VK 5302.201
ISSN 0920-0592

The relative importance of public transport trip-time attributes in route choice

May 1988

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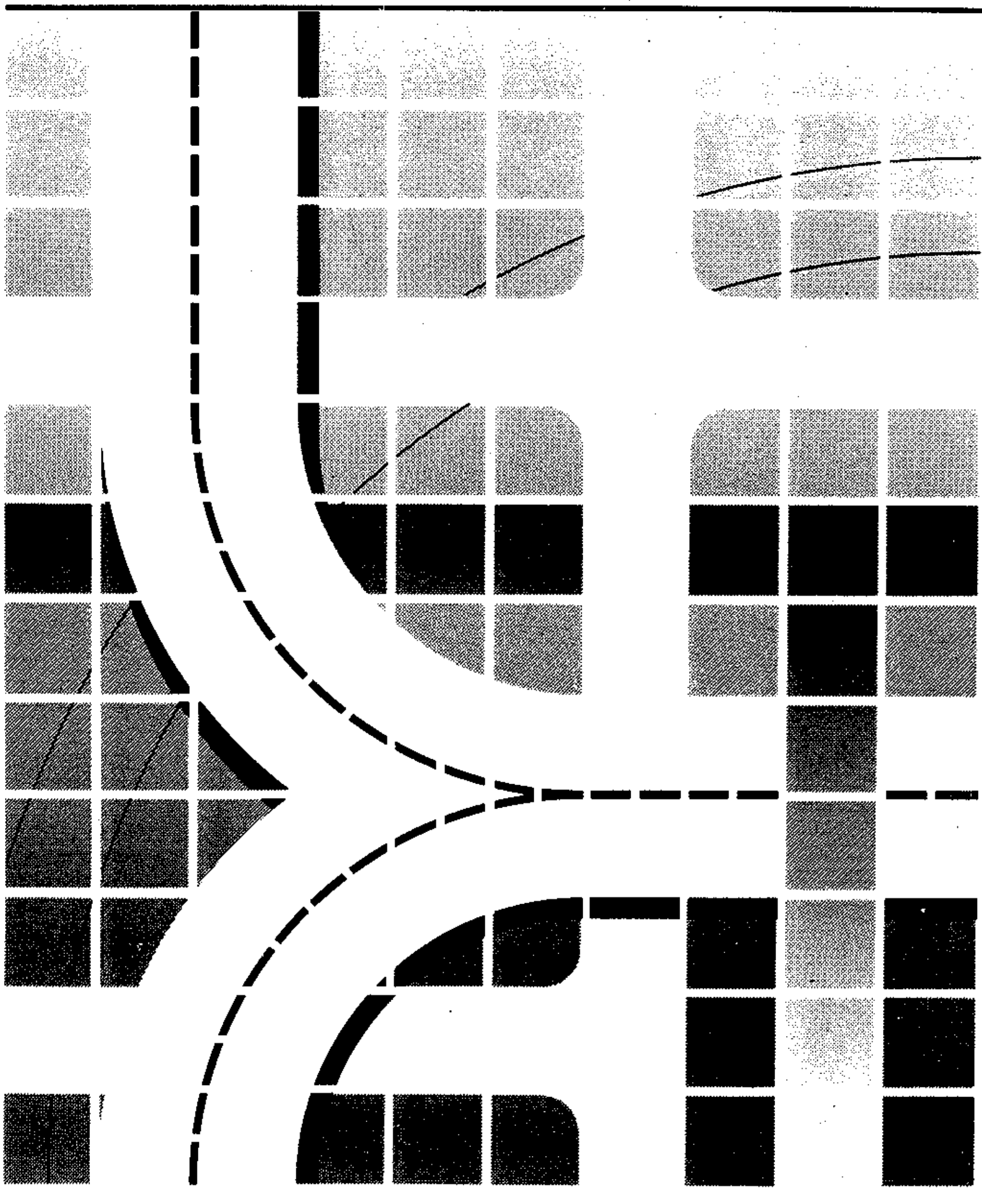

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Document vakgroep Verkeer Technische Universiteit Delft

1. **Rapportnummer** VK 5302.201	6. **ISSN-nummer** 0920-0592
2. **Titel rapport** The relative importance of public transport trip-time attributes in route choice	7. **Thema** Public Transport
3. **Schrijvers** ir. J. van der Waard	8. **Onderzoekproject** Relative importance of trip-time attributes
4. **Uitvoerend instituut** Dept. Transportation Planning and Highway Engineering PO Box 5048 2628 CN DELFT The Netherlands	9. **Categorie rapport** Paper prepared for PTRC Summer Annual Meeting 1988, Bath, England
5. **Opdrachtgever** Netherlands Technology Foundation (STW)	10. **Datum publicatie** May 1988

11. **Samenvatting**

At Delft University of Technology research is taking place into the relative importance of quality determining attributes of a trip by public transport for different categories of public transport users and trip. The relative importance of the trip-time attributes is determined by analysing route-choice behaviour of individuals who stated to know their route alternatives. A multinominal logit model is used and a distinction is made between different categories of public transport users and trips. These categories are defined by for instance car-availability, trip purpose and period of the day. The relative importance of different types of in-vehicle time (bus,metro) and different types of transfers is analysed by using various model specifications.

In the paper the current research project is outlined and results concerning the differences found between the estimation results for various categories of public transport users and trips, representing different market segments, are presented. The paper also focusses on the consequences of these differences for planning and design purposes.

12. **Begeleidingscommissie** STW-project DCT36.0522	14. **Bijbehorende rapporten** -	
13. **Praktijkcontacten** -	15. **Aantal blz.** 19	16. **Prijs** ƒ 3,80

THE RELATIVE IMPORTANCE OF PUBLIC TRANSPORT TRIP-TIME ATTRIBUTES IN ROUTE CHOICE

Paper prepared for the PTRC Summer Annual Meeting 1988, Bath, England

The research project described in this paper is supported (in part) by the Netherlands Technology Foundation (STW).

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May 1988

TWO LINE SUMMARY

Analysis of route-choice behaviour of different categories of public transport users depending on the quality of the public transport system.

ABSTRACT

At Delft University of Technology research is taking place into the relative importance of quality determining attributes of a trip by public transport for different categories of public transport users and trip.
The relative importance of the trip-time attributes is determined by analysing route-choice behaviour of individuals who stated to know their route alternatives. A multinominal logit model is used and a distinction is made between different categories of public transport users and trips. These categories are defined by for instance car-availability, trip purpose and period of the day. The relative importance of different types of in-vehicle time (bus,metro) and different types of transfers is analysed by using various model specifications.

In the paper the current research project is outlined and results concerning the differences found between the estimation results for various categories of public transport users and trips, representing different market segments, are presented. The paper also focusses on the consequences of these differences for planning and design purposes.

1. INTRODUCTION

The growing need to maintain and improve the competitiveness of the public transport system has in recent years increased the attention for its quality. Quality improvement is pursued by applying various types of measures, ranging from measures aimed at better punctuality and regularity of the existing services to measures that ensure an entirely new system for specific user groups.

To be able to improve the quality of the public transport system it is necessary to know which attributes determine the quality and to what extent they are effective in choice behaviour. In view of the many different types of measures that can be applied, there is a need for this knowledge at different levels of detail. The public transport planners are faced with a financially limited choice between this wide range of different measures and existing research results are often not detailed enough to answer their specific questions. Common reasons for this lack of detail are:

- Various trip-time attributes are combined when modelling passenger behaviour (it is for instance quite common to combine access time, waiting time and egress time as out-of-vehicle time);
- Usually no quality determining factors such as comfort at stops and type of vehicle are incorporated in the research;
- Usually no distinction is made between different categories of (potential) public transport users.

The objective of a current research project at Delft University of Technology is to detail the knowledge required by the transport planners, faced with the financially limited choice between the various quality improving measures. The research project looks at the way the behaviour of public transport users is influenced by the quality of the system. In this paper the research project is outlined and some results are presented.

2. QUALITY OF THE PUBLIC TRANSPORT SYSTEM

The quality of a trip by public transport is determined by its many objective attributes, ranging between the access time to the nearest busstop and the availability of seats at interchanges. All these quality determining attributes will not equally contribute to the total quality of the trip. Furthermore, the attributes will not influence the choice behaviour of every passenger in the same way.

In principle there are four choices to be made leading to the decision to travel on a certain route by public transport:
1. the choice to undertake an activity at another location,
2. the choice of a destination,
3. the choice of a transportation mode,
4. the choice of a route.

The quality determining attributes form only one part of the input variables in the decision processes concerning the four choices mentioned. Other input variables are the characteristics of the individuals and their (objective) choice constraints.
On a certain route, the total demand for public transport is determined by the outcome of all four decision processes mentioned and the total number of individuals making the choices.
Research into the relative importance of quality determining attributes should therefore not be limited to quantification of the relation between the quality of the public transport system and the demand for public transport. Strictly speaking, all four decision processes should be taken into account.

In order to be able to get a first insight in the relative importance of the various quality determining attributes of the public transport system, the research focusses on the decision process that is only influenced by the attributes of the public transport system, i.e. the route choice process of public transport users.

3. OUTLINE OF THE RESEARCH PROJECT

The relative importance of the objective attributes in route choice is analysed by estimating the coefficients of the variables in the utility function of a multinominal logit-model [6]. An example of such a function is:

$$U = a_a T_a + a_w T_w + a_r T_r + a_e T_e \; (+ a_{ca} T_{ca} + a_{cw} T_{cw} + a_n NRC)$$

The trip-time attributes incorporated in this function are:

- T_a = access time (walking),
- T_w = waiting time at the first stop,
- T_r = (sum of) in-vehicle time(s),
- T_e = egress time (walking),
- T_{ca} = (sum of) walking time at interchange(s),
- T_{cw} = (sum of) waiting time at interchange(s),
- NRC = number of transfers.

U is the total (dis)utility of a certain route by public transport and a_a through a_n are the coefficients of the various attributes.
Other attributes of the system, that were included in the research as variables in the utility function are "vehicle type" and "type of interchange". For the calibration of the models a program developed by IWIS-TNO [4] was used.

To analyse the influence of relevant attributes not included in the utility function, the coefficients of the model were estimated for sub-populations of public transport users that differ with regard to such relevant attributes.
Characteristics of the trip and the public transport users thus considered in the research are age, sex, car- and bicycle-availability, frequency of use, trip purpose and period of the day.
Due to the fare structure (zone-system) in the Netherlands, the price of a trip is a non-significant variable in urban route choice. Because only urban trips were considered in the research, the influence of the variable "trip-cost" was not examined.

The data for this research were collected by conducting an inquiry among public transport users at their waiting location (stops) in the origin areas of selected pairs of origin and destination areas between which there were two to four route-alternatives available.
A total of about fourty of these origin-destination pairs were selected, making sure that a fair amount of variation would be found in the attributes that had to be analysed, such as time-length of the various trip-time attributes, type of vehicle, number of transfers.

The collected data consist of:

a. exact origin address of the public transport user,
b. trip-time attributes of the chosen alternative,
c. exact destination address of the public transport user,
d. characteristics of the trip (e.g. trip purpose),
e. characteristics of the public transport user,
f. trip-time attributes of the non-chosen alternative(s).

All trip-time attributes were calculated from network data using the following definitions:

* access time (walking)	- measured distance divided by average walking speed of 1.2 m/s.
* waiting time at first stop	- derived from headway according to the time-table, using the waiting time series of Weber (see table 1).
* in-vehicle time	- according to the time-table.
* egress time (walking)	- as access time.
* walking time at interchange	- as access time.
* waiting time at interchange	- half the headway according to the time-table.

Table 1. Waiting time related to headway (Weber [7])

Headway in minutes	Waiting time in minutes	Headway in minutes	Waiting time in minutes	Headway in minutes	Waiting time in minutes	Headway in minutes	Waiting time in minutes
2	1.5	7	3.4	12	5.0	17	6.2
3	1.7	8	3.8	13	5.3	18	6.4
4	2.0	9	4.1	14	5.5	19-40	6.5
5	2.5	10	4.4	15	5.8	41-90	7.0
6	3.0	11	4.7	16	6.0		

4. THE COLLECTED DATA

The necessary data were collected on weekdays between 7.30 a.m. and midday in the spring of 1986. This was mainly done for trips to the city centres of Amsterdam, Rotterdam, The Hague and Utrecht. Data concerning the behaviour of a total of 1863 individuals were obtained. As a result of considering mainly city centre orientated trips during morning hours, the main origin of the individuals is the home address (89 %).

For a detailed insight in the relative importance of the trip-time attributes, it is necessary to analyse individual choice behaviour. By using all cases in the analysis, the results would be biased by respondents that did not make a choice, due to lack of knowledge about the alternatives.
Theoretically the use of disaggregate choice models is not allowed for these individuals. Where choices exist, they must be fully perceived and there must be grounds for believing that individuals are aware of the alternatives available (Harrison [2]).
To be able to check whether the individuals were aware of their alternatives, they were asked to mention these alternatives and to state why they didn't use them. It was, however, not possible to establish whether those who didn't mention alternatives (n=768) really didn't make a choice. It is after all possible that they failed to mention an alternative because they felt it was not suitable for them, due to reasons related to the trip-time attributes, thus actually making a choice based on these attributes. The number of such individuals was, however, believed to be very small, because no correlation was found either between the knowledge about alternatives and the difference in the trip-time attributes for chosen and non-chosen alternatives, or between knowledge about alternatives and the characteristics of individuals and trips.
Based on these results, it was decided to analyse only the behaviour of the 1095 respondents that stated to know their alternatives, because they were believed to have certainly been aware of their alternatives. The trip-time attributes of the alternatives used by these 1095 individuals are shown in table 2.

Table 2. Trip-time attributes of the chosen alternatives

Trip-time attribute	Mean	Standard deviation
Access time (walking)	4.2 min.	2.4 min.
Waiting time at the first stop	4.3 min.	1.3 min.
(Sum of) in-vehicle time(s)	16.4 min.	7.7 min.
Egress time (walking)	3.7 min.	2.5 min.
(Sum of) walking time at interchange(s)	1.1 min.	0.9 min.
(Sum of) waiting time at interchange(s)	4.0 min.	2.0 min.
Number of transfers	0.4	0.5

5. RESULTS OF THE ANALYSIS

5.1. Calibrations for the population of individuals that made a choice

The calibration results of three logit-models for individuals who stated to know their alternatives are given in table 3. The three logit-models differ with respect to the variables representing one or more transfers in the utility function.

Table 3. Estimating results for total population (n=1095)

Trip-time attribute	Coefficient Ratio to coefficient of in-vehicle time		
	Model 1	Model 2	Model 3
Access time (walking)	-0.296 **2.4**	-0.299 **2.3**	-0.301 **2.2**
Waiting time at first stop	-0.200 **1.7**	-0.199 **1.6**	-0.202 **1.5**
In-vehicle time	-0.121 **1.0**	-0.128 **1.0**	-0.134 **1.0**
Egress time (walking)	-0.142 **1.2**	-0.151 **1.2**	-0.151 **1.1**
Walking time at interchange			-0.314 **2.3**
Waiting time at interchange		-0.151 **1.2**	-0.169 **1.3**
Number of transfers	-1.587 **13.1**	-1.047 **8.2**	-0.761 **5.7**
Prediction	71.8	72.8	73.8

All the model coefficients are negative. This means that, according to expectations, an increase in time of any of the trip-time attributes in an alternative will lead to a decrease in probability of choice for the alternative. All coefficients differ significantly from 0 at the 5 % level (all absolute t-values are higher than 1.96). This shows that all the trip-time attributes influence the choice behaviour significantly. Table 3 also shows the ratio of all coefficients to the coefficient of the variable "in-vehicle time" (in bold type). For access time, waiting time, egress time and waiting and walking time at the interchange this ratio represents the weight of each minute of these trip-time attributes expressed in minutes of in-vehicle time. For the number of transfers this ratio represents a penalty for each transfer, expressed in minutes in-vehicle time.

The row "Prediction" in the table represents the percentage correctly predicted route choices.

Based on these results the following comments can be made:

- The results of model 3 show that a major part of the disutility of a transfer is formed by the walking and waiting time incorporated in the transfer.
- Access time appears to be more important than egress time. Two factors are suspected to yield this result. The first factor is the difference in conditions under which both times are spent. Nearly all trips are city centre orientated. The conditions for pedestrians during egress time are therefore relatively good. A similar effect was reported by Han [1], who found a very high coefficient for egress time under very poor conditions. Another more influencing factor is the fact that access time usually involves a certain amount of tension, concerning the rest of the trip (e.g. uncertainties about waiting and in-vehicle time), whereas during egress time this kind of tension does not exist. One is sure to arrive at ones destination within a very short time.
- An interesting result is the rather low relative importance of waiting time at the first stop, compared with values obtained from mode choice behaviour analysis (see for instance Hensher [3]). Only part of this difference is caused by the differences in applied definitions of waiting time. A similar effect was found by Jansson [5] using a stated preference technique for route choice analysis.

5.2. Detailed results for specific trip-time attributes

Table 4 shows the contribution of each trip-time attribute to the total disutility of an average trip that includes one transfer. For this example the coefficients of model 3 were used.

Table 4. Contribution of trip-time attributes to total disutility

Trip-time attribute	Time in minutes	Perc. of trip time	Disutility in min. in-vehicle time	Percentage of disutility
Access time	3.9	10.8	8.6	16.8
Waiting time at first stop	4.1	11.4	6.2	12.1
Total in vehicle time	19.7	54.9	19.7	38.6
Walking time at interchange	1.0	2.8	2.3	4.5
Waiting time at interchange	3.8	10.6	4.9	9.6
Number of transfers			5.7	11.2
Egress time	3.4	9.5	3.7	7.2
Total	35.9	100.0	51.1	100.0

The table shows that a major part of the disutility is formed by in-vehicle time (38.6 %) and transfer (4.5 + 9.6 + 11.2 = 25.3 %). Both components were analysed in furher detail, to establish whether their quality influences the contribution to the disutility.

The analysis concerning in-vehicle time was conducted by using a model with three different variables for the variable in-vehicle time (model 4). A distinction was made between "in-bus time", "in-tram time" and "in-rapid transit time" (= all urban railway lines, metro, tram lines with segregated right of way).

The analysis of the disutility of transfer was conducted by using a model with three different variables for the variable "number of transfers" (model 5).

A distinction was made between the following types of interchanges:
- interchanges where passengers hardly need to walk (type A),
- interchanges where passengers need to walk, but don't need to overcome differences in height (type B),
- interchanges where passengers need to walk and need to overcome differences in height (type C).

For both models the relative importance of the trip-time attributes in the form of the calibrated ratios of all coefficients to the coefficient of the reference variable "in-vehicle time" are shown in table 5. For model 5 the variable "in-bus time" was used as a reference. The table also shows the ratios for the basic model 3 (see table 3).

Tabel 5 Calibrations for different types of vehicle and interchange

Trip-time attributes	Model 3	Model 4 different types of vehicle	Model 5 different types of interchanges
Access time	2.2	2.3	2.3
Waiting time at first stop	1.5	1.4	1.6
In-veh. time (all types)	1.0		1.0
In-bus time		1.0	
In-tram time		1.0	
In-rapid transit time		0.9	
Egress time	1.1	1.2	1.1
Walking time at interchange	2.3	2.2	0.0
Waiting time at interchange	1.3	1.2	1.2
Number of transfers (all types)	5.7	5.9	
Number of transfers type A			4.2
Number of transfers type B			8.2
Number of transfers type C			9.2

The calibration results of model 4 show that there is only a slight difference between the ratios of the three variables for in-vehicle time. The public transport users apparently value a high-quality rail service, as offered by rapid transit, only somewhat higher than a more common bus- or tram-service. Notice, however, that the replacement of bus by rapid transit in the example of table 4, will mean a reduction in total disutility of the alternative comparable with about 2 minutes in-vehicle time (not including speed increase due to the new vehicle type). This is comparable to a reduction of the average waiting time at the first stop by about 1.3 minutes.

In model 5 the explanatory value of the variable "walking time at interchange" as shown in model 3 has gone to the three variables representing the penalty of a transfer at different types of interchanges. The coefficients of the model show that an interchange where there is hardly any distance to walk causes a considerable lower transfer-penalty than an interchange where there is a distance to walk. The results show that elimination of walking distances at interchanges can offer a reduction in disutility that is comparable with a reduction in in-vehicle time of 4 to 5 minutes.

5.3 Calibrations for different categories of public transport users

Until now no distinction was made between different categories of public transport users. However, it was suggested earlier that the various quality determining attributes do not influence the choice behaviour of all public transport users in the same way. To be able to establish differences between certain categories of users, the behaviour of several categories of users was analysed.

Some significant differences were found regarding the freedom of choice related characteristic "car-availability" and the trip-related characteristic "trip-purpose". No differences were found between sub-populations with regard to the more physical personal characteristics such as "age" and "sex".

Table 6 shows the calibration results for the two different categories concerning car-availability. Both for the population with a car available as for the population without a car available the calibration results of model 2 are presented.

Having a car available was defined as having a car available for the specific trip. Individuals who usualy had a car available, but didn't for the specific trip (car in repair or in use by other member of the household) were not included in the calibrations. By omitting these

individuals the two categories coincide with two opposite categories regarding freedom of choice in the mode choice process.
The two populations only differ significantly in individual characteristics related to car-availability (e.g. drivers licence and car ownership). This table also shows the t-values for each coefficient.

Tabel 6. Calibration results for different populations regarding car-availability

Trip-time attribute	Coefficient (t-value) Ratio to coefficient of in-vehicle time	
	no car available (n = 737)	car available (n = 165)
Access time (walking)	-0.287 (-9.761) **2.5**	-0.318 (-4.719) **1.7**
Waiting time at the first stop	-0.173 (-3.197) **1.5**	-0.342 (-2.682) **1.8**
In-vehicle time	-0.116 (-6.742) **1.0**	-0.190 (-4.473) **1.0**
Egress time (walking)	-0.129 (-3.782) **1.1**	-0.290 (-3.213) **1.5**
Waiting time at interchange	-0.062 (-0.990) ***)**	-0.683 (-3.407) **3.6**
Number of transfers	-1.317 (-4.814) **11.4**	+0.242 (+0.369) ***)**

*) Coefficient not significantly different from 0

Regarding these results the following comments can be made:

- The coefficients of the variables "access time" and "in-vehicle time" for the population with a car available are significantly higher than the respective coefficients for the population with no car available at the 5 % level (one-sided t-test; t-values for differences higher than 1.65). Notice that this significant difference makes the calculated ratios uncomparable.
- The calibrations for the two populations differ with respect to the significance of the variables representing the disutility of transfer. Individuals with a car available apparently only incorporate the waiting time at the interchange in their choice process (t-value number of transfers is very low). For individuals without a car available the fact that a transfer has to be made appears to be more relevant than the waiting time involved in the transfer.

The results show that individuals having freedom of choice in the mode choice process value all trip-time attributes higher than individuals not having freedom of choice. It needs to be emphasised that individuals who chose for the car are not represented in the research. The decision made by such individuals (i.e. car) indicates that they value the trip-time attributes even higher.
In general it can therefore be concluded that non-captive individuals are more susceptible to changes in quality of the public transport system than captive individuals.

The calibration results also show that a public transport network can be made more attractive for individuals with a freedom of choice in the mode choice process by assuring as short as possible waiting times at interchanges.

Besides the distinction between two categories regarding car-avalibility, a destinction was made between four categories of home based trips, that differ with regard to type of destination. The four different types being:

- work (n=471),
- school (n=119),
- shop or shopping centre (n=168),
- all other destinations, ranging from other home addresses via doctors visits to recreational destinations (n=208).

The following conclusions can be drawn from the results:

- The percentage of well predicted choices for the calibrated model for trips with destination type "other destinations" was found to be low, compared with the models for work, school and shopping trips. This leads to the conclusion that other factors, not included in the research, must play an important role in the route choice behaviour concerning such trips.
- No significant differences were found between the models for work and shopping trips.
- No significant differences were found between all four models, regarding the coefficients of variables representing the transfer.
- The coefficient of the variable "waiting time at the first stop" for school trips is significantly higher than the coefficient found for work trips. For school trips each minute of waiting time is weighed as 4.5 minutes of in-vehicle time.

Because some significant differences were found between the four sub-populations, with regard to individual and trip characteristics it can not be concluded that the differences found between the different types of trips are completely due to the difference in purpose of the trips. Because no significant differences were found between calibration results for sub-populations regarding the characteristics concerned, it can be concluded that the difference in trip-purpose is the main cause for the differences found.

6. GENERAL CONCLUSIONS AND IMPLICATIONS FOR PLANNING AND DESIGN

The calculated coefficients of the different trip-time attributes can be seen as a priority list concerning the effectiveness of quality improving measures, aimed at reducing the time-lengths of the respective trip-time attributes.
By making a distinction between different populations of public transport users, the effectiveness of such measures can be evaluated for specific user groups.
Many quality improving measures do not effect the time-length of the trip-time attributes but influence the conditions under which the trip-time attributes are spent. By taking some of these different conditions into account, the priority list can also be used to evaluate the effectiveness of this kind of measures.

With regard to measures aimed at reducing waiting time at the first stop, in-vehicle time or walking and waiting times at interchanges, the coefficients found can directly be applied as a priority list to evaluate their effectiveness, because such measures can be applied without changing the concept of the existing network.

With regard to measures aimed at reducing access and egress time and the number of transfers, the use of the coefficients as a priority list is indirect as a result of the existing relationship between the time-length of various trip-time attributes and the concept of the public transport network.
Reducing the number of transfers will, for instance, not necessarely lead to a higher quality, because offering more direct trip-possibilities will lead to lower frequencies, in return leading to longer waiting times at the first stop. A similar effect will occur when a finer network-grid is offered, aimed at reducing access and egress times. In these cases the coefficients can be used to evaluate different network alternatives.

Specific research results and their consequences for the design of the public transport system are:

- The valuation of trip-time attributes by public transport users appear not to be influenced significantly by general personal characteristics such as age and sex. Only specific trip related characteristics such as the purpose of the trip and the personal choice constraints appear to be of significant influence.

- The significant differences found between two sub-populations regarding car-availability, indicate that non-captive public transport users are more susceptible to quality changes in the trip-time attributes of the public transport system than captive users.

- There is a significant difference between individuals with and without a car available, regarding their disutility of tranfers. For individuals without a car available the waiting time appears much less relevant than the fact that a transfer has to be made. For individuals with a car available, however, only the waiting time involved in the transfer appears to be relevant.

- In the route choice behaviour of individuals making a trip with a destination other than work, school or shop, the various trip-time attributes play an inferior role.

- For school trips each minute of waiting time is weighed as 4.5 minutes of in-vehicle time. This result indicates that the quality of school trips can be improved by a relatively small reduction in the waiting times at the first stop. Because school trips usually only occur during short periodes, such a reduction can be reached by offering a higher frequency during such a short period.

- Transfers, although not taking very much time, are responsable for a major part of the disutility.
  The disutility of a transfer can be limited by minimising the waiting time incorporated in the transfer. Specifically for individuals with freedom of choice in the mode choice process, the public transport system can be made more attractive in this way, because these individuals value each minute of waiting time at the interchange as 3.6 minutes of in-vehicle time.

- The disutility of a transfer can also be limited by eliminating walking distances in the design of interchanges. Elimination of the walking distance can offer a reduction in disutility, comparable with 4 to 5 minutes of in-vehicle time.

- The difference found in the valuation of in-vehicle time for different vehicle-types shows that reductions in disutility can be obtained by replacing bus and tram services by more sophisticated rapid transit services.

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