General NDP is solvable by several metaheuristics, e.g., ant colony system, tabu search, simulated annealing, genetic algorithm and their hybrids [28and 29]. For the Problems 2.1 and 2.2, a new method is presented, based on the following lemma:

### 4.1 Lemma

Let $G = (V, E, d)$ be a connected undirected finite graph without loops with the length $d(e)$ for each $e \in E$. Let $d(p) = d(v_0, e_1, v_1, e_2, v_2, ..., v_{n-1}, e_n\, v_n) = d(e_1) + ... + d(e_n)$ be the length of the path $p = v_0, e_1, v_1, e_2, v_2, ..., v_{n-1}, e_n\, v_n$ and let $d(v, w)$ denote the distance between the vertices $v$ and $w$ on the graph $G$. Let $E' \subset E$, let $q > 1$ and let

$d'(e) = d(e)/q$ for each $e \in E'$ and $d'(e) = d(e)$ for $e \in E - E'$

Let $v \in V$ and $v \in V$ be arbitrary. Let $p = v_0, e_1, v_1, e_2, v_2, ..., v_{n-1}, e_n, v_n$ be the shortest path connecting the vertices $v, w$ in the graph $G_o = (V, E, d')$. Then $d(p) \le q.d(v, w)$.

*Proof.* Obviously

$q.d'(p) = q(d'(e_1) + d'(e_2) + d'(e_n)) \ge d(e_1) + d(e_2) + d(e_n) = d(p)$

Let $r$ be the shortest path connecting the vertices $v, w$ in the graph $G$. Of course, in the graph $G_o$ it need not be true and thus

$d'(p) \le d'(r) \Rightarrow d(p) \le q.d'(p) \le q.d'(r) \le q.d(r) = q.d(v, w)$

since $d'(e) \le d(e)$ for each $e \in E$. The proof is complete.

### 4.2 The Heuristic Algorithm

1°: Put $j = 0$, $E_j = \emptyset$, $G_j = G$.

2°: Find the shortest path $p(v, w)$ on $G_j$ for each pair $(v, w) \in V \times V$.

3°: For each $e \in E - E_j$ put $m_j(e) = \mathrm{card}\{(v, w) \in V \times V : e \in p(v,w)\}$

4°: Find such $e^* \in E - E_j$ that $m_j(e^*) = \max\{m_j(e) : e \in E - E_j\}$.

a) If $m_j(e^*) = 0$ then put $E' = E_j$ and stop.

b) If $m_j(e^*) > 0$ then do 5°.

5°: Put $E_{j+1} = E_j \cup \{e^*\}$, $d_{j+1}(e^*) = d(e^*)/q$, $d_{j+1}(e) = d_j(e)$ for each $e \in E - \{e^*\}$, $G_{j+1} = (V, E, d_{j+1})$, add 1 to $j$ ("put $j = j + 1$") and go to 2°.

*Comments:* The heuristic algorithm ends when 4°a) occurs. Then for each pair $(v, w) \in V \times V$ the shortest path $p = (v, e_1, v_1, e_2, v_2, ..., v_{n-1}, e_n\, w)$ connecting the vertices $v$ and $w$ in the graph $G_j$ passes through $E' = E_j$ only (i.e. $e_1 \in E_j, ..., e_n \in E_j$). Hence it is the shortest path between $v$ and $w$ in the graph $G' = (V, E', d')$, i.e. $d'(p) = d'(v, w)$. On the other hand, the conditions of the lemma 4.1 hold, which implies $d'(v, w) \le q.\, d(v, w)$, i.e., the constraint C2 of the problem 2.1 is met and thus the set $E'$ represents a feasible but not necessarily optimal solution of it.

If the heuristics 4.2 is modified in such a way that instead of "each pair $(v, w) \in V \times V$" each pair $(v, w) \in W \times W$" is taken, the solution of the problem 2.2 is resulting.

## 5. Solution by Integer Linear Programming

In the next text, only the problem 2.2 is studied, since the problem 2.1 is its particular case.

Let $n \ge 2$ be a positive integer, let $V = \{1, 2, ..., n\}$ and let $G = (V, E, d)$ be a connected undirected finite graph without loops with the length $d(e)$ for each $e \in E$. Further, let $d(v, w)$ be the distance between the vertices $v$ and $w$ on the graph $G$. Let $\emptyset \ne W \subset V \times V$ and finally let $q \in \langle 1, \infty )$.

**The problem** is to find the values of the following integer variables:

$x_{ij} \in [0, 1]$ for $(i, j) \in E$, $i < j$, (5.1)

$y_{vwij} \in [0, 1]$ for $(v, w) \in W$, $(i, j) \in E$, (5.2) minimizing the objective function

$$\sum_{(i,j)\in E} d(i,j)x_{ij} \rightarrow \min \qquad (5.3)$$

and satisfying the following constraints

$$\sum_{(i,j)\in E} d(i,j)y_{vwij} \leq qd(v,w) \text{ for } (v, w) \in W, \qquad (5.4)$$

$$\sum_{(i,v)\in E} y_{vwiv} + 1 = \sum_{(v,k)\in E} y_{vwvk} \text{ for } (v, w) \in W, \qquad (5.5)$$

$$\sum_{(i,w)\in E} y_{vwiw} = \sum_{(w,k)\in E} y_{vwwk} + 1 \text{ for } (v, w) \in W, \qquad (5.6)$$

$$\sum_{(i,j)\in E} y_{vwij} = \sum_{(j,k)\in E} y_{vwjk} \text{ for } (v, w) \in W, j \neq v, j \neq w, \qquad (5.7)$$

$$y_{vwij} \leq x_{ij} \text{ for } (v, w) \in W, (i, j) \in E, i < j \text{ and}$$

$$y_{vwij} \leq x_{ji} \text{ for } (v, w) \in W, (i, j) \in E, j < I \qquad (5.8)$$

*Comments:* The value $x_{ij}$ = 1 means that the edge $(i, j)$ remains in the reduced network, $x_{ij}$ = 0 means that it is omitted. The value $y_{vwij}$ = 1 means that, in the reduced network, the shortest path from $v$ to $w$ passes through the edge $(i, j)$, $y_{vwij}$ = 0 means the opposite.

The objective function (5.3) expresses the total length of the reduced network.

The constraint (5.4) ensures that the relative extension of the shortest path between any important pair $(v, w) \in W$ does not exceed the value $q$.

The constraints (5.5), (5.6) and (5.7) ensure that the shortest path between $v$ and $w$ starts in $v$ ends in $w$ and passes other vertices without any branching and merging.

The constraint (5.8) ensures that the shortest path from $v$ to $w$ passes only through the reduced network.

## 6. Computational Experience

Table 1 summarizes the results of described methods on 10 randomly generated test networks. In case of the networks 1 to 9 the number of vertices is 20 and the number of edges varies between 28 and 32. In case of the network 10 it is 30 vertices and 47 edges. The experiments were carried out with q set to 1.2 and 1.5 and with the numbers of randomly chosen important pairs of vertices (NIP) set to 13 and 20.

Observing the table one can see the exactness of the heuristics. The average difference of the length from the optimal solution is 14%. In four cases from forty it is 0, in further 3 cases it is less than1%. On the other hand, in 5 cases the difference is greater than 30%.

The differences are not only metrical but also topological. For instance, Fig. 1 depicts the test network No. 3. In the second case, there are 20 important pairs belonging to the set $W$: (1, 2), (1, 6), (1, 10), (1, 15), (1, 17), (2, 6), (2, 9), (2, 10), (2, 15), (2, 16), (2, 17), (2, 19), (6, 10), (6, 15), (6, 17), (9, 17), (10, 15), (10, 17), (15, 17), (17, 19). The vertices which belong to at least one important pair are filled and bold. Excluded edges are dotted.

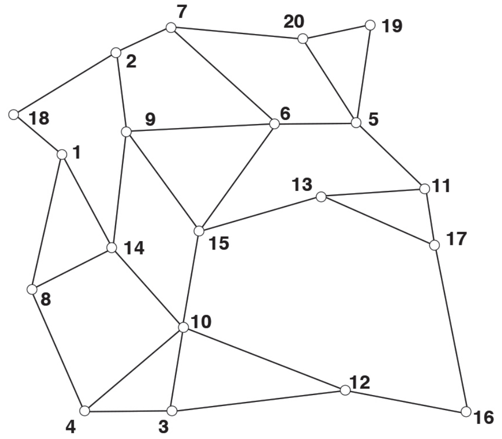


*Fig. 1 The original test network No. 3*

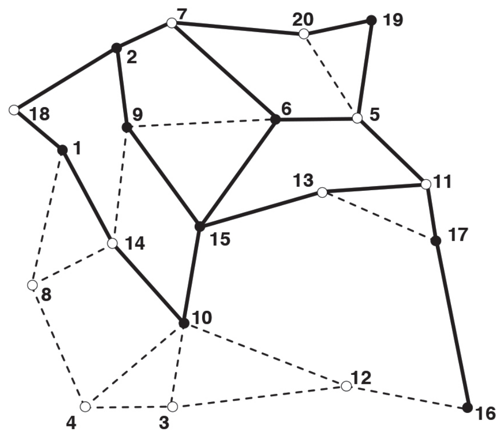


*Fig. 2 Exact solution - NIP = 20 and q = 1.2*

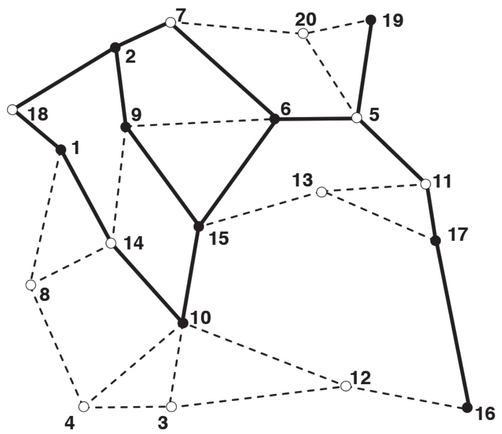


*Fig. 3 Exact solution - NIP = 20 and q = 1.5*

Table 1

| | | | | | | Exact method (EM) | | Heuristic method (HM) | | Integer linear programming (LP) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TN | ONV | ONE | ONL | q | NIP | RNL | CT [s] | RNL | CT [s] | RNL | CT [s] |
| 1 | 20 | 30 | 213.3 | 1.2 | 13 | 88.5 | 1596 | 91.2 | < 1 | 88.5 | 3.5 |
| | | | | 1.2 | 20 | 88.5 | 1053 | 88.5 | < 1 | 88.5 | 11.4 |
| | | | | 1.5 | 13 | 72.8 | 12430 | 82.5 | 1 | 72.8 | 2.4 |
| | | | | 1.5 | 20 | 72.8 | 8844 | 79.8 | 1 | 72.8 | 8.6 |
| 2 | 20 | 30 | 204.2 | 1.2 | 13 | 65.8 | 5205 | 65.8 | < 1 | 65.8 | 7 |
| | | | | 1.2 | 20 | 65.8 | 3658 | 83.3 | 1 | 65.8 | 10.8 |
| | | | | 1.5 | 13 | 54.9 | 7757 | 65.8 | 1 | 54.9 | 9.5 |
| | | | | 1.5 | 20 | 65.8 | 1194 | 65.8 | 1 | 65.8 | 9.8 |
| 3 | 20 | 32 | 232.7 | 1.2 | 13 | 84.8 | 3033 | 89.5 | 1 | 84.8 | 7.9 |
| | | | | 1.2 | 20 | 127.6 | 142 | 128.8 | 1 | 127.6 | 27.6 |
| | | | | 1.5 | 13 | 78.6 | 146 | 89.5 | 1 | 78.6 | 8.9 |
| | | | | 1.5 | 20 | 99.9 | 2681 | 122.4 | 1 | 99.9 | 31.8 |
| 4 | 20 | 30 | 204.6 | 1.2 | 13 | 74.1 | 2735 | 74.6 | 1 | 74.1 | 4.2 |
| | | | | 1.2 | 20 | 103.0 | 226 | 105.3 | 1 | 103 | 17.5 |
| | | | | 1.5 | 13 | 73.4 | 7884 | 74.6 | 1 | 73.4 | 5.1 |
| | | | | 1.5 | 20 | 85.2 | 1906 | 87.4 | 1 | 85.2 | 19.7 |
| 5 | 20 | 29 | 209.6 | 1.2 | 13 | 87.7 | 485 | 99.7 | < 1 | 87.7 | 7.8 |
| | | | | 1.2 | 20 | 103.5 | 41 | 112.6 | 1 | 103.5 | 11.5 |
| | | | | 1.5 | 13 | 80.3 | 2479 | 99.7 | 1 | 80.3 | 8.6 |
| | | | | 1.5 | 20 | 90.4 | 555 | 120.2 | 2 | 80.3 | 19.2 |
| 6 | 20 | 32 | 212.9 | 1.2 | 13 | 92.5 | 3168 | 128 | 1 | 92.5 | 13.6 |
| | | | | 1.2 | 20 | 96.6 | 1611 | 138.5 | 1 | 96.6 | 46.7 |
| | | | | 1.5 | 13 | 81.4 | 13856 | 97.5 | 1 | 81.4 | 790.6 |
| | | | | 1.5 | 20 | 96.6 | 7237 | 108.2 | 1 | U | - |
| 7 | 20 | 31 | 176.5 | 1.2 | 13 | 48.3 | 16672 | 54.1 | 1 | 48.3 | 10.5 |
| | | | | 1.2 | 20 | 59.9 | 2491 | 65.7 | 1 | 59.9 | 41.5 |
| | | | | 1.5 | 13 | 48.3 | 17912 | 54.1 | 1 | 48.3 | 8.1 |
| | | | | 1.5 | 20 | 59.9 | 4818 | 65.7 | 1 | 59.9 | 44.8 |
| 8 | 20 | 28 | 197.7 | 1.2 | 13 | 81.8 | 900 | 95.7 | 1 | 81.8 | 4.3 |
| | | | | 1.2 | 20 | 91.8 | 347 | 115.2 | 1 | 91.8 | 15.2 |
| | | | | 1.5 | 13 | 66.3 | 1606 | 69.9 | 1 | 66.3 | 8.9 |
| | | | | 1.5 | 20 | 66.3 | 730 | 66.3 | < 1 | 66.3 | 17.9 |
| 9 | 20 | 30 | 191.6 | 1.2 | 13 | 115.2 | 11 | 137.9 | 2 | 115.2 | 6.8 |
| | | | | 1.2 | 20 | 122.9 | 6 | 145.7 | 1 | 122.9 | 17.8 |
| | | | | 1.5 | 13 | 75.3 | 2370 | 101.5 | 1 | 75.3 | 25.7 |
| | | | | 1.5 | 20 | 93.3 | 240 | 125.5 | 1 | 93.3 | 64 |
| 10 | 30 | 47 | 271.9 | 1.2 | 13 | U | - | 95.8 | 1 | 78.1 | 15.9 |
| | | | | 1.2 | 20 | U | - | 101.8 | 4 | 84 | 49 |
| | | | | 1.5 | 13 | U | - | 70.1 | 1 | 58.8 | 32.7 |
| | | | | 1.5 | 20 | U | - | 76.1 | 1 | 75.8 | 128.6 |

**The legend:** TN = Test network, ONV = Number of vertices, ONE Number of edges and ONL = Total length of the original network, NIP = Number of Important Pairs, RNL = Total length of the reduced network, CT = Computational time, U = Solution was not reached in an acceptable time

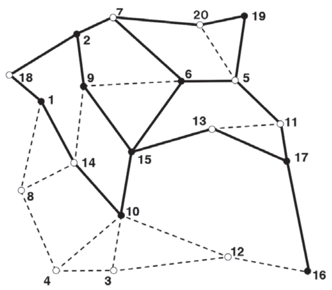

*Fig. 4 Heur. solution - NIP = 20 and q = 1.2*

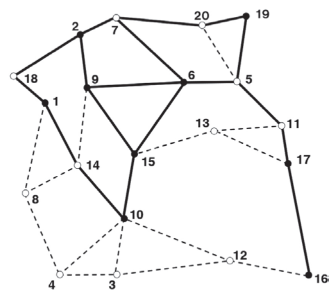

*Fig. 5 Heur. solution - NIP = 20 and q = 1.5*

Fig. 2 depicts the exact solution of the problem 2.2 in the case of $q$ = 1.2 and Fig. 3 the same for $q$ = 1.5. Analogically, Figs. 4 and 5 depict the same for the heuristics. It is remarkable, that the resulting subgraphs in Figs. 2 and 4 are almost equal. I.e., in this case, the heuristic solution for $q$ = 1.2 is nearly the same as the optimal solution for $q$ = 1.2.

## 7. Application in Practice

The abovementioned heuristic method was applied to the practical situation in the Slovak town of Piestany with about 30 thousands permanent residents and (at least) hundreds of spa guests. The number of vertices is 20, the number of edges is 31 and the number of important pairs of vertices (NIP) is 20. The network – see Fig. 6 – represents all streets that are suitable for bi-directional bus traffic on the right bank of the Vah River. It does not contain the connections to the western suburb from the vertex 14, to the northern suburb from the vertex 3 and to the spa area from the vertex 8, since these links must not be omitted by any reduction.

Figure 7 depicts the result of the heuristics for $q$ = 1.2. It was finally chosen as the base for routing of the proposed urban bus network.

The reached reduction is about 23%. This result was preferred by the urban authority, although for $q$ = 1.5 it was possible to reduce the length of the original network by 48%. The last mentioned density seemed too small.

## 8. Conclusion

The paper started with identification and formulation of a problem of road network reduction and its applications to different practical networks was outlined. An exact method of solution based on depth-first search technique was presented and, since the problem is NP-hard, a heuristic method was proposed. Moreover, it was shown that the problem is solvable by linear programming as well. Afterwards, the results of computational experience are drawn up. Finally, a practical application to the urban transport network in the Slovak town Piestany was presented.

**Acknowledgement**

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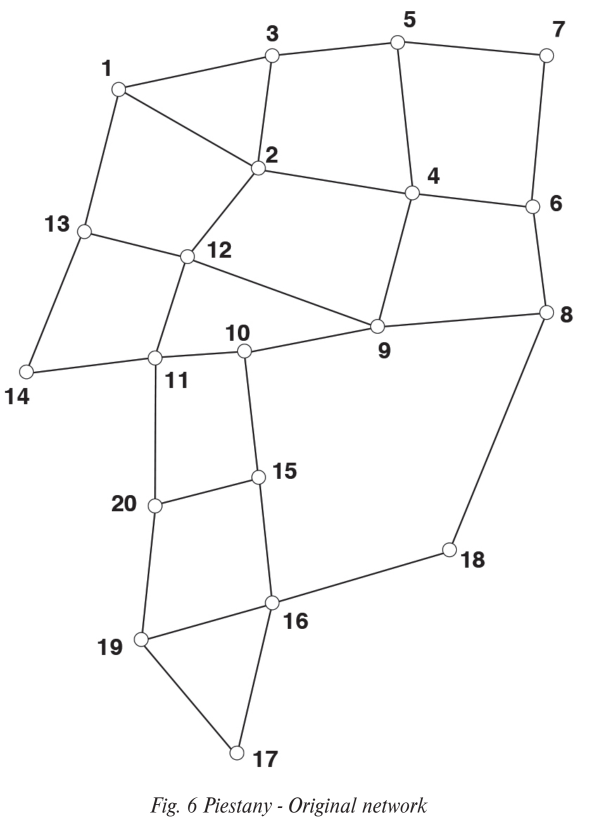


*Fig. 6 Piestany - Original network*

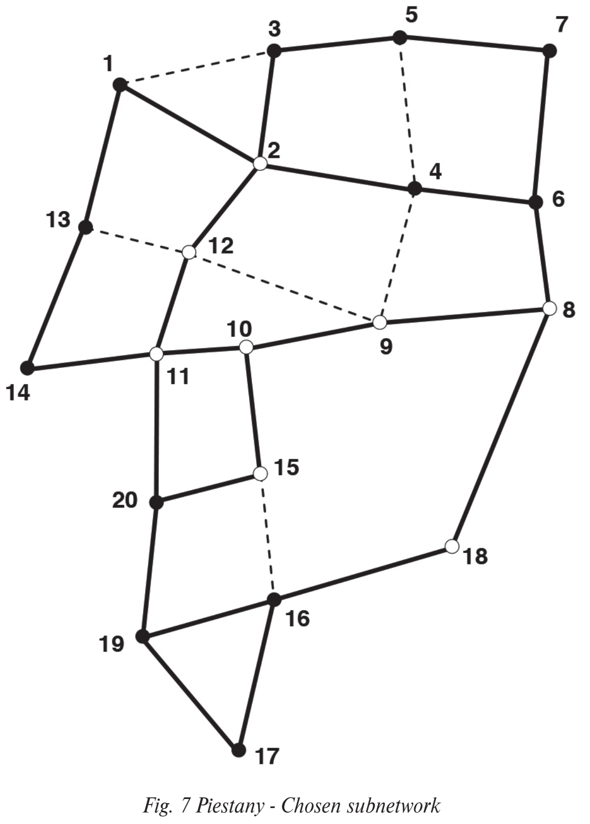


*Fig. 7 Piestany - Chosen subnetwork*

## References


[1] CERNA, A.: Economic and Social Harmonization of Sustainable Public Transport. *Prague Economic Papers,* 21(1) 83-100, 2012.

[2] YANG, H., BELL, M. G. H.: Models and Algorithms for Road Network Design: A Review and Some New Developments. *Transport Reviews,* 18(3), 257-278, 1998.

[3] GAO, Z. Y., WU, J. J., SUN, H. J.: Solution Algorithm for the Bi-level Discrete Network Design Problem. *Transportation Research Part B – Methodological,* 39(6), 479-495, 2005.

[4] MENG, Q., YANG, H., BELL, M. G. H.: An Equivalent Continuously Differentiable Model and a Locally Convergent Algorithm for the Continuous Network Design Problem. *Transportation Research Part B - Methodological* 35(1), 83-105, 2002.

[5] MENG, Q., YANG, H.: Benefit Distribution and Equity in Road Network Design. *Transportation Research Part B - Methodological* 36(1), 19-35, 2002.

[6] MIANDOABCHI, E., ZANJIRANI FARAHANI, R., SZETO, W. Y.: Bi-objective Bimodal Urban Road Network Design Using Hybrid Metaheuristics. *CEJOR* 20(4), 583-621, 2012.

[7] XIE, F., LEVINSON, D.: Modeling the Growth of Transportation Networks: A Comprehensive Review. *Networks and Spatial Economics,* 9(3), 291-307, 2009.

[8] GUTIERREZ, J., GARCIA-PALOMARES, J. C.: New Spatial Patterns of Mobility within the Metropolitan Area of Madrid: Towards more complex and dispersed flow networks. *J. of Transport Geography,* 15(1), 18-30, 2007.

[9] KELLY, M. E., NIEDZIELSKI, M. A.: Efficient Spatial Interaction: Attainable Reductions in Metropolitan Average Trip Length. *J. of Transport Geography,* 16(5), 313-323, 2008.

[10] JENELIUS, E.: Network Structure and Travel Patterns: Explaining the Geographical Disparities of Road Network Vulnerability. *J. of Transport Geography,* 17(3), 234-244, 2009.

[11] DREZNER, Z., WESOLOWSKY, G. O.: Network Design: Selection and Design of Links and Facility Location. *Transportation Research Part A - Policy and Practice* 37(3), 241-256, 2003.

[12] BORUVKA, O.: About a Certain Minimal Problem (in Czech, German summary), *Prace mor. prirodoved. spol. v Brne,* III (3), 37-58, 1926.

[13] CAI, L., CORNEIL, D. G.: Tree Spanners*. SIAM J. Discrete Mathematics,* 8 (3), 359-387, 1995.

[14] EADES, P., FOULDS, L. R., GIFFIN, J. W.: An Efficient Heuristic for Identifying a Maximum Weight Planar Subgraph. *Combinatorial Mathematics IX, Lecture Notes in Mathematics,* No. 952. Springer-Verlag, Berlin 1982, 2003.

[15] GABOW, H. N., GOEMANS, M. X., TARDOS, E., WILLIAMSON, D. P.: Approximating the Smallest k-Edge Connected Spanning Subgraph by LP-Rounding. *SODA '05 Proc. of the sixteenth annual ACM-SIAM symposium on Discrete algorithms*. Society for Industrial and Applied Mathematics Philadelphia, 562-571, 2005.

[16] CHERIYAN, J., THURIMELLA, R.: Approximating Minimum-Size k-Connected Spanning Subgraphs via Matching. *SIAM J. Comput.,* 30 (2), 528-560, 2000.

[17] FERNANDES, C. G.: A Better Approximation Ratio for the Minimum Size k-Edge-Connected Spanning Subgraph Problem. *J. Algorithms*, 28 (1), 105-124, 1998.

[18] CARR, R., RAVI, R.: A New Bound for the 2-Edge Connected Subgraph Problem. *R. E. Bixby, E. A. Boyd, and R. Z. Rios-Mercado (Eds.): IPCO VI, LNCS 1412*. Springer-Verlag Berlin Heidelberg 1998, 112-125, 1998.

[19] SUZUKI, A. TOKUYAMA, T.: Dense Subgraph Problem Revisited. *Proc. Joint Workshop New Horizons in Computing" and "Statistical Mechanical Approach to Probabilistic Information Processing,* 2005, Sendai, 1-2, 2005.

[20] SAFARI, M. A., SALAVATIPOUR, M. R.: A Constant Factor Approximation for Minimum λ-Edge-Connected k-Subgraph with Metric Costs. *A. Goel et al. (Eds.): APPROX and RANDOM 2008, LNCS 5171*. Springer-Verlag Berlin Heidelberg, 233-246, 2008.

[21] CHERIYAN, J., VEMPALA, S., VETTA, A.: An Approximation Algorithm for the Minimum-Cost k-Vertex Connected Subgraph. *SIAM J. Computing,* 32(4), 1050-10552003.

[22] AMINI, O., PELEG, D., PERENNES, S., SAU, I., SAURABH, S.: Degree-Constrained Subgraph Problems: Hardness and Approximation Results. *E. Bampis and M. Skutella (Eds.): WAOA 2008, LNCS 5426*. Springer-Verlag Berlin : Heidelberg 2009, 29–42, 2009.

[23] VASSILEVSKA, V., WILLIAMS, R., YUSTER, R.: Finding the Smallest H-Subgraph in Real Weighted Graphs and Related Problems. *M. Bugliesi et al. (Eds.): ICALP 2006, Part I, LNCS 4051.* Springer-Verlag Berlin Heidelberg 2006, 262-273, 2006.

[24] HINTSANEN, P.: The Most Reliable Subgraph Problem. *J.N. Kok et al. (Eds.): PKDD 2007, LNAI 4702*. Springer-Verlag Berlin Heidelberg 2007, 471–478, 2007.

[25] FERRER, M., SERRATOSA, F., VALVENY, E.: On the Relation between the Median and the Maximum Common Subgraph of a Set of Graphs. *F. Escolano and M. Vento (Eds.): GbRPR 2007, LNCS 4538*. Springer-Verlag Berlin Heidelberg 2007, 351-360, 2007.

[26] BERGER, B., SHOR, P. W.: *Approximation Algorithms for the Maximum Acyclic Subgraph Problem.* SODA '90 Proc. of the first annual ACM-SIAM Symposium on Discrete Algorithms. Society for Industrial and Applied Mathematics Philadelphia, 236-243, 1990.
[27] CZIMERMAN, P., CERNA, A., CERNY, J., PESKO, A.: Network Reduction Problems. *J. of Information, Control and Management Systems,* 5 (2), 139-147, 2007.
[28] POORZAHEDY, H., ABULGHASEMI, F.: Application of Ant System to Network Design Problem. *Transportation* 32(3), 251-273, 2005.
[29] POORZAHEDY, H., ROUHANI, O.: Hybrid Meta-heuristic Algorithms for Solving Network Design Problem. *European J. of Operational Research,* 182(2), 578-596, 2007.

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# THE IMPORTANCE OF THE RISK IN PUBLIC PASSENGER TRANSPORT FINANCING

*The paper deals with the importance of the risk in financing public passenger transport. The first part analyses the risks affecting financing public passenger transport. These risks can be divided into two basic groups: cost risks and revenue risks. The second part describes the ways of dividing risks between contractual parties. The risk determination in financing public passenger transport is discussed in the last part of the paper.*

***Keywords:*** *Transport, financing, risk, factor, region, public.*

## 1. Introduction

Under current conditions in terms of general economic interest, the public passenger transport services cannot be provided on a commercial basis. Therefore, the mechanisms arise by which the services in public transport are provided even in the time of low demand because it is necessary to ensure the access to basic population's needs such as work, healthcare and education. At present, the following mechanisms are used: the award of exclusive rights to public service operators (the public service operator is considered to be a person who performs transportation, operates the means of transport; and some regulations use the term of carrier), and the grant of financial compensation to public service operators. The mentioned principles are also incorporated in EU legislation [1]. The problem is the determination of financial compensation which includes a share of reasonable profit, mainly in case of the direct award of contract.

One of the reasons for adopting the regulation (EC) No. 1370/2007 was a requirement that the reasonable profit must be dependent on the risk presence [2]. However, the national application of the regulation is different across EU Member States. Based on the public service contracts concluded in the Slovak Republic (SR), the level of reasonable profit and methods for its determination are matters for the agreement between contractual parties – public authority (self-governing regions or cities) and public service operator [3]. The level of reasonable profit is set in range from 3.5 to 5.0% of economically justified costs in all contracts concluded in the SR to 2011 (e.g. public service contract in the town of Bardejov provides the reasonable profit of 5% during contract period; the contract is valid until 31.12.2018) [4]. The similar problem can be found also in other EU Member States. For example, in Hungary, public service contract concluded between the authority (Budapest city) and public service operator contains the provisions according to which the level of reasonable profit is a maximum of 4% of the economically justified costs [5]. In the Czech Republic, the government decree determining reasonable profit at the maximum level of 7.5% from operating assets per year was adopted in 2010 [6].

The reasonable profit must depend on level of risk-taking. However in practice, it is determined as a percentage of economically justified costs. But this method is not correct, because the operator who efficiently manages and achieves lower costs, also achieves a lower level of reasonable profit in comparison with the operator who provides comparable performance but at higher costs. Public funding should be dependent on the risk that is borne by the public service operator. From this reason, the objective of the paper is to determine the relationship between the risk existence and financing public passenger transport from the position of public authorities.

## 2. Analysis of the risks affecting the financing public passenger transport

Several authors deal with the risks and their distribution between operator and authority (e. g. Stanley, J., van de Velde, D.; Henscher, D. A, Stanley, J. van de Velde, D.). According to

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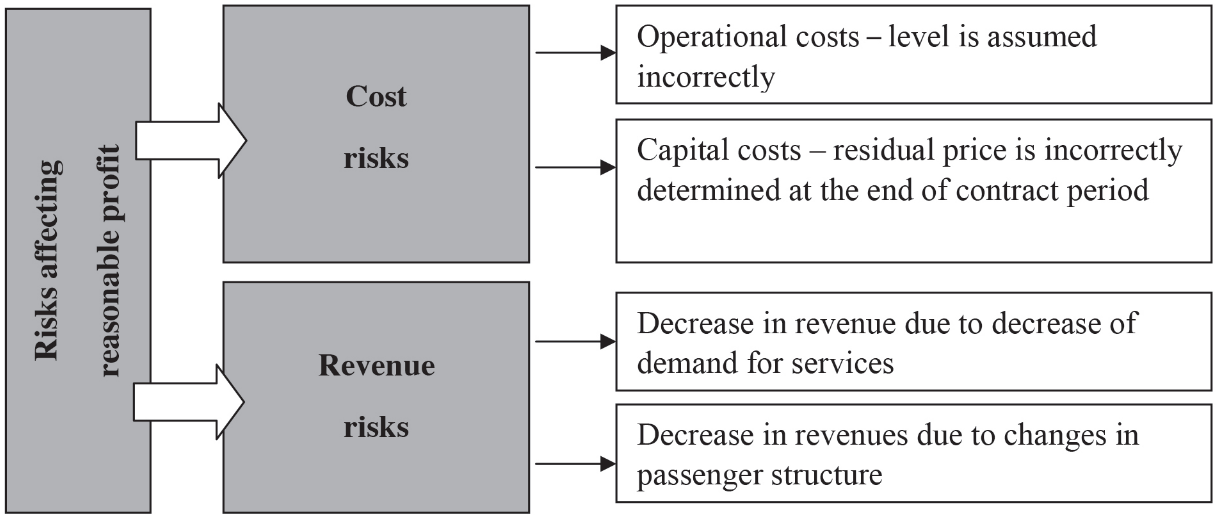


*Fig. 1 Classification of the risks affecting the reasonable profit [10]*

their studies, the risks should be divided into two groups – cost and revenue risks [7], [8] and [9].

### 2.1. Cost risks

Cost risks are related to the cost calculation when contracting public service contracts. In these contracts, it is necessary to agree on a price for realized performance. The price consists of the costs and profit of operator. When operators assume cost risks, it is necessary to determine a range of realized performance during contract period and economically justified costs per unit of realized performance in public service contracts. The cost risks can be divided into two groups [9]:

- operational cost risks – the risks that are related to the difference of the expected costs calculated and the actually observed costs after performance realization. The reasonable profit must depend on an allocation of this risk. When the operator does not assume the risk and after realization of performance he proves eligibility of costs to public authority for the purpose of compensation, the operator takes no cost risk for the performance realization. In the case that the agreed unit costs in public service contract are final, the operator assumes the cost risk and this should be reflected in appropriate level of reasonable profit. The operational cost risks can be divided into:
    - external operational cost risks – the risk that cannot be influenced by the operator at all (e.g. cost increasing due to flooding streets in the event of natural disasters). This group can also include the risk which can be influenced by operator indirectly or only in a small extent (e.g. changes in energy prices during the contract period, change of employees' costs, and etc.),
    - internal operational cost risks – the risk that can be influenced by the operator, e.g. the costs of maintaining of vehicle fleet (the operator can decide on the maintenance process in order to avoid failure of vehicle and higher costs),
- investment cost risks – the risks that are related to the difference of the anticipated life of the fixed assets of the operator. While providing public passenger transport it is primarily the means of transport and infrastructure (e.g. bus and tram stops, tram tracks, and etc.). The reasonable profit must depend on which party assumes the risk of the difference of actual net book value of fixed assets at the end of a contract period compared to anticipated net book value.

### 2.2 Revenue risks

Revenue risks are associated with the difference between the expected revenue from an operation of public passenger transport and the revenue actually achieved at the end of contract period. Revenue risks can be borne by either public authorities or operators and in this regard there must be appropriately set a profit level of the operator. When the authority assumes the revenue risk, then a contractual relationship between the authority and the operator which sets a compensation for realized performance is based on following formula:

$$K = (NJ + PZ) * RV - V \text{ (€)} \quad (1)$$

where:
K – compensation to operator from authority,

NJ – costs per unit of realized performance,
PZ – reasonable profit for operator expressed per performance unit,
RV – realized performance,
V – revenues achieved when realizing performance.

When there are agreed final costs per unit in public service contract, which cannot be changed during a contract period, the cost risks are fully borne by the operator. The revenue risks are borne by the authority. This means that if operator's revenue is decreasing, the compensation from authority's side is increasing.

When the operator assumes the revenue risk, in the contract there is determined in addition to realized performance also absolute amount of compensation which cannot be changed during a contract period. The compensation is based on anticipated costs and revenue while changes in costs and revenue pose a risk of the operator. A part of the compensation is a reasonable profit of the operator resulting from cost and revenue risk of realized performance.

The cost risks are not usually related with interventions of public authorities (with an exception of changes in tax burden of the operator), and currently they are usually transmitted to operators. In the case of revenue risks, it is possible to define influence of public authorities on revenue risks; the risks can be divided into two groups:

- revenue risk associated with a decrease in demand – it is the risk related to the changes in number of passengers carried when providing public passenger transport. In the case that the authority bears the revenue risk, it is necessary to appropriately involve the operator in compliance with required quality because the amount of the compensation in this case does not depend on the number of passengers carried [10]. In the SR, this risk is very significant because the demand for public passenger transport expressed in passenger-kilometres (pskm) is decreasing annually in road and railway transport.

While the performance of regular bus transport was on the level of 8.4 billion pskm in 2000; in 2011, it was on the level of only 4.611 billion pskm (Table 1). It represents a performance decrease by about 45%. A similar development can be also observed in railway transport where the performance was at the level of 2.87 billion pskm, in 2000. In 2011, performance of railway transport achieved a value only 2.431 billion pskm. This represents a performance decrease by about 15% (Table 1). Significant decrease in railway transport can be found between 1995 and 2000. Decreasing in demand can be also found in other countries. Changes in demand for public services are elaborated by the authors of studies [12], [13] and [14]. Table 1 shows data from the whole SR, however, the performance decrease is not the same throughout territory of the SR. Therefore, when it comes to the revenue risk associated with a decrease in demand, it is necessary to distinguish territories in which the transport services are operated. The development of number of passengers carried depends to some extent on the interventions of public authorities which can indirectly influence the number of passengers carried through a fulfilling their strategic objectives. The strategic objectives of public authorities can be divided to [15]:

  - economic - maximizing the effectiveness and efficiency of resource use (e.g. limitations of unused connections, fare increase for less used connections, taxation of passenger cars as a source of compensation for losses of public passenger transport, etc.);
  - environmental - minimizing the impact of transportation in a served area (e.g. limiting access of cars at defined time intervals in a serviced territory);
  - social - ensuring possibility of mobility for all people, particularly for vulnerable groups of passengers (lower fares for students, pensioners, etc.);
  - public - planning transport policy and other policies in a region (e.g. deployment of schools raises a demand for carriage, etc.).

- revenue risk associated with a change of passenger structure – it is the risk of revenue change because of a change of passenger structure. For example, when the selected groups of passengers (students, pensioners) travel with special fares, an increase in number of those passengers while keeping the total number of passengers causes a decrease in total revenue for providing transport services. The good solution is setting an appropriate pricing policy of transport services. However, it is important to monitor the impact of price changes on the demand, which varies considerably for particular groups of passengers [16]. In the SR, the discounted fares known as saver tickets (half price of a full fare ticket) are for young people aged 6 to 15 and students to 26, and fares known as "other fares" are for [17] and [18] :
  - senior citizens over 70 ( e 0.20 per every 50 km),
  - severely disabled people (half price of a full fare ticket),
  - parents travelling to visit their physically or mentally disabled, chronically ill children nourished in special facilities in the SR (half price of a full fare ticket).

Performance development (in million pskm) in the SR [authors' processing on the base of dates from [11]] Table 1

| Mode of transport | 2000 | 2005 | 2008 | 2009 | 2010 | 2011 | % change from 2000 to 2011 |
|---|---|---|---|---|---|---|---|
| Railway passenger transport | 2 870 | 2 182 | 2 296 | 2 264 | 2 309 | 2 431 | - 15% |
| Regular bus service | 8 435 | 7 525 | 6 446 | 4 538 | 4 436 | 4 611 | - 45% |
| Urban transport | 1 173 | 1 399 | 1 370 | 1 127 | 1 119 | 1 172 | 0% |

The public passenger transport fare is regulated by public authorities that decide which specific groups of passengers will be entitled to reduced fares; and, therefore, the revenue risk associated with the change in passenger structure can be classified as the risks associated with interventions by public authorities.

Based on the above analysis, it can be stated that the most passengers leaving public passenger transport system are those who have an option of other means of transport, mainly a passenger car. This group consists of the passengers travelling for full fare. Students who usually do not have the option of travelling by passenger car, and they are subjected to compulsory school attendance, remain as the users of public passenger transport. Similarly in case of pensioners, the transition to individual motoring is limited at present. Therefore, the need for increasing public funding can be expected because the current trend of increases in number of passengers travelling with special fares persists and these fares bring lower income for operator in comparison with the full fares.

## 3. Risk allocation between contractual parties and impact on financing public passenger transport

There are several options of risk allocation which are related with three basic forms of contractual relation between authority and operator [9]:

- operator bears no risk – cost and revenue risk is borne by authority that pays the economically justified costs to operator. Those costs are accounted in the end of contract period. This means that the risk from difference between anticipated and actual costs is borne by authority which bears also the risk from difference between anticipated and actual revenue. In this case, the level of reasonable profit of operator should relate only to tie up capital during providing transport services because he bears no risk. ,
- operator bears cost risks – the operator bears the risk from difference between anticipated and actual costs in the end of period and the authority bears the risk from difference between anticipated and actual revenue. In this case, the reasonable profit must contain not only tied up capital but also a reward for taking cost risk,
- operator bears cost and revenue risk - in this case the operator bears the risk from difference between anticipated and actual costs/revenue which are identified in the end of contract period. The authority pays only compensation which is agreed before realized performance to operator. This means that the authority bears no risk. The reasonable profit must include the components related to cost risk, revenue risk, and tied up capital.

The analysis of the risk allocation between operator and authority in selected regions of Great Britain, Norway, Sweden, Finland, Denmark, Netherlands, Italy, USA, Australia, and New Zealand shows that in practice all the mentioned ways of the risk allocation can be found [19]. The risk can be also divided between contracting parties in a certain share regardless of whether there is cost or revenue risk

- full allocation of complete risk to one of the parties – risk of entire difference between anticipated and actual costs/revenue is allocated to one of the parties,
- sharing risk by contracting parties – a specific share of risk from difference between anticipated and actual costs/revenue, is assigned to one of the parties, e.g. each party bears the cost risk of 50%,
- sharing of risk between the parties, taking into account specified constraints – this represents risk-sharing proportionally up to a certain limit (e.g. the operator bears revenue risk up to limit of 500 000 € and the risk over this limit is shared between contracting parties in the same proportion – 50%).

When contracting, the authorities must decide how to appropriatelyallocate the risks between contractual parties (van de Velde, D., Veeneman, W., Schipholt, L. L. and Wallis, I., Bray, D., Webster, H.) [20] and [21]. The risks can have a negative impact on the result of contracting; and therefore, the authorities should consider several facts such as:

- increasing risk increases surcharge to reasonable profit,
- the high level of risk borne by operator can cause a risk of operator's insolvency,
- the higher risk, the lower number of candidates is interested in realization of public transport services.

## 4. Risk determination in financing public passenger transport

Determination of reasonable profit as a percentage of costs is economically incorrect in a regulated sector. The reasonable profit must relate to the risk that is borne by operator in regard with realized performance. This means that the level of reasonable profit must be higher in case of the operator bearing cost and revenue risks in comparison with the operator bearing only cost risks while keeping the same range of performance.

Based on the previous analysis of risk allocation, the level of reasonable profit can be defined as follow:

- operator bears no cost or revenue risks – the risks associated with providing transport services are borne only by authority; and therefore, the level of reasonable profit should relate only to the capital used by operator when providing transport services. A reward for provided capital of operator should depend on profitability level of capital invested in term deposits with guaranteed returns. The reasonable profit in management contracts is calculated according to following formula:

$$PZ = VK * k \ (€) \quad (2)$$

where: - PZ - reasonable profit,
- VK - capital invested by operator in regard with providing transport services,
- k - capital profitability,

- operatorbears cost risks – the level of reasonable profit must consist of two parts: the reward for provided capital of operator (the same as mentioned above) and the reward corresponding to the cost risks. The reasonable profit when contracting for public interest and where operator bears cost risk is possible to determine according to following formula:

$$PZ = VK * k + \left(\sum_{i=1}^{n} \left(N_i * R_{Ni}\right)\right) * RV \ (€) \quad (3)$$

where: - Ni - i's value of cost item of operator in unit expression,
- RNi - risk of assumed value of i's cost item in percentage expression from cost item value,
- n - number of operator's cost items,
- i - i's cost item of operator,
- RV - realized performance.

It is necessary to defined the way of risk determination of estimated values of individual cost items in relation to reasonable profit. The risk can be calculated by using the relationship for determination of safety surcharge to net premiums. Principle of the safety surcharge is based on the fact that number of insurance events is a binomial variable which can be approximated by a normal one and risk premium is chosen in extent of the standard deviation σ according to following formula [22]:

$$RP = \lambda * \sigma \quad (4)$$

where: - RP - risk premium,
- σ - standard deviation of damage level,
- λ - non-negative coefficient depending on the number of insurance contracts.

When determining cost risk in contracting between authority and operator, the value of λ coefficient can be assumed equal 1 because there is only one public service contract.

Based on the cost development in 2008, Table 2 shows elaborated cost risks for individual cost items of operator. The analysis is elaborated from the data of the public authorities for suburban bus service in SR by comparing the contractually agreed level of costs in the beginning of contract period and the actual level of costs accounted by operator in the end of contract period. The cost risk is calculated by using the standard deviation in euro per kilometer.

Determination of costs risk within SR conditions in 2008 in €/km [author's processing] Table 2

| Cost item | Standard deviation |
|---|---|
| Fuel | 0.0165 |
| Tires | 0.0030 |
| Other direct material | 0.0272 |
| Wages | 0.0464 |
| Depreciation | 0.0496 |
| Repairs and maintenance | 0.0585 |
| Travel expenses | 0.0048 |
| Payroll levies | 0.0152 |
| Another direct costs | 0.0142 |
| Operating overhead | 0.0235 |
| Management overhead | 0.0187 |

- operator bears cost and revenue risks – the level of reasonable profit must consist of three parts: the reward for provided capital of operator (mentioned above), the reward corresponding to the cost risks (mentioned above), and the reward corresponding to revenue risks. The reasonable profit when contracting for public interest and where operator bears cost and revenue risks is possible to determine according to following formula:

$$PZ = VK * K + \left(\sum_{i=1}^{n} \left(N_i * R_{Ni}\right)\right) * RV + \\ + \left(\sum_{i=1}^{m} \left(T_j * R_{Tj}\right)\right) * RV \quad (€) \quad (5)$$

where: - j - j's group of passengers with the same fare level,
- m - number of passenger groups which are different by fare level,
- Ti - assumed revenue of j's passenger group in unit expression,
- RTi - revenue risk of j's passenger group expressed in percentages.

Determining revenue risk is done by an analogous method such as in case of determining cost risk. Revenue risk is possible to determine at standard deviation level of income change per individual groups of passengersin observed period.

## 5. Conclusion

The reasonable profit in returns for realized performance in public interest must depend on the risks borne by operator. A method for determining reasonable profit as a percentage of costs exists not only in the SR but also in other states. However, thus determined reasonable profit does not motivate the operators to cost savings and it is also inconsistent with EU policy. Despite the fact that several authors defined existing risk in providing transport services in the form of cost and revenue risk, the method determining reasonable profit dependent on risk-taking has not been developed so far.

The contribution of this paper is processing risk analysis on the cost as well as revenue side within the SR conditions on the basis of known approaches published abroad. The result is also elaborating possible ways of risk allocation between public authorities and public service operators with pointing to their impact. The main benefit of the paper is a procedure for calculating the level of reasonable profit dependent on the risks borne by operator and classification of the risks. Mentioned procedure can be applied in practice in any EU Member State because it is in compliance with EU policy.

## References


[1] Regulation of the European Parliament and of the council (EC) No. 1370/2007 on public passenger transport services by rail and by road and also national regulations of SR (Law No. 56/2012 Z. z. on road transport and Law No. 514/2009 Col. on railway transport).

[2] VAN DE VELDE, D.: A New Regulation for the European Public Transport.*Research in Transport Economics* 22 (2008), 2008, pp. 78-84.

[3] Law No. 56/2012 Col. on road transport.

[4] Internal materials of Bardejov town (City bus service contract in the town of Bardejov).

[5] City bus service contract between operator of BKV and the town of Budapest, in 2008.

[6] Decree No. 296/2010 Col. of the Czech Republic On Methods for Determining Financial Model and Defining Maximum Level of Compensation.

[7] STANLEY, J., VAN DE VELDE, D.: Risk and Reward in Public Transport Contracting.*Research in Transport Economics* 22, 2008, pp. 20-25.

[8] HENSHER, D. A., STANLEY, J.: Performance-based Quality Contracts in Bus Service Provision.*Transportation Research A*, No. 37, 2003, pp. 519-538.

[9] VAN DE VELDE, D., BECK, A., VAN ELBURG, J., TERSCHUREN, K.: Contracting in Urban Public Transport. *Amsterdam: European Commission*, 2008, p. 123.

[10] STANLEY, J., VAN DE VELDE, D.: Risk and Reward in Public Transport contracting.*Research in Transport Economics* 22, 2008, pp. 20-25.

[11] Statistical Office of the Slovak Republic.

[12] CETIN, U., INCE, N., BAYINDIR, P., SAVASANERIL, S.: Route Selection and Scheduling for Urban Public Bus Transportation. *Communications – Scientific Letters of the University of Zilina*, No. 1, 2013, pp. 19-24.

[13] NOSAL, K.: How to Change the Travellers' Mobility Behaviours? – Examples of Mobility Plans. *Communications – Scientific Letters of the University of Zilina*, No. 4, 2009, pp. 52-55.

[14] FAITH, P.: Passenger Road Transport Trends in the Slovak Republic. *Communications – Scientific Letters of the University of Zilina*, No. 3, 2008, pp. 33-39.

[15] STANLEY, J., VAN DE VELDE, D.: Risk and Reward in Public Transport Contracting, *Research in Transport Economics* 22, 2008, pp. 20-25.

[16] GNAP, J., KONECNY, V., POLIAK, M.: Elasticity of Demand in Public Passenger Transport. *Economic J.*, vol. 7, No. 54, 2006.

[17] Enactment of Authority for rail transport regulation No. 654//2005 Z. z. which determines extent of price regulation in rail transport and price assessments of self-governing regions, which determine maximum prices at national regular bus service on condition that distance between initial stop and final stop is maximum 100 km.

[18] POLIAK, M.: Risk Analysis of Financing Public Passenger Transport. *Transport and Communications – Scientific J. 2011-2,* ISSN 1336-7676, pp. 125-135.

[19] HENSHER, D. A., WALLIS, I. P.: Competitive Tendering as a Contracting Mechanism for Subsidizing Transport. *J. of Transport Economics and Policy*, vol. 39, part 3, 2005, pp. 295-321.

[20] VAN DE VELDE, D., VEENEMAN, W., SCHIPHOLT, L. L.: Competitive Tendering in the Netherlands: Central Planning vs. Functional Specifications. *Transportation Research A*, No. 42, 2008, pp. 1152-1162.

[21] WALLIS, I., BRAY, D., WEBSTER, H.: To Competitively Tender or to Negotiate - Weighing up the Choices in a Mature Market, *Research in Transport Economics* 29, 2010, pp. 89-98.

[22] CIPRA, T.: Insurance Mathematics-Theory and Practice *(in Czech)*, vol. 2, 2006.

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