Acceptance of Train Delays by Passengers

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ABSTRACT: The article deals with an analysis of a final evaluation of a survey among passengers which aimed at defining a subjective rate of delay acceptance by passengers and disorder of the mass public transport system's connections in cases of delays.

KEY WORDS: Public transport, railway traffic, delay, passenger survey.

1 CONTEXT AND SIGNIFICANCE OF THE SUBJECT OF INQUIRY

A substantial characteristic of Mass Public Transport (MPT) is the ensuring of changing relations between its individual lines (of the same or different types of transport or carriers). The issue of the interlinking of MPT lines in the stages of traffic schedules preparation in the Czech Republic has already been sufficiently mastered. However, the principles for the operational solving of links to delayed services during operational exceptionalities are not so clear.

For each expected stopover, one of the following situations may arise in the case of a delay:

1) Schedule of linked services will be kept strictly. This means that the delay will not be transferred onto other services with a positive impact on both passengers in linked services and carriers. On the other hand, a linked service will be disappeared, leading to the longer waiting of transferring passengers.

2) A set waiting time of linked services will be followed. This will lead to a generation of delays in the linked services with a possibility of the avalanche spreading throughout the whole public transportation network, but passengers will regard the MPT (or Integrated Transport System – ITS, respectively) system as reliable – they will assume that they will, in most cases, get to their destination with just a slight delay.

The above described possibilities both have their advantages and disadvantages and in every case a certain group of passengers is impaired. A universal decision on the correctness of a variant (at the assembly of schedules or during the operative traffic control) does not exist – it depends on particular cases. Unfortunately, a request from the side of MPT contractors (Ministry of Transport, regions), or ITS organizers respectively, inclines more and more towards not waiting for delayed services. As a consequence of an effort to increase the attractiveness of MPT, and also, among others, to minimize the total commercial time in MPT means of transport, the MPT contractors try to shorten the time

necessary for transfers between MPT lines. Nevertheless, if there is a delay, it automatically leads to an increase in the probability of the occurrence of the negative impacts of such a situation. For this reason, the authors try to elaborate on a method for the optimum solving of operating particularities in transfers between MPT means of transport, especially between trains.

2 OBJECTIVE HARM SUFFERED BY PASSENGERS BY THE DELAY OF A SERVICE

In each transfer link whose maintaining is threatened by the delay of a service with which a transfer is planned, the interests of two groups of passengers come into conflict. On the one hand, there will be a significant harm suffered by the passengers waiting at the transfer point in the transport vehicle for the delayed service, as well as by passengers getting in the delayed service at wayside stations ("departing" group). On the other hand, harm is caused to passengers arriving at the stopover station in the delayed service ("arriving" group) and a loss of a connecting service for them means another (usually significant – according to the interval and the number of further transfers) increase in the delay to their destination.

In order to compare both described cases, the authors proposed a value which, in its nature, represents the total time loss for passengers from one or the other group (Jacura & Týfa, 2007). This is calculated for both groups of passengers as a multiple of the waiting time and a total of the multiples of the numbers of persons travelling for the same total travelling time, and a coefficient of the sensitivity of a passenger towards the delay – see formula (1).

$$F = t_w \cdot \sum_{(j)} P_j \cdot c_j \tag{1}$$

where:

F – harm suffered by passengers due to delay [persons·min]

P_j – number of persons in group j, travelling for same travelling time [persons]

t_w – waiting time (explained further in greater detail) [min]

c_j – coefficient of sensitivity of group j passenger on delay [-]: $0 < c_j < 1$

The coefficient of sensitivity towards delay c was introduced into the formula because the authors assume that the subjective negative perception of a delay by a passenger depends mainly on his/her total travelling time. In the practical usage of the described mathematical formula it can be expected that personnel of a carrier will, in the case of an occurrence of an exceptional situation, be able to estimate the waiting time, number of passengers and the route of their travel (and so, also the commercial time), but coefficient c must already be known before the emergence of such a situation. A hypothesis was formed (Jacura & Týfa, 2007) that the tolerance of a passenger for the length of delay C rises with the travel time by the so-called logistic function (S-curve) – see formula (2).

In order for the substitution of a level of tolerance into the function of harm suffered by passengers due to delay F to correspond with the logic of the reality (function F reaches higher values, the more negative the impact is on passengers due to delay)

it is necessary to carry out a conversion from the value level of tolerance to a variable of the coefficient of sensitivity of passengers according to formula (3).

$$C = \frac{q}{1 + b_0 \cdot b_1^{t_{tot}}} \tag{2}$$

$$c = 1 - C \tag{3}$$

where:

C – [-]: $0 < C < 1$

c – coefficient of sensitivity of a passenger on delay [-]: $0 < c < 1$

q – higher asymptote of logistic function [-]: $q = 1$

b_0 – parameter of logistic function [-]: $b_0 > 1$

b_1 – parameter of logistic function [-]: $0 < b_1 < 1$

t_{tot} – total passenger's commercial time [min]

Determination of both unknown parameters of the logistic functions b_0 and b_1 is possible only on the basis of a regressive analysis of the results of a survey among passengers. Therefore, the authors made a survey involving train passengers in the Czech Republic and Slovak Republic whose main output was the behaviours of regressive logistic functions for three different cases of delay. Readers will be acquainted with the procedure and the results of the search of parameters b_0 and b_1 in chapter 3.

2.1 Limit waiting time

When determining limit waiting time for which, from the point of view of harm to a passenger, it pays to wait at a transfer point for a delayed service, the authors draw on the comparison of function F in two extreme cases. The first extreme situation occurs if a connecting service never waits at a transfer point. In such a case, passengers on the service arriving to the transfer point ("arriving" group) will have to wait for the next service of the connecting line for time $t_{w,}$ which is equal to the line (or track, as case may be) interval of the connecting MPT line deceased by the delay, that is, time remaining to the regular departure of the next connecting service. The second extreme case happens if a connecting service always waits for the arrival of the service to which it is linked. In such a case, the "departing" group is impaired and the waiting time t_w represents the time of delay of the service for which the connecting service waits at the transfer point which the passengers of this group must spend in excess in the MPT means of transport.

A more detailed form of formula (1) thus corresponds to formulas (4) and (5).

$$F_{ar} = (i - t_{del}) \cdot \sum_{(j)} P_j \cdot c_j \tag{4}$$

$$F_{dep} = t_{del} \cdot \sum_{(k)} P_k \cdot c_k \tag{5}$$

where:

F_{ar} – harm inflicted upon "arriving" group of passengers [persons·min]

F_{dep} – harm inflicted upon "departing" group of passengers [persons·min]

i – line interval of connecting line (or track interval) [min]

t_{del} – time of delay [min]: $t_{del} < i$

The limit time of delay is, therefore, calculated from the equation of the right sides of formulas (4) and (5), and gains the form of formula (6):

$$t_{del,\lim} = \frac{\sum_{(j)} P_j \cdot c_j}{\sum_{(j)} P_j \cdot c_j + \sum_{(k)} P_k \cdot c_k} \cdot i \tag{6}$$

where: $t_{del,lim}$ – limit time of delay [min]

Formula (6) can be interpreted in such a way that the limit time of delay is a part of a connecting line interval which equals the proportion of reduced numbers of passengers (number of passengers multiplied by the coefficient of sensitivity of passengers on delay) "arriving" from the total number of passengers on both services (i.e., both the "arriving" and "departing").

3 PASSENGER SURVEY AND ITS EVALUATION

The passenger survey was carried out from 2nd July 2008 to 11th January 2009 through a form placed on the website of the project (http://stanice.fd.cvut.cz) and also in June and July 2009 through oral questioning at railway stations and stops in Prague and around the city.

3.1 Questionnaire content

In the first part of the survey, data are collected from a respondent about one route selected by him/her where he/she goes by train. The data collected from this part of the survey are used mainly as explanatory variables for regression and correlation analyses (Řezánková, 2007). The inquiries include a selected travel route, its commercial time (subsequently corrected according to the schedule), purpose and frequency. Question five asks for the number of transfers a passenger must make on a selected route during regular operation.

Question six, beginning the second part of the survey, asks the respondent about the amount of time saving necessary in transport on his/her route for he/ she to be willing to transfer regularly one more time due to this. Question seven probes the limit frequencies of varying delays on a given route that still do not deter a passenger from a further journey. Similarly, question eight investigates the highest tolerated delay on arrival to a destination due to a missed connecting train. Similarly, question nine tries to trace the level of acceptance of a delay in the case of a passenger sitting in a train waiting for a delayed service. The last, third part of the survey concentrates on respondent's personal data (year of birth and sex) if respondents are willing to provide them.

The aim of this article is not to acquaint the reader with complete results of the survey among the travelling public, but merely with an assessment of the parameters of the level of passengers´ tolerance of the delay function.

3.2 Calculation of regressive logistic function

As stated in chapter 2, the main aim of the passenger survey is the assessment of constants of the logistic function (2), which should determine the level of the passengers´ tolerance of the delay. Since the logistic function's parameters are not linear, it is not possible during the general determining of all three constants q, b_0 and b_1 by means of regressive analysis to use an unequivocal method of the least squares. But, because in our particular case we have the defined value $q = 1$ (see above) in advance, by gradual modification of formulas (7)–(9), whose key part is linearizing logaritmization, the authors came to the substitution (10), by which the logistic function transforms into the linear function (11). As is standard, first the values of the parameters B_0 and B_1 are determined by the method of the least squares and the values of the constants b_0 and b_1 are determined by reverse substitution.

$$\boldsymbol{C} = \frac{1}{1 + b_0 \cdot b_1^{\,t_{tot}}} \tag{7}$$

$$\frac{1}{C} - 1 = b_0 \cdot b_1^{\,t_{tot}} \tag{8}$$

$$\log\left(\frac{1}{C} - 1\right) = \log b_0 + t_{tot} \cdot \log b_1 \tag{9}$$

$$\boldsymbol{SUBST.:}\ C' = \log\left(\frac{1}{C} - 1\right);\ B_0 = \log b_0\ ;\ B_1 = \log b_1 \tag{10}$$

$$\boldsymbol{C' = B_0 + B_1 \cdot T_{TOT}} \tag{11}$$

Quality of the detected regressive logistic function was evaluated mainly by the determination index I^2. Another parameter used for determination of the expressive value of the regression function is the mean square error of estimation (*MSE*), which confirms a better regression function the closer it drops to zero. Also, for each regression a so-called F-test of dispersion analysis was carried out on the suitability of the created model (quality test of balancing points by a regression curve. The test zero hypothesis claims that the calculated regression function has no real predicative value. (Hindls, 2004)

3.3 Results of the regression of tolerance of delay to commercial time

A total of 404 passengers participated in the survey, 78 % of whom filled in the internet version of the questionnaire.

The results of the regression analysis, including its quality characteristics, can be found in table 1 and figures 2 and 3. The markings in table 1 correspond to markings in chapters 3.2. Quantile F-division with 1 and 404-1-1 = 402 degrees of freedom $F_{0.95}[1; 402] = 3.865$, and so it is possible, at the level of significance of 5 % in all cases, to reject the zero hypothesis of an unsuitable regression model. In figures 2 and 3, points describe the calculated values of C_i, the strong curve represents the determined regression logistic curve with parameters according to table 1.

Table 1: Characteristics of the regression logistic function of the level of tolerance of delay to total commercial time.

q. no.	delay characteristics	b_0	b_1	I^2 [%]	*MSE*	statistics *F*	rejection H_0
7	delay in destination	11.530	0.993	39.68	0.032	204.587	yes
8	missed connecting train	236.592	0.987	35.03	0.060	121.640	yes
9	waiting for connecting train	31.912	0.989	54.99	0.030	365.680	yes

The sensitivity during waiting for a connecting train seems to be the best explanation, even though its determination index exceeds the 50 % limit only slightly. Relations in the remaining two cases were not explained so well by regression but, despite this fact, they give us at least a general idea of the relation trend.

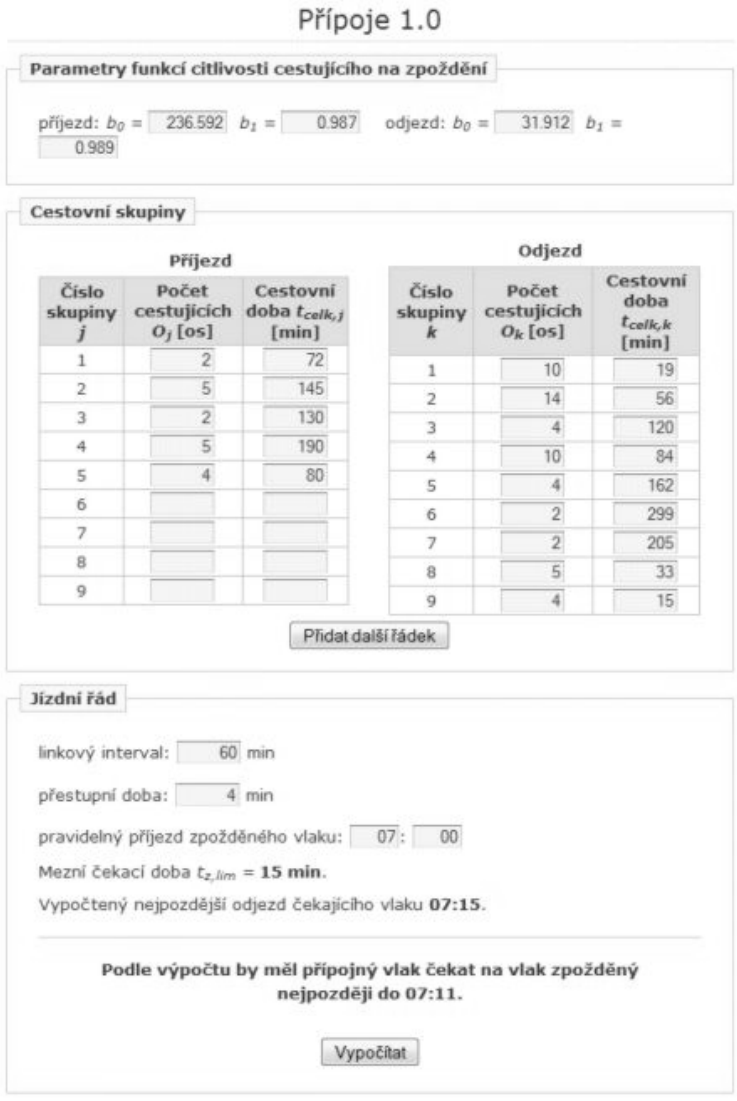
3.4 Practical use of the methodology

For a practical use of the methodology described in this report an internet application "Přípoje 1.0" (Connections 1.0) was created. It can be used free of charge anytime by accessing the internet site of the project (*http://stanice.fd.cvut.cz*). The application is aimed at supporting the decision-making about the optimal waiting time for the delayed connecting train in the public transport change node. A demonstration of the application's functionality will be described later using a hypothetical sample.

According to the timetable, a train (thereinafter "the first train") arrives at the station at 7:00 with a connecting train (thereinafter "the second train") leaving the station at 7:10. The transfer time between these trains is 4 minutes. The line interval relative to the second train is 60 minutes. If there is a possibility for the dispatcher to influence the waiting time of the second train in the case that the first train is delayed and there is a will or an obligation to consider the time loss of the passengers in both trains, the dispatcher, with the help of the train personnel, will have the passengers' routes in both trains gathered, where in the first train only passengers changing for the second train are considered. For practical use inserting an exact route of every passenger would be very slow in many cases, therefore it is possible to group similar routes. Gathering information about the target destinations of the passengers and its forwarding to the dispatcher for the purpose of setting the waiting time of the connecting trains is already being done using mobile phones.

After that, the relevant worker (dispatcher, traffic controller) assigns a total travelling time (i.e., not only from the change node to the target destination) to each of the passengers´ routes

according to the timetable, using his own knowledge or suitable software (IDOS). The number of the passengers and their total travelling time from both the delayed first train ("arrival group") and the connecting second train ("departure group") are then inserted in the "Přípoje 1.0" (Connections 1.0) form by a responsible dispatcher. The line or route interval of the second train is also to be inserted, i.e., at what time the next suitable train departs with the same route stopping at the same stations. For the routine use of the described application it would be suitable to be directly connected to an application for the total travelling time computation, as manual calculation consumes too much time.



parametry funkcí citlivosti cestujícího na zpoždění - **passenger sensitivity to delay function parameters**

příjezd – **arrival**
odjezd – **departure**

cestovní skupiny – **travelling groups**
číslo skupiny – **group number**
počet cestujících – **passengers number**
cestovní doba – **travelling time**
přidat další řádek – **add a new row**

jízdní řád – **timetable**
linkový interval – **line interval**
přestupní doba – **transfer time**
pravidelný příjezd zpožděného vlaku – **the late train schedule arrival**
mezní čekací doba – **limit waiting time**
vypočtený nejpozdější odjezd čekajícího vlaku – **computed latest departure of the second train**

podle výpočtu by měl přípojný vlak čekat na vlak zpožděný nejpozději do… – **according to the calculation the connecting train should wait for the delayed train no longer than until...**
vypočítat - **compute**

Translation:

Figure 1: Layout of the "Přípoje 1.0" (Connections 1.0) internet application.

A layout of the Connections 1.0 application, including the inserted and later computed data according to the sample above, is shown in figure 1. When adding groups of passengers with different travelling times any number of these groups can be added – by pressing the "Přidat další řádek" (add a new row) button. The quantities description corresponds

to the relations in the chapter 2. The parameter values of the logistic functions b_0 and b_1 are filled in automatically but can be changed anytime, e.g., according to the own findings of the personnel. After pressing the "Vypočítat" (compute) button the user of the online application acquires the limiting delay time of the first train $t_{del,lim}$. If the scheduled arrival of the first train, the scheduled departure of the second train, and the transfer time between these trains are inserted, an exact time corresponding to the computed delay time is also displayed.

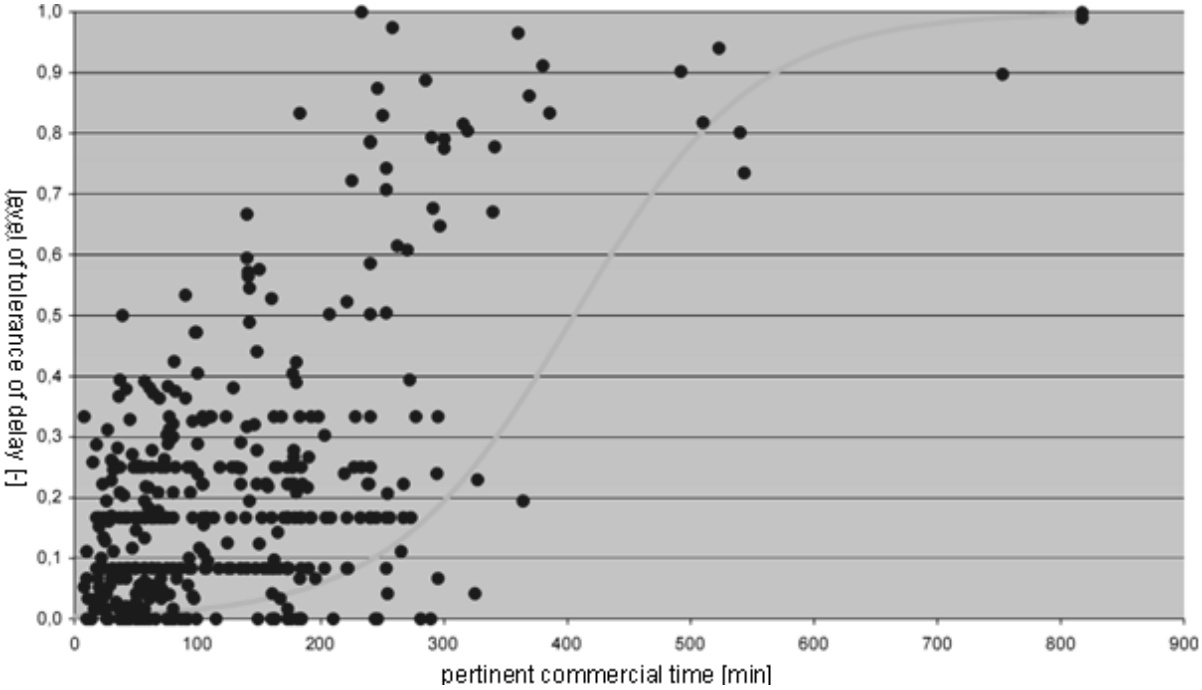


Figure 2: Level of passengers tolerance of delay to total commercial time in the case of a missed connecting train.

Considering the sample data used in the example above the limiting delay time of the first train where it is still worth the second train waiting for its arrival is 15 minutes. If the transfer time between the trains is subtracted from this value then the second train should wait for the arrival of the first train no longer than until 7:11.

4 CONCLUSION

A solution to connecting relations in MPT during the delays of individual services in the Czech Republic gains more and more importance in relation with the development of ITS and interval long-distance railway traffic. Deciding whether to wait or not for a service in the case of its delay can be aided by the method described in this paper.

The procedure described above takes into account only the subjective feelings of the passengers regarding their time loss and only in the two trains in between a connection. A delay transfer over the whole net and the operation needs must therefore be taken into consideration and so the described algorithm must be understood only as one of decision features. Consequently, a maximum waiting time restriction must be given in the General Timetable Appendix, which would set the limit where the passengers´ sensitivity to the delay

is no more concerned. Nevertheless, the currently used waiting times are considered insufficient by the authors of this report.

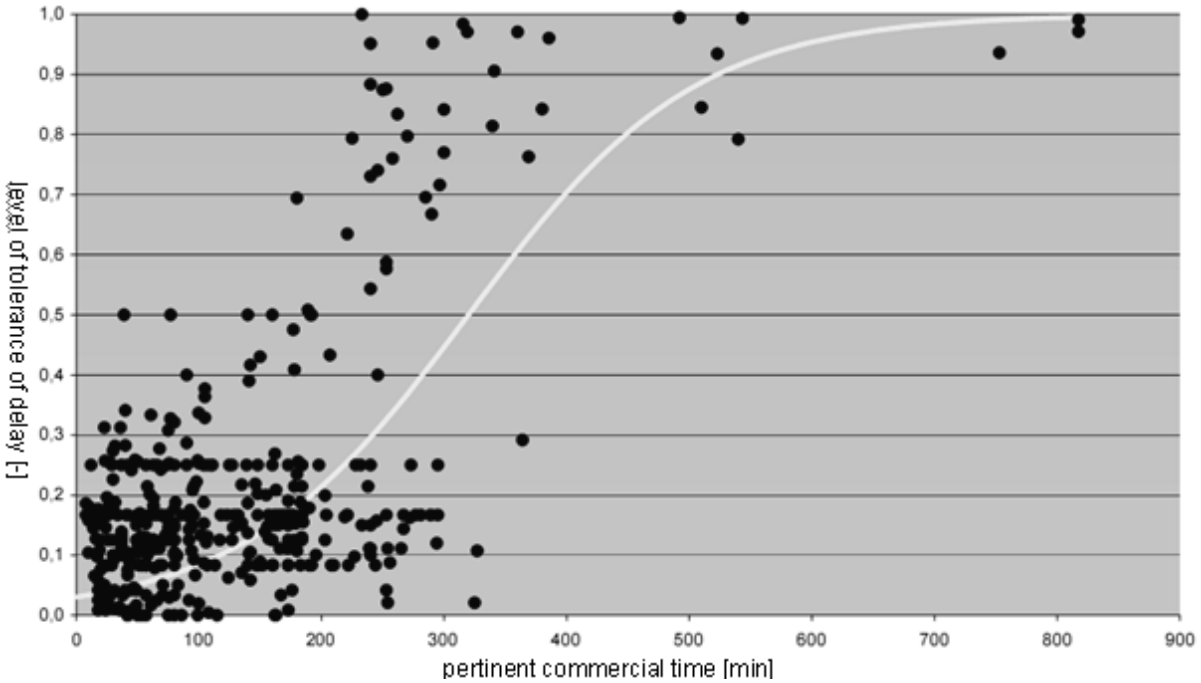


Figure 3: Level of passengers tolerance of delay to total commercial time in the case of waiting for a connecting train.

The methodology can be used during the designing of the General Timetable, where transfer traffic currents can be estimated with the help of a regular survey of the carrier and, based on this data, waiting times between the connecting trains can be set regarding the optimal transport services of the region and the public transport lines interlacing.

Even though the predicative ability of the created regression functions and the respondents sample are not ideal because the determination index does not near 100 % (however, other regression quality parameters are positive), according to the authors it is possible to use the survey results and specify them in greater detail in future on other occasions, as case may be.

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REFERENCES

Hindls, R. et al., 2004. Statistika pro ekonomy. 5th edition. Praha : Professional Publishing, 2004. 415 pages. ISBN 80-86419-59-2.

Jacura, M., Pöschl, D., Týfa, L., 2009. Hodnocení zpoždění a přípojových vazeb cestujícími v železniční dopravě. In *Verejná osobná doprava 2009*, pp. 97–100. ISBN 978-80-89275-18-2.

Jacura, M., Týfa, L., 2007. Problematika čekacích dob a zastavování ve veřejné hromadné dopravě. In *Verejná osobná doprava 2007*, pp. 125–130. ISBN 978-80-89275-09-0.

Lübke, D. et al., 2008. Das System Bahn. 1st edition. Hamburg : DVV Media Group, 2008. 680 pages. ISBN 978-3-7771-0374-7.

Řezánková, H., 2007. Analýza dat z dotazníkových šetření. 1st edition. Praha : Professional Publishing, 2007. 212 pages. ISBN 978-80-86946-49-8.