The Reliability of the Transportation System and its Influence on the Choice Behaviour

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Abstract

Our society and especially today's business life is structured by time-tight schedules. Time has been established as an expensive good. Transportation planning takes account of the time spent and its value. It is considered in the usual choice models such as destination-, route- or mode-choice models. These choice models calculate a utility for each alternative and choose the one which shows the highest utility. Currently time is included in the utility function, as either the mean trip duration or the mean speed of vehicles.

But what is the utility of a fast car while it is standing in a traffic congestion? When people choose a mode to go somewhere they think not only about the normal duration of a trip but also about the reliability of the arrival time in the particular situation. Still the choice models mentioned generally do not contain a term concerning how reliable the alternatives are. One reason for not considering this item on the problem of how to measure and describe reliability for the users of transportation systems. This paper focuses on this problem. The measurement instrument was a SP-survey. It employed different methods of questioning as well as several types of presentation. The results of the survey were modelled by using the MNL approach.

Keywords

Transportation Systems - Reliability – Discrete Choice Modelling –Swiss Transport Research Conference – STRC 2002 – Monte Verità

1. Approach

The expected reliability of a route, a transportation mode or a destination is one of the main variables when planning a trip or even a whole day. The route choice and the mode choice coheres with the choice of the departure time to reach a destination in time with an acceptable probability. The destination choice depends on the probability of the possibility to achieve the planned objectives (shopping, activities, etc.) at this place within a given time budget.

In fact there is an obvious influence of the reliability but it is rarely implemented as a factor in current choice models. This neglect has got serious consequences in terms of political decisions for transport planning and the actions of public transport providers. For example it might lead to the construction of roads with unsatisfactory capacities, because the cost-benefit-analysis do not contain the costs of the unreliability. In the field of public transport speed will be overemphasised in stead of investing into the vehicle pool or into keeping a staff reserve. Time tables might imply faster but also unrealistic and unreliable travel times.

One main reason for this neglect is the difficulty of measuring the reliability. The Institute of Transport Planning, Traffic, Highway and Railway Engineering (IVT) performed a study for the Swiss Traffic Engineering Association (SVI) under cotractof the Swiss Federal Highway Office (ASTRA), during which the effect on the choice behaviour by different types of presenting the reliability were analysed. The main target is to include reliability as a factor into choice models, estimate a value of the reliability and give recommendations for further research.

2. Basics of choice modelling

2.1 Discrete Models

The usage of discrete choice models is established in all kinds of transport planning. First approaches where developed by Domencich and McFadden (1975) and Ben-Akiva and Lerman (1987). The roots of these econometric utility models can be found in the field of economic science. The most common model family is the logit model with its extensions. In principle, the subjective individual utility is calculated for all possible alternatives. The alternative with the highest utility will be chosen. The model assumes a rational choice by observed of the transportation network users. The aspect of the subjectivity is very important, because the estimated behaviour is based on the subjective information, which differs from person to person; e.g. there is is substatial variaty in the knewlegde about the offer of a specific public transport company. To consider this fact, the objective utility of an alternative has to be modified by a stochastic term.

Mentioned above, a first assumption is, that every person is informed perfectly about the attributes of all alternatives: The possible destinations, the available modes (including data about the time table, the travel times, parking possibilities, the trip costs, etc.) or a complete overview of the network.

To consider the lack of perfect information about the transport system and the preferences of the users the estimated utility in the model consists of two parts; see also Ortuzar and Willumsen (1994):

- One measurable, systematic part V_{jq}, representing the value of the objective utility of an alternative j for a person q
- One stochastical part respectively error ε_{jq}, of V_{jq} considering the individual unobservered characteristicsof each user

The utility U_{jq} is calculated as follows:

$$U_{jq} = V_{jq} + \varepsilon_{jq}$$

With V_{jq} considering the attribute of the alternatives, the choice situation of the user and the characteristics of the user.

More detailed information with reference to discrete choice analysis can be found in Ben-Akiva and Lerman (1987), Ortuzar and Willumsen (1994) or Maier and Weiss (1990).

2.2 The reliability in discrete choice models

For a number of years research projects have shown the importance of the factor reliability in the decision process. First studies dealt with this topic 20 years ago, e.g. Prashker (1979). In this survey variations of that variables travel time, car park searching time and bus stop waiting time were generated. The variations of the variables were presented as day to day variations in minutes. It was determined, that the reliability of waiting times and of the searching time for a parking place is more important in the decision than a dependable travel time. Another result were the differences between the perception of PT users and car drivers of the travel time and waiting time variance.

Abkowitz (1981) studied a survey undertaken in the San Francisco Bay Area. He investigated the effect of the reliability in choice models in the context of working trips. The estimated choice model showed an obvious influence of theses variables, in particular in those models, which describe the departure time choice.

Another important insight was, that the departure time variables concerning the reliability do not correlate with the other explainatory variables of conventional models like travel time. A nested logit model combining mode choice and departure time choice yielded the highest goodness of fit. The conclusion of the study is, that the right choice of the measurement method is a very important factor.

Although several studies showed the importance of the reliability and tried to implement the variable in choice models as an auxiliary aspect, a concrete satisfying and fully solution has not been found. Recent British studies focussed directly on the reliability; see Bates (2000) and Cook, Jones, Bates and Haight (2000).

Bates suggests for further development of this problem and its implementation into choice models three points:

- A clear description of the situation in SP-surveys, especially the information about the travel time variabilities and how they accrue in each situation.
- The distribution of the variable characteristics should be linear and the characteristics should have approximately an equal probability.
- The described delay should relate directly to the preferred departure respectively arrival time.

An important point for the measurement of the reliability is its definition. Especially delays are not necessarily a kind of unreliability. Once they are predictable, e.g. the morning congestion in the peak hour, they have a bit of a certain reliability. The degree of the reliability is defined by a random and not predictable variety of a normality, which is for each situation specific.

For these types of unexpected delays in of travel time by congestion the studies mentioned measure a value of CHF 40,- per hour over all. Similar values were observed by Hultkrantz (2001) in a Swedish study. The study measured also a value of unexpected travel time savings. This value was only the half of the value of the travel time loss. But the study showed some important limitations of such values. They depend very much on the over all travel time: Even a ten minute delay in short trips was felt to be not as relevant by a car driver or PT passenger. The consideration of these short delays in the choice process is secondarily.

A Californian study by Small and Yan (2000) tried to measure a value of travel time (VoT) and a value of reliability (VoR). A number of choice models were estimated for route and mode choice. The values measured were nearly the same as in the British studies.

In addition to the studies mentioned, which concentrate on the measurement of values, there is research on different methodological approaches: A US study, based on a five part stated preference survey, analysed the behaviour of route choice for varying travel times and information; see Abdel-Aty, Kitamura and Jovanis (1995). The model estimation considered also revealed preference data. It was shown, that in this context the stated preference data with variations of time is sufficient. Fujii and Kitamura (2000) made a RP-survey to measure the different behaviour of car drivers, who were affected by the temporary closure of a freeway. In this case the variable of Risk Management was introduced. The study showed big differences in the choice behaviour between person groups such as older employees as those employees with flexible working hours.

The combination of RP and SP surveys bas not been tested in the context of reliability. There are applications with other topics, in which positive experiences were made. Examples are Polydoropoulou and Ben-Akiva (2001), Brownstone, Bunch and Train (2000) and also Bradley and Daly (1997).

A further extensive overview of the subject reliability can also be found in Noland and Polak (2001).

3. Method and content of the survey

The questionnaires of this study are SP-experiments. Surveys with hypothetical situations can consider the reliability without problems in principal. The difficulty is the way of presenting the variable, because it has to be understandable and plausible to the answering person.

The survey was designed to consider two different aspects: On the one hand, the SP-experiments should vary methodologically, therefore different types of SP-experiments were presented; and on the other hand, the content was varied by different types of choices (route or mode choice). In addition to this a graphical presentation of the experiments was part of the design.

The questionnaire consists of six parts. The parts 1, 2, and 5 are single questions and the parts 3 and 4 are designed as SP-experiments with five or six iterations of each. The characteristics of the choice variables vary in each experiment. The orthogonal design was generated by the statistical software SPSS10.0.

The telephone recruiting of the "KEP" survey was available for capturing socio-demographic data, so that enough participants could be divide into PT riders and car drivers. For this reason the questions 2 and 3 were formulated differently for these groups of persons. However, the variables and their characteristics were identical. The groups were definied, so that the total sample split about 50:50

The first question is an introduction to the topic reliability of the transportation system. The participant should become sensible of his current travel behaviour and his personal assessment and management of the reliability. The person is asked to specify a buffering time for the two modes car and PT considering the need to arrive for an important appointment right in time.

The Question 2 asks for the limit of a just acceptable delay reliability in different scenarios. An unexpected delay for a specified trip (by purpose) is presented to the participant. He has to specify his threshold value for cancelling the trip. For trip purposes which have a free choice of destination, there is the possibility for the respondent to switch to another destination.

The experiments of question 3 have a more complicated structure. The participant has to indicate a monetary valuation of 100% reliability. He is asked to choose between an unreliable route and a new route which is liable to charges for his daily working trip. The SP-type is Stated Choice.

For the forth question, the sample was divided into halves again. The one half was presented a mode choice SP, the second half a route choice SP.

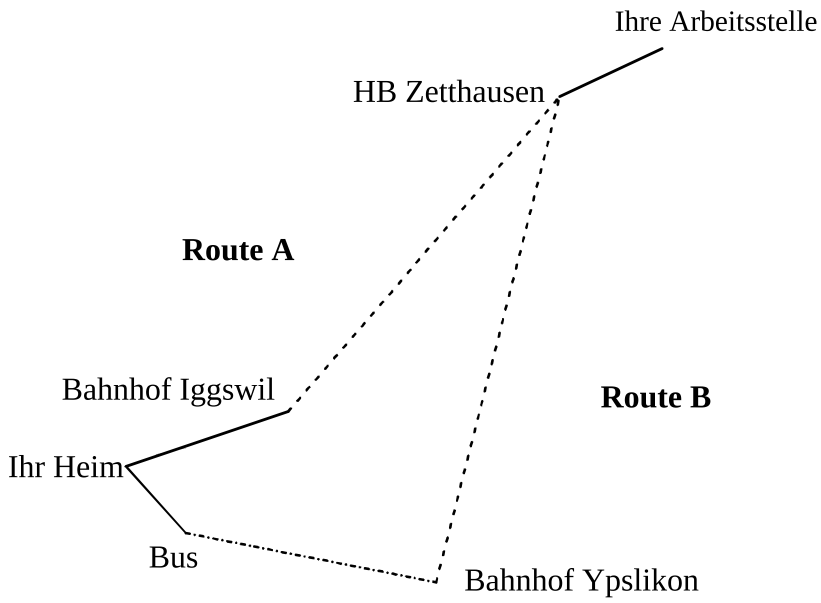
The mode choice SP offers three alternatives. The two alternatives rail and car, with the same reliable but fairly long travel time and a second alternative for the mode car, which is normally shorter but it has got a high unreliability. With a congestion the trip on this route can take longer than on the other routes.

In the route choice SP the participant can choose between a longer route with a high grade of reliability and a route with a shorter distance. A congestion on this second route leads to a later arrival time than on the first reliable route. This SP is assisted by a figure. It shows the two routes schematically. The attributes of the alternatives are described below the figure. Figure 1 shows an example.

The last question was intended to measure the rank of reliability in comparison to other determinants of mode choice. The participant should additionally weigh there determinants by his personal opinion of their importance.

Finally the participants got the opportunity to give commentaries on a separate page. Figure 2 shows again the flew of the survey for the participants.

Figure 1: Example of Question 4 (route choice)



Fahrzeit **Route A:** **50 Minuten**

Fahrzeit **Route B:** **45 Minuten**

Aufgrund Ihrer Erfahrung **verpassen Sie an 2 Tagen der Woche den Anschluss**, weil der Bus unpünktlich ist.

Dann benötigen Sie für die **Route B 75 Minuten.**

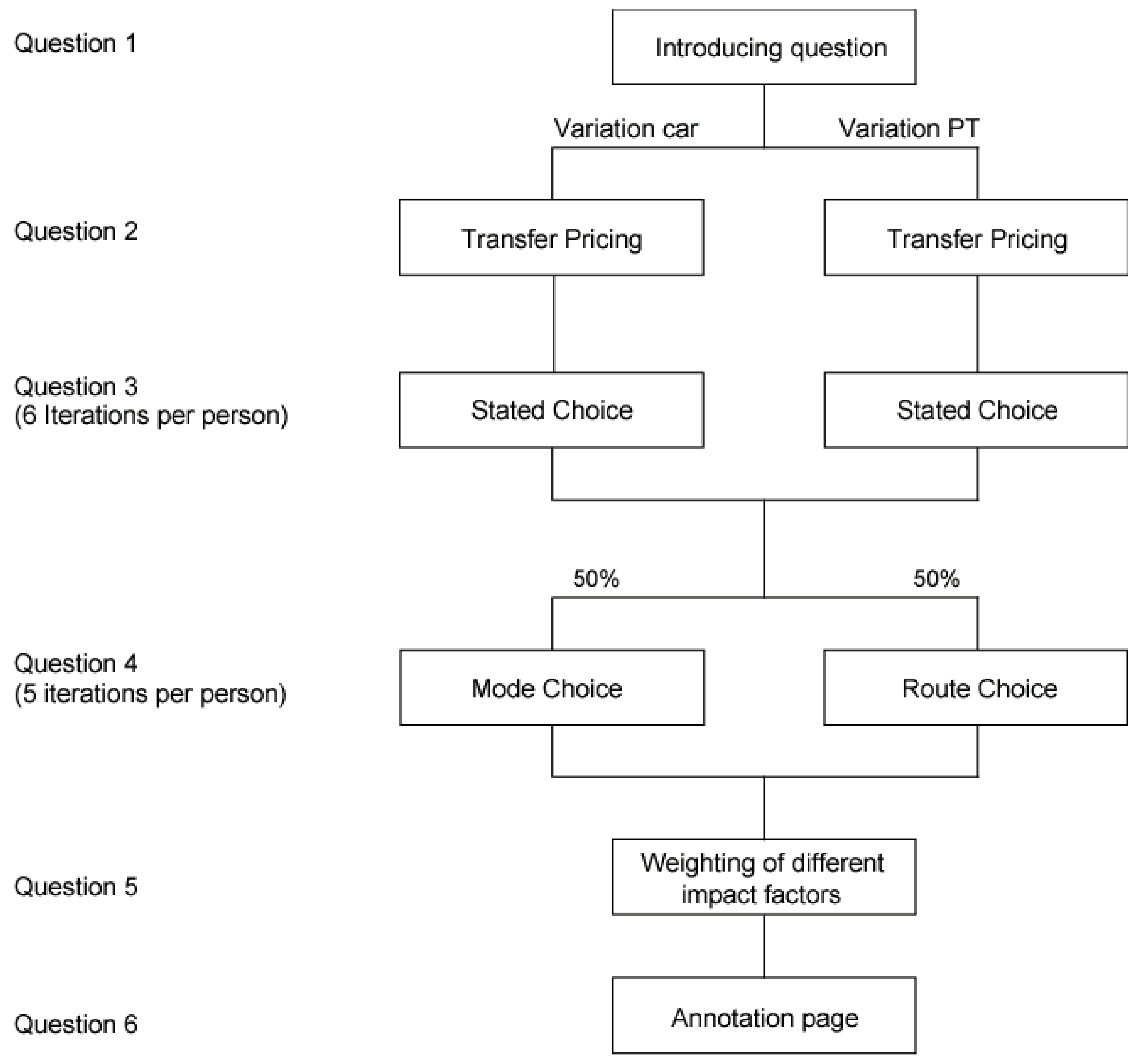
Aber das wissen Sie ja erst, wenn Sie bereits unterwegs sind. Welche Route wählen Sie für diesen täglichen Weg?

Antwort:

Ich wähle Route A. ❑

Ich wähle Route B. ❑

Figure 2: Structure of the survey



4. Model estimation

The search for the best model is a long iteration process, which contains partially unstructured steps. Even the definition of the aim is quite difficult, because the model's goodness of fit is not the cole indicator. There are other indicators such as the complexity of the model or the consitency with prior theory. Nevertheless, one important principle is to keep a model as simple as possible. In the following the major steps, models and their quality will be described.

Four model series were estimated altogether. One for each of the three SP-types (questions 3 – route choice, questions 4 – route choice and question 4 – mode choice) and another series of combined route choice models (questions 3 and 4 – route choice). The used estimation tool the software Limdep 7.0; see Green (1995).

During the estimation of the series the constants and independent variables were addede step by step. Additional variations were the implementation of generic and specific parameters as well as squared and logarithmic terms; finally socio-demographic parameters were added.

The tables 1 to 3 show the model development of the three route choice models. Basis was always a model without coefficients. The value of the Log-Likelihood function, L(β), could be maximised in all cases, i.e. the model estimation converged normally. This value represents the most important indicator of the goodness of fit .

Nonsignificant parameters were skipped during the model development. Reliability was presented in two forms: pürobability and duration of delay, as in the survey and as mean and variance of delay. The first approach led to a better goodness-of-fit and therefore used throughout The parameters weren't significant either. A model approach considering travel time restriction, based on over all daily time budgets and monetary budgets lead to much better results in a French study, see Blayac and Causse (2001). In this study, unfortunately, there could be no progress noted in terms of model quality.

Table 1 Model development route choice (Question 3)

	Constants only		Linear model		Squared terms	
Variables	Coeff.	t-Test	Coeff.	t-Test	Coeff.	t-Test
Constant for the unreliable route	0.3036	10.618	1.4709	12.269	3.5072	8.334
Probability of delay			-0.8397	-16.608	-2.5771	-7.675
Probability of delay^2					0.4771	5.353
Duration of delay			-0.0533	-17.479	-0.1352	-6.273
Duration of delay ^{2}					0.0013	3.771
Additional costs (Toll)			-.06767	-28.170	-0.1051	-8.335
Additional costs^2					0.0067	3.171
L(0)	-3469		-3469		-3469	
L	-3468		-2564		-2547	
adj ρ^2	0.0162		0.2599		0.2645	

Table 2 Model development route choice (Question 4)

	Constants only		Linear model		Squared terms	
Variables	Coeff.	t-Test	Coeff.	t-Test	Coeff.	t-Test
Constant for the reliable route	0.2783	5.109	2.3127	3.944	-15.5434	-2.330
Travel time reliable route			-0.0603	-5.501	0.2422	0.994
Travel time reliable route^2					-0.0031	-1.287
Probability of delay			0.0472	9.868	-0.1759	-2.581
Probability of delay^2					0.0187	3.547
Duration of delay			-0.0723	-7.530	-0.1375	-2.832
Duration of delay ^{2}					0.0179	2.235
L(0)	-952		-952		-952	
L	-939		-718		-695	
adj ρ^2	0.0131		0.2425		0.2654	

Table 3: Model development combined route choice model

	Constants only		Linear model		Squared terms	
Variables	Coeff.	t-Test	Coeff.	t-Test	Coeff.	t-Test
Constant for the unreliable route	-0.2783	-0.126	-2.4083	-3.980	-32.7124	-5.771
Constant for the reliable route	-0.1518	-0.215	-3.0702	-16.564	-8.7597	-6.645
Travel time reliable route			-0.2141	-12.871	-0.1751	-1.302
Travel time reliable route^2					0.0037	0.219
Probability of delay			-0.9442	-9.868	-7.6054	-4.803
Probability of delay^2					1.7506	4.372
Duration of delay			0.1418	13.851	0.0837	3.985
Duration of delay ^{2}					0.0032	2.002
Additional costs (Toll)			-0.0677	-16.608	-0.1051	-8.335
Additional costs^2					0.0067	3.171
L(0)	-8841		-8841		-8841	
L	-4350		-3283		-3242	
adj ρ^2	0.5077		0.6281		0.6333	

Table 4 shows for each of the three series one possible final model. As mentioned all variables are significant. All other tested approaches did not lead to a better result concerning the goodness of fit. Another important attribute of models in general is their simplicity. The presented final models take account to this principle. The variables are just linear or quadratic and the choice variables can be arranged into the three groups travel time, costs and reliability.

The models show that reliability should be included in route choice models as well as time or monetary costs. Conspicuous is the high importance of the time variance, which is represented by probability of the delay. It is much higher than the one of its duration. This insight is one of the major results. Obviously, it is the fact of being not in time whis is more important for travellers than the duration of the lateness.

There were just a few significant socio-demographic parameters, which could be identified. Especially the language spoken showed a slight impact for the observed choices. The language of the participants is not directly related to the residential place in one of the language regions, but it can be seen as an indicator for different attitudes and values. Obviously these characteristics are relevant for the choice behaviour.

Table 4: Model characteristic route choice models

	Route choice (Question 3)		Route choice (Question 4)		Combined route choice model	
Variables	Coeff.	t-Test	Coeff.	t-Test	Coeff.	t-Test
Constant for the unreliable route	3.267	7.348			-21.876	-5.700
Constant for the reliable route			-24.587	-4.772	-11.532	-13.685
Travel time reliable route			0.654	3.782	-0.306	-11.385
Travel time reliable route^2			-0.073	-4.153	0.002	9.124
Probability of delay	-2.603	-7.733	-0.274	-4.938	-3.125	-10.097
Probability of delay^2	0.483	5.399	0.003	5.668	0.626	7.824
Duration of delay	-0.137	-6.318	-0.033	-2.966	0.122	10.078
Duration of delay ^{2}	0.013	3.810			-0.001	-1.142
Additional costs (Toll)	-0.106	-8.376			-0.117	-9.392
Additional costs^2	0.007	3.201			0.001	4.132
Trip purpose work	-0.070	-4.689			-0.071	-4.697
Spoken Language French	0.144	1.635			-0.207	2.646
N	5004		1374		6378	
L (0)	-3469		-952		-8841	
L (C)	-3411		-939		-4350	
L (β)	-2535		-695		-3235	
adj ρ^2	0.267		0.266		0.633	

Table 5: Model characteristic mode choice model

	Mode choice (Question 4)	
Variables	Coeff.	t-Test
Constant rail	0.393	0.619
Constant car, unreliable route	-0.217	-0.313
Travel time rail	-0.035	-10.873
Travel time car reliable route	-0.031	-7.498
Travel time car reliable route	-0.060	-9.987
Probability of delay	-0.003	-0.648
Halbtax	-0.110	-3.588
Spoken language French	-0.533	-2.634
Age	0.022	3.167
N	1251	
L (0)	-1374	
L (C)	-1269	
L (β)	-1122	
adj ρ^2	0.173	

The question 4 (mode choice SP) is not a classic mode choice SP-experiment, because there is no monetary cost variable integrated.Table 5 shows one possible final model estimated for the data of this SP-experiment. The power of explanatary of the variables is low. The current fomulation is not satisfactory, as some of the model attributes are mot significant.

5. Conclusions and outlook

The analysis of the research which has been done over the last decade has shown, that the reliability of the transportation system is a decisive factor in the choice behaviour of people. Numerous studies with different approaches were conducted during in the last years, which take account on this important variable in a discrete choice modelling context.

Though one problem of the validation of the reliability is not solved satisfactionally, which is the empirical measurement of its influence. This study addresses to those deficits. Several kinds of SP-Experiments were implemented by different types of choices. In addition to this the problem of presenting the reliability was considered by different scenario descriptions. Based on the measured data particularised and combined discrete choice models were estimated.

The results confirm again the weight of reliability within the choice process of car drivers and public transport users. The delay itself and its amount must be treated differently. The influence of a possible unpunctuality is much higher than the duration of the lateness.

Not tested until yet is if the departure time choice could be used as a measurement context, because a free choice of departure time can strongly compensate the variations of travel time. People have the possibility to increase the reliability by choosing another starting time. Further research may focus on this topic and detect the restrictions, which come up when choosing the departure time. In this case there could be made final statements of the opportunity of people using the transportation system to maximise actively the personal specific reliability by choosing another departure time.

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