Periodica Polytechnica
Transportation Engineering

43(2), pp. 73-80, 2015
DOI: 10.3311/PPtr.7539

RESEARCH ARTICLE

Analysis of Delay Causes in Railway Passenger Transportation

Enikő Nagy[1] *, Csaba Csiszár[1]

Received 28 May 2014; accepted after revision 04 August 2014

Abstract
One of the most important quality indicators of public transportation is punctuality. Deviations from schedule reduce the level of service. Analyzing historical data, exploring and categorizing the causes of delays correlations can be determined. Based on them, the schedule deviations are predictable. In our research the schedule deviations on railway stations have been investigated based on the manually registered information of the Hungarian Railways. The study mainly focused on the delay causes that were generated by random external factors. Particularly, effects of the certain weather conditions have been highlighted. The analysis has been conducted on railway lines with different infrastructure. Contexts based on the results of the research can be built into traffic prediction models.

Keywords
delay causes, rail transport schedule investigation

[1] Department of Transport Technology and Economics,
Faculty of Transportation Engineering and Vehicle Engineering,
Budapest University of Technology and Economics,
H-1521 Budapest, P. O. B. 91, Hungary
* Corresponding author, email: eniko.nagy@mail.bme.hu

1 Introduction

Passenger service quality consists of several factors. Researchers applied and validated the Satisfaction with Travel Scale (STS) method that measures the service experience in public transportation. The results confirmed that service experience is multidimensional, consisting of a cognitive dimension related to service quality and two affective dimensions related to positive activation, such as enthusiasm or boredom, and positive deactivation, such as relaxation or stress (Olsson et al., 2012). One of the most important of the quality factors influencing experience is punctuality. Time keeping of schedule is important both on operational and passenger side. The punctuality is not a simple parameter, but a rather complex indicator. According to it both the operational quality of the organization and the technical state of development can be assessed.

Passengers plan their journey according to the schedule and the most uncertain element of travel chain is the interchange. On operational side, guaranteeing the connections is a huge challenge, especially in case of infrastructure in bad condition. For these purposes delay prediction is a helpful tool. A study (Corman et al., 2013) proposes a compromise solution for minimization of train delays by comparison of timetable options.

Level of service can be modelled by quality loops. The study of the optimal service quality shows that public transport reliability and thereby volume of clientele is often lower at equilibrium compared to first-best social optimum (Monchambert and Palma, 2014). One component of the quality loop is planned quality that is presented to the passengers by the service provider. This quality level depends on the budget, the standards expected by passengers and the performance of competitors. The provided (realized) quality may be varying day by day because of the external factors. Causes of the differences are: factors of the operator (e.g. technical breakdowns) or independent factors (e.g. weather conditions, incidents, accidents). The aim of our research has been determined on basis of literature review: study, analysis and comparison of traffic characteristics of railway lines with different infrastructure (Lindfeldt, 2011) and similar surveys in Norway where 1000 departures identified many reasons for delay (Harris et al., 2013).

Efficiency and level of quality can be improved by minimizing the "gaps" between the elements of the quality loop Heinitz and Fritzlar, 2013). Provision of passenger information significantly affects the quality perception, which helps smoothing the possible quality "gaps".

Our research focused on the analysis of the causes of deviations between planned and provided quality. Provided quality can be described numerically by the examination of the number of delays on a selected line and the loss of time. Delay is defined as the deviation from the planned departure/arrival time registered on the railway stations. Based on the data the level of the service can be evaluated and the different lines are to be compared. Identification of the delay events and their causes helps the future planning of service and it can be used for traffic forecast:

- on operational side: in view of delay trends, the schedule and connections are to be modified;
- on passenger side: in view of the certain factors (weather conditions, lines, service type, etc.) the punctuality of vehicles (departure and arrival time) are predictable. These values can be used for passenger information on stations as well as on personalized travel information applications (journey planners).

For operational side aiding purposes various optimisation algorithms for various scenarios were examined (Fan et al., 2012). Another considerable operational issue during connection guaranteeing is the capacity of stations. It was thoroughly investigated and the results presented in details (Yuan and Hansen, 2007). On passenger side an promising algorithm for delay management planning was examined in order to minimize passengers' dissatisfaction (Kanai et al., 2011).

The choice between transport modes is influenced by several factors. One of them is the reliability of travel time. In study (Sweet and Chen, 2011) the reliability of travel time and its variation in different traffic zones has been investigated. Reliability changes not only inside the zone but between the zones as well. It means that 'unstable' zones are moving between different territories during the day (correlated with mainstreams). It has been examined that how the decisions (mode choice) of the traveller groups were affected by both travel time and reliability at the same time. The longer is the travel distances (time), the higher is the probability of shifting to railway, especially when travel time is predictable. The choice was particularly influenced by the reliability of the modes in the working areas. A similar study examined the impact of service frequency and reliability on the choice of departure time. It resulted that the optimal head start decreases with service reliability, but not necessarily decrease with service frequency (Benezech and Coulombel, 2013).

In another study the reliability has been investigated by exploring how the valuation of train delays depends on delay risk and delay length. The results showed that the average delay approach does not hold. (Börjesson and Eliasson, 2011)

According to the study (Tu et al., 2012), in regards of mode choice influencing factors, 1 minute reduction in the standard deviation of travel time is equivalent to 2 minutes reduction in travel time. Based on risk analysis, a common-used travel time reliability model has been also devised. In the mentioned study, probability and severity of incidents was determined as well.

The topic of study (Beaud et al., 2012) is the reliability of estimated travel time. It was approximated in two different ways: the methods of mean-variance and specific coefficients. Two definitions have been introduced for the value of reliability:

- the maximum amount of money over the basic fare that passengers are willing to pay in order to avoid uncertainty (meanwhile travel time does not change),
- the maximum additional travel time that passengers are willing to accept in order to avoid uncertainty.

It has also been observed in studies how passengers decide in case of a choice between certain and uncertain travel time. According to the study (Higgins et al., 1995), the reliability of arrivals is a critical performance measure for all rail markets. In another study modelling frameworks and empirical measurement paradigms have been used to obtain willingness to pay for improved travel time reliability (Zheng et al., 2010).

A sensitivity analysis for determining what operation delays affect other operations was proposed through a research. The analysis gave another measure of timetable robustness and also provided control information that can be used when delays occur in practice. (Burdett and Kozan, 2014)

Based on the available delay data (manually registered data by station staff) in Győr and its suburban area, aggregate indicators have been revealed by us as well. In deeper analysis, the stations and the service types have been compared and weather sensibility of lines and causes of delays has been investigated.

Our results can be applied in traffic estimation models. There are several studies in connection with travel time prediction in public transportation. One of the proposed methodologies provides a foundation for constructing prediction intervals for neural networks. Itstates that each source of uncertainty contributes to total prediction uncertainty (Mazloumi et al., 2011).

While some research proposed a fuzzy Petri net (FPN) model for estimating train delays (Milinkovic et al., 2013), and others demonstrated the distribution of train delays by *q*-exponential functions (Briggs and Beck, 2007), our research is based on the calculated values and correction factors have been proposed. Using these factors the estimated delay - for different stations, services, and weather conditions - is predictable considering real-time information, too. Our results help to draft proposals for action plans in order to improve current schedule (and connections).

2 Data analysis and method

Analysis has been executed on the following Hungarian railway lines (with different infrastructure):

- Győr-Sopron (8): single-track, electrified railway line [data were available only on Győr station],
- Komárom-Hegyeshalom (1): double-track, electrified railway line,
- Győr-Pápa (10): single-track, non-electrified railway line,
- Győr-Bakonyszentlászló (11): single-track, non-electrified railway line.

The mentioned railway lines are connected in Győr, where two railway companies have connections. Therefore delay analysis is important in this area.

Situation of analyzed railway lines can be seen on Fig.1 with different colours. The city names of terminals are underlined. Delay events were registered on 25 stations (in total) of the mentioned railway lines.

During analysis, special attention has been paid to the stations located in the suburban area of Győr (within 10 kilometres) where commuter traffic is high. These stations are the followings:

- Győr,
- Győr-Gyárváros,
- Győr-Rendező,
- Győrszabadhegy,
- Győrszentiván,
- Ménfőcsanak.

Fig. 1 Situation of analyzed railway lines
[own edition based on railway maps of Hungarian Railways]

2.1 Data collection

For analysis, the following data groups have been used:

- detailed list of delay events,
- code tables for delays,
- weather data.

2.2 Detailed list of delay events

Hungarian Railways made data available for each line in .xls format. Previously, days with typical and different weather conditions had been selected and classified into groups. Fact data registered by stations are collected and stored in a central database. The Excel sheets contained the data of vehicle identification, service type, delay (in minutes), situation and timestamp of delay and cause of delay as listed in Table 1. The sheets contained data as well that were not used for analysis but important to show the original database. These are information about final stop delay, responsible group, auxiliary code and explanation of delay. In Table 1 the non-used information are marked with grey background. Prior to processing, false data were filtered and an Access database has been created.

2.3 List of delay codes

A special list of delay codes was also provided. It contains in detail the conditions of use of delay codes in case of a delay event. There are 67 different delay codes with explanation of usage are distinguished. Based on this unstructured list, the delays have been categorized (less delay groups were composed).

2.4 Weather data

Studies that investigate the effects of weather or climate change on rail transport and infrastructure are scarce (Koetse and Rietveld, 2009). However it has significant effect on travel time. According to some studies, the impact of rain and snow dependson their intensity. The total travel time increases due to all mild, moderate and heavy rains. Mild snow results in travel time slight increases, whilst heavy snow causes the highest percentage delays (Tsapakis et al., 2013)

In our research in order to analyse the effects of weather conditions on schedule, typical days for different weather conditions have been selected in the year of 2012 and 2013. These are summarized in Table 2. Weather data (daily precipitation, minimum and maximum temperature) were provided by *Időkép*

Table 1 Number and measure of daily delay events [own edition]

Train category	Date depart.	Delay final station	Responsible group	Main code	Aux. code	Duty station	Real arrival time	Real dep. time	Event	Delay	Explanation	Locomotive or motor unit
H	2012-02-03	**3**	PV	31	3P	Győr	2012.02.03. 22:35:00	2012.02.03. 22:37:00	Arrival	1	Speed restriction	938111160439
H	2012-02-03	**8**	PV	31	3P	Győr	2012.02.03. 20:37:00	2012.02.03. 20:39:00	Arrival	2	Speed restriction	915504700096
H	2012-02-03	**14**	VV	22	2S	Győr	2012.02.03. 9:31:00	2012.02.03. 9:33:00	Departure	1	Passenger traffic	915504700088
L	2012-02-03	**1**	M	15	--	Győr		2012.02.03. 16:39:00	Departure	8	Waiting time	955553410031
E	2012-02-03	**17**	VV	20	2S	Győr	2012.02.03. 19:31:00	2012.02.03. 19:48:00	Departure	2	Breaking test	915504800029
E	2012-02-03	**2**	M	15	--	Győr	2012.02.03. 12:23:00	2012.02.03. 12:54:00	Departure	14	Arrival at 12.49	925504181189

Key: H – High speed train, L – Local train, E – Express train

Table 2 Selected dates for different weather conditions [own edition]

	Fall categories		
	Without fall	**Fall**	
cold	3 February 2012 7 February 2012 8 February 2012 26 January 2013 27 January 2013	18 January 2013	All-day snowfall
		14 March 2013	All-day snowfall with medium intensity
		26 March 2013	All-day intensive snowfall
		27 March 2013	Morning snowfall with medium intensity
~0 C	7 February 2013 8 February 2013	2 April 2013	Intensive rainfall from 17 p.m.
		3 April 2013	Intensive rainfall until 10 a.m.
hot	4 July 2012 29 April 2013 30 April 2013	28 November 2012	Mild rainfall between 18-19 p.m., then intensive rainfall between 22-24 p.m.
		29 November 2012	Mild rainfall around 18 p.m.
		6 May 2013	Intensive rainfall between 18-20 p.m.
		7 May 2013	Intensive rainfall with ice around 12 a.m.
		8 May 2013	Morning rainfall with medium intensity around 5 a.m.

Kft. and *Hungarian Institute of Meteorology (OMSZ)* and valid for the whole region as individual meteorological equipment are not available at each station. The weather events of a day were determined in hourly intervals based on radar images of OMSZ. Weather categories have been determined with consideration to the temperature and the precipitation:

- Cold, dry weather (temperature between -15 and -5 °C).
- Cold, wet weather (temperature between -3 and +3 °C, medium, intense snowfall).
- Moderate, dry weather (temperature around 0 °C).
- Moderate, wet weather (temperature around 0 °C, medium, intense rain).
- Hot, dry weather (temperature around 30 °C).
- Hot, wet weather (temperature between +15-23 °C, medium, intense rain).
- Weather conditions do not affect traffic: this code has been assigned to the delay events that could not have been classified into the above mentioned categories (by the timestamp of delay registration).

2.5 Data processing

After investigation of tables, the criteria of the analyses have been determined. The raw data provided suitable information for study of data by train categories, duty stations and main

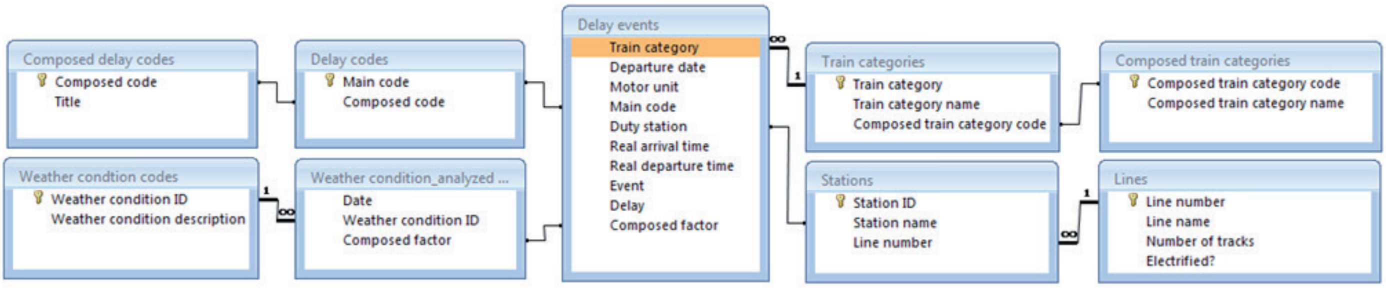

Fig. 2 Structure of database [own edition]

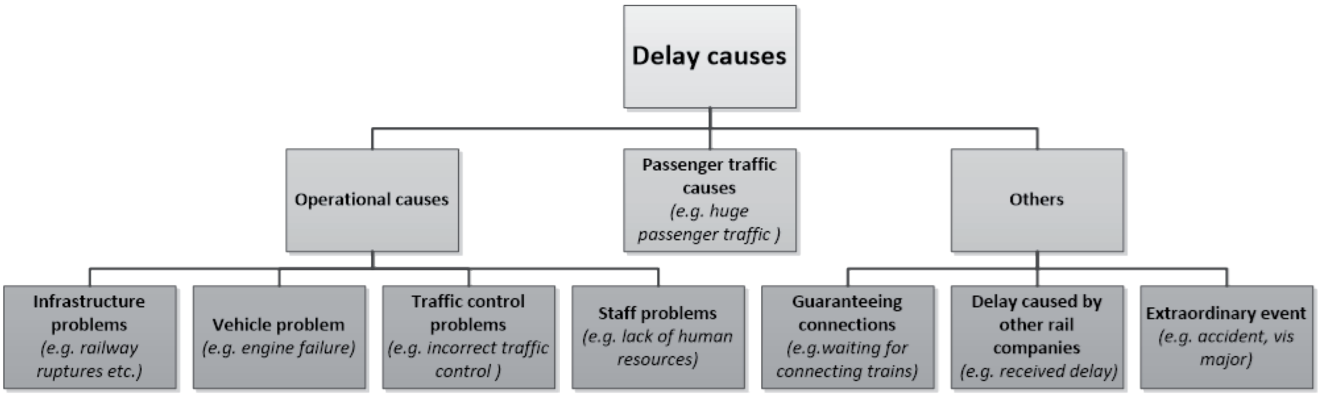

Fig. 3 Categories of delay causes [own edition]

delay codes. Main aim was the examination of effects of weather events. For this purpose, meteorological data were used.

After filtering the tables 2984 records remained. The structure of the created Access database is illustrated on Fig. 2 that includes nine tables. The "central table" is the *Delay events* table that was created based on the Excel sheets. A new attribute was added to the table: the "composed factor" that determines which hour and quarter of the day the delay event was registered in. It was necessary for the punctual alignment of weather conditions and time of delay events. Sub-tables are linked to the central table. Sub-tables contain the attributes that were simplified in *Delay events* central table.

Delay codes and Composed delay codes:

For the registered delay events a delay code was assigned. A code table clarified the reason of delay. It contains the main delay code registered by the service provider and its description. As a lot of delay code were applied (and some of them are very similar), less delay code categories have been created using a system approach. Several main delay codes have been ranked to the same composed delay category. Categories are illustrated on Fig. 3 and the names are summarized in *Composed delay codes* table.

Train categories and Composed train categories:

In tables provided by Hungarian Railways, 10 train categories were distinguished. For the analysis of delay causes and service types, larger groups have been created from the train types. *Composed train categories* table contains the name of groups. Three main categories have been identified, these are the followings:

- high quality, high-speed train (EuroNight, Intercity, International express train and Railjet),
- express train (express and fast train),
- local train (EuroRegio, local train and suburban train).

Queries have been created based on the „new" categories.

Stations:

The table contains the name of stations and the line number.

Line:

The table contains the name of lines and the attributes: the number of tracks and electrification property.

Weather condition_analyzed days:

This table assigns the weather condition code to the composed factor that shows the quarter-hour of the delay event. Thereby, the weather condition that occurred during the delay event can be determined.

Weather condition codes:

The table contains the identification code of weather categories and the name/description of it.

Queries have been created in the Access database considering the examination aspects (categories) separately and combined. Frequency and measure of schedule deviations and statistical characteristics have been determined.

3 Results

Two kinds of queries have been distinct:

1. the whole database (all the 25 stations) has been used, 2. only the stations in the suburban area of Győr have been considered. Departure and arrival delay events have been investigated separately. In case of registering an arrival delay event, the

schedule deviation in the moment of arriving to the station was registered (in minutes). In case of registering a departure delay event, the delay born in the station was registered.

It has been revealed, that arrival and departure delay events have not been registered jointly in each station. Therefore, not all the cells contain value in the resulted tables. It is to be eliminated in the future with more processed data, namely investigation of delay events on more days.

3.1 Aggregated indicators

Aggregated indicators have been created for both the whole database and only the stations in the suburban area of Győr. The daily frequency of delays (number of events) and the measure of delays have been investigated in each station. Results are summarized in Table 3 and 4.

Table 3 Aggregated indicators of the whole database [own edition]

	Daily frequency of delays (number of events)		**Measure of delays (min)**	
	Departure	Arrival	Departure	Arrival
Average	4,1	3,6	5,4	4,1

Table 4 Aggregated indicators of the suburban area stations of Győr [own edition]

	Daily frequency of delays (number of events)		**Measure of delays (min)**	
	Departure	Arrival	Departure	Arrival
Average	8,67	7,57	7,45	5,60

Based on the tables it can be stated that higher values were obtained both for the frequency and the measure of delays in the suburban area of Győr.

3.2 Results of analysis by stations

In order to prove the statement above in Section 3.1., a query has been created: it shows the number of daily delay events and the mean value of delays in each station. Summary of these results is shown in Table 5, highlighting with grey background the stations in the suburban area of Győr.

It is clear that in station of Győr, the number and measure of delay events are above average. It is caused by significant traffic. Results of further investigations of stations near Győr are seen in Fig. 4. In Győr the measure of departure delays is lower, but more frequent; however the measure of arrival delays is higher, but less frequent. It means that a few trains arrive with huge delay to the station, whereas a lot of trains depart with little delay. The causes for these outstanding high values have been also identified.

3.3 Results of analysis by delay causes

It has been stated that in the stations in the suburban area of Győr the most frequent reason for delay is guaranteeing connections. The measure of it here is slightly above average. Further examinations may reveal which trains cause the delay of those waiting for connection. Some modifications in schedule regarding these trains would increase quality of service.

Delays above average value are caused by delays of other railway companies or by extraordinary events (e.g.: snowing, problems at switches due to extremely cold weather). The delay events that caused outstanding values were registered in January and in March. The factors that cause the most frequent and most significant delays are summarized in Table 6.

Table 5 Number and measure of daily delay events [own edition]

Station	Daily frequency of delays (number of events)		Measure of delays (min)	
	Departure	Arrival	Departure	Arrival
Ács	1,9	1,0	9,4	4,3
Bakonyszentlászló	1,1	3,7	3,8	2,0
Gecse-Gyarmat	3,1	1,4	3,7	1,7
Gyömöre	3,2	2,5	4,0	1,7
Gyömöre-Tét	1,5	n.a.	1,7	n.a.
Győr	38,7	14,3	8,1	11,4
Győr-Gyárváros	2,0	n.a.	21,5	n.a.
Győr-Rendező	1,0	n.a.	6,5	n.a.
Győrszabadhegy	5,8	6,9	4,2	1,9
Győrszemere	5,7	1,5	4,2	8,3
Győrszentiván	3,5	1,6	2,5	3,6
Hegyeshalom	4,0	2,3	6,6	7,8
Kimle	3,0	1,2	1,5	3,9
Komárom	1,9	1,3	9,3	4,1
Lébény-Mosonszentmiklós	1,0	1,5	3,0	6,3
Ménfőcsanak	1,0	n.a.	2,0	n.a.
Mosonmagyaróvár	9,4	20,0	1,6	1,7
Nagyszentjános	2,4	1,4	4,0	4,3
Öttevény	1,5	1,7	2,8	3,4
Pannonhalma	1,4	1,9	13,9	7,8
Pápa	2,0	1,1	3,3	1,2
Szerecseny	3,5	n.a.	1,6	n.a.
Tarjánpuszta	1,7	1,7	4,5	1,5
Vaszar	2,2	2,2	3,9	1,6
Veszprémvarsány	1,2	2,7	8,3	2,6

Table 6 Delay causes in stations near Győr [own edition]

Delay causes	Daily frequency of delays (number of events)		Measure of delays (min)	
	Departure	Arrival	Departure	Arrival
Infrastructure	1,6	4,0	3,4	1,6
Vehicle	1,1	1,0	**12,4**	4,1
Traffic control	2,4	2,2	6,1	2,4
Staff	4,9	n.a.	1,8	n.a.
Passenger traffic	3,5	1,0	1,7	1,0
Guaranteeing connections	**10,8**	1,3	**7,8**	2,6
Other railway company	3,2	8,5	**15,9**	**15,7**
Extraordinary event	3,1	3,8	**18,7**	**8,6**

Table 7 Daily frequency and measure of delays in the suburban area of Győr by weather categories [own edition]

Weather categories		Daily frequency of delays (number of events)		Measure of delays (min)	
		Departure	Arrival	Departure	Arrival
Irrelevant in view of transport		8,3	4,2	2,9	n.a.
Cold	**wet**	**10,3**	**10,3**	**10,0**	**10,5**
	dry	**11,5**	**7,5**	3,6	2,8
Normal	wet	5,6	2,9	6,2	5,7
	dry	7,1	3,8	3,1	4,2
Hot	wet	2,5	1,0	2,3	1,5
	dry	**11,7**	4,1	3,1	2,8

3.4 Results of analysis by weather categories

Rail transportation is sensitive for weather conditions as well. It has been examined which weather conditions affect the transportation in the concerned sections.

According to the Table 7, extreme weather conditions (extreme cold weather especially with snow, or extreme hot and dry) cause delay events. Data in table belong to the stations near Győr, but after examination of the whole database it was clear that there is no significant difference between the two data sets in this regard.

4 Sum-up and conclusion

During the research, delay events in railway passenger transport have been examined in the region of Győr. Specific days have been selected according to typical weather conditions. Delay data of these days have been provided by Hungarian Railways. The statements (depending on the type of investigation) refer either to all lines or to the station in the near area of Győr or simply to Győr duty station. According to the number and measure of delays, the following statements have been made:

1. More significant delay values have been obtained regarding both the frequency and the measure in stations in suburban area of Győr.
2. In Győr station, the number and measure of delay events are above average (it is caused by significant traffic).
3. In Győr, a few trains arrive with huge delay to the station, whereas many trains depart with little delay.
4. The most frequent reason for delay is guaranteeing connections.
5. Delays above average value have been caused by other railway companies and in case of extraordinary weather conditions.
6. The delay events with high values were registered in January and in March.

It has been found that in Győr station the delays are mostly originated in capacity shortage.

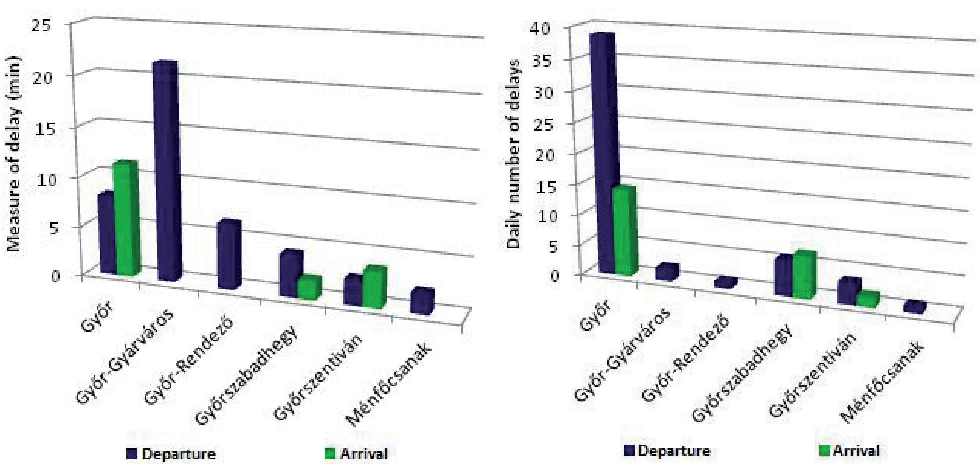

Fig. 4 Daily frequency and measure of delays in the suburban area of Győr [own edition]

These results are based on only one year data set therefore trends cannot be determined. Different years are to be compared by repeated analysis.

Determination of delay causes facilitates the prediction of measure of delay. The aim of our future research: preparation a mathematical model for the prediction of probable delays. In passenger transport the main aim is to decrease delays and travel time.

In view of the delay causes, railway companies can introduce programs in order to avoid the delays. Loss of time can be reduced with eliminating the faults of traffic control and technical incidents (organizational and investment actions). Management of the delays caused by other railway companies can be improved by companies' cooperation and data exchange. In this way, interchanges can be handled efficiently, too. In case of passengers, not only the real delays but also the perceived delays cause quality degradation. It is to be reduced with the improvement of customized passenger information systems (provision of the real or predicted delay information; the causes and their effects).

Our aim is to develop a prediction model based on these research results and the statements drawn. Calibration can be carried out by analysis of similar data regarding other regions. The prediction model could be built into personal applications (e.g. journey planner).

Acknowledgement

„TÁMOP-4.2.2.C-11/1/KONV-2012-0012: "Smarter Transport" - IT for co-operative transport system - The Project is supported by the Hungarian Government and co-financed by the European Social Fund"

References

Beaud, M., Blayac, T., Stephan, M. (2012) Value of travel time reliability: two alternative measures. *Procedia - Social and Behavioral Sciences*. 54. pp. 349-356. DOI: 10.1016/j.sbspro.2012.09.754

Benezech, V., Coulombel, N. (2013) The value of service reliability. *Transportation Research Part B: Methodological*. 58. pp. 1-15. DOI: 10.1016/j.trb.2013.09.009

Börjesson, M, Eliasson, J. (2011) On the use of "average delay" as a measure of train reliability. *Transportation Research Part A: Policy and Practice*. 45 (3). pp. 171-184. DOI: 10.1016/j.tra.2010.12.002

Briggs, K., Beck, C. (2007) Modelling train delays with q-exponential functions. *Physica A: Statistical Mechanics and its Applications*. 378 (2). pp. 498-504. DOI: 10.1016/j.physa.2006.11.084

Burdett, R., Kozan, E. (2014) Determining operations affected by delay in predictive train timetables. *Computers & Operations Research*. 41. pp. 150-166. DOI: 10.1016/j.cor.2013.08.011

Corman, F., D'Ariano, A., Hansen, I. (2014) Evaluating disturbance robustness of railway schedules. *Journal of Intelligent Transportation Systems: Technology, Planning and Operations*. 18 (1). pp. 106-120. DOI: 10.1080/15472450.2013.801714

Fan, B., Roberts, C., Weston, P. (2012) A comparison of algorithms for minimising delay costs in disturbed railway traffic scenarios. *Journal of Rail Transport Planning & Management*. 2 (1-2). pp. 23-33. DOI: 10.1016/j.jrtpm.2012.09.002

Harris, N., Mjøsund, C. S., Haugland, H. (2013) Improving railway performance in Norway. *Journal of Rail Transport Planning & Management*. 3 (4). pp. 172-180. DOI: 10.1016/j.jrtpm.2014.02.002

Higgins, A., Kozan, E., Ferreira, L. (1995) Modelling delay risks associated with train schedules. *Transportation Planning and Technology*. 19. pp. 89-108. DOI: 10.1080/15472450.2013.801714

Kanai, S., Shiina, K., Harada, S., Tomii, N. (2011) An optimal delay management algorithm from passengers' viewpoints considering the whole railway network. *Journal of Rail Transport Planning & Management*. 1 (1). pp. 25-37. DOI: 10.1016/j.jrtpm.2011.09.003

Koetse, M. J., Rietveld, P. (2009) The impact of climate change and weather on transport: An overview of empirical findings. *Transportation Research Part D: Transport and Environment*. 14 (3). pp. 205-221. DOI: 10.1016/j.trd.2008.12.004

Li, Z., Hensher, D. A., Rose, J. M. (2010) Willingness to pay for travel time reliability in passenger transport: A review and some new empirical evidence. *Transportation Research Part E: Logistics and Transportation Review*. 46 (3). pp. 384-403. DOI: 10.1016/j.tre.2009.12.005

Lindfeldt, O. (2011) An analysis of double-track railway line capacity. *Transportation Planning and Technology*. 34 (4). pp. 301-322. DOI: 10.1080/03081060.2011.577150

Mazloumi, E., Rose, G., Currie, G., Moridpour, S. (2011) Prediction intervals to account for uncertainties in neural network predictions: Methodology and application in bus travel time prediction. *Engineering Applications of Artificial Intelligence*. 24 (3). pp. 534-542. DOI:10.1016/j.engappai.2010.11.004

Milinković, S., Marković, M., Vesković, S., Ivić, M., Pavlović, N. (2013) A fuzzy Petri net model to estimate train delays. *Simulation Modelling Practice and Theory*. 33. pp. 144-157. DOI: 10.1016/j.simpat.2012.12.005

Monchambert, G., Palma, A. (2014) Public transport reliability and commuter strategy. *Journal of Urban Economics*. 81. pp. 14-29. DOI: 10.1016/j.jue.2014.02.001

Olsson, L. E., Friman, M., Pareigis, J., Edvardsson, B. (2012) Measuring service experience: Applying the satisfaction with travel scale in public transport. *Journal of Retailing and Consumer Services*. 19 (4). pp. 413-418. DOI: 10.1016/j.jretconser.2012.04.002

Sweet, M. N., Chen, M. (2011) Does regional travel time unreliability influence mode choice?. *Transportation*. 38 (4). pp. 625-642. DOI: 10.1007/s11116-011-9335-z

Tsapakis, I., Cheng, T., Bolbol, A. (2013) Impact of weather conditions on macroscopic urban travel times. *Journal of Transport Geography*. 28. pp. 204-211. DOI: 10.1016/j.jtrangeo.2012.11.003

Tu, H., Li, H., Lint, H., Zuylen, H. (2012) Modeling travel time reliability of freeways using risk assessment techniques. *Transportation Research Part A: Policy and Practice*. 496 (10). pp. 1528-1540.

Yuan, J., Hansen, I. A. (2007) Optimizing capacity utilization of stations by estimating knock-on train delays. *Transportation Research Part B: Methodological*. 41 (2). pp. 202-217. DOI: 10.1016/j.trb.2006.02.004