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New insights in resistance to interchange

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Abstract

Train passengers experience an interchange between trains in their trip as a nuisance. To model this resistance, a penalty is usually added in the calculation of the perceived journey time. For many years, NS and ProRail used a fixed penalty of 10 minutes per interchange for rail trips in the Netherlands. This penalty was based on expert-judgement.
A stated preference survey in 2011 [De Keizer et al, 2012, customer resistance to interchanges, ETC Glasgow] demonstrates that customers experience a much higher penalty than 10 minutes. The penalty also strongly differs with characteristics of their transfer, like transfer time, frequency of the connecting service and whether the transfer is cross platform or not. Recently, the SP data have been re-analyzed, based on the recommendations of an audit on the 2011 work. This new analysis shows that a reference penalty is 23 minutes (including 2 minutes transfer time), which is more than twice as high as the current value. However, under certain optimal circumstances, the penalty can be lower than 14 minutes. Comparing the findings with earlier results and findings from international literature shows a similar dependence between punctuality, the connection time and the frequency of the connecting train in all studies. The added value of the new survey is a more detailed analysis of the importance of the various aspects of interchanges between trains. The outcomes of the new analysis have been compared with real-world data. This comparison showed that using the new values led to a much better fit with reality. For example, growth rates of various direct connections to Schiphol Airport were 30-100% higher in reality than had been predicted with the fixed 10 minutes penalty . Applying the new differentiated penalty led to a forecast with a maximum deviation of only 15% compared with the real-world figures.

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1. Introduction

Train passengers experience an interchange between trains as a nuisance. To model this resistance, a penalty is usually added in the calculation of the perceived journey time. For many years a fixed penalty of 10 minutes per interchange was used for rail trips in the Netherlands. This penalty was based on expert-judgment.

A stated preference survey conducted by NS in 2011 [De Keizer et al, 2012] demonstrated that customers experience a penalty which is much higher than 10 minutes. The penalty also strongly varies with characteristics of the transfer, such as transfer time, frequency of the connecting service and whether the transfer is cross platform or not. In the Netherlands NS, the operator of the core rail service (whose market share in Passenger-Rail-Kilometres is app. 90%), and ProRail, the infrastructure provider, work closely together in improving the quality of the timetable. Because of this common interest, NS and ProRail decided to use these new insights for future timetable development. Before that, Steer Davies Gleave (SDG) was commissioned to conduct an audit on the study and Significance was asked to improve the model estimations following the recommendations of SDG.

This paper discusses the re-analysis and compares the findings with earlier results and findings from international literature. It also shows the comparison between the model outcomes with the real-world observations and discusses its application in demand forecasting models.

2. Discussion of re-analysis

The 2011 SP survey contained two experiments. In the first, respondents were asked to choose between two travel alternatives. Both with one interchange but different characteristics of the interchange. Each alternative was described by its travel time, the transfer time and the type of interchange (cross-platform, cross-station with escalators, cross-station without escalators). In the second experiment, the number of interchanges between the alternatives varied from 0 to 2 interchanges. The alternatives were described by travel time, transfer time, number of interchanges, possible additional waiting time when missing a connection and cost of the trip. The type of interchange was not presented in the second experiment.

We estimated utility functions to model the choices of the respondents (Ben-Akiva and Lerman, 1985). Data from both experiments were pooled using appropriate scale factors.

We assumed a linear disutility for travel time, travel cost and possible additional waiting time. For the number of interchanges and the type of interchange, we estimated constant disutility factors. For the transfer time, a linear utility term did not fit the data. A transfer time of 5 minutes was clearly preferred above a shorter transfer time (2 minutes) or a longer transfer time (8 minutes or higher), so a 5-minute interchange is viewed as optimal by the respondents (Figure 1). Therefore, we assumed a linear declining disutility function for interchanges between 2 and 5 minutes, and an increasing disutility for transfer times above 5 minutes.

We estimated separate utility functions for three travel purposes: commuting & business, education and other. A general-purpose model was estimated on data from all respondents, using weight factors to correct for an unbalance in the distribution over the purposes in the sample. Error margins were corrected for the panel structure of the data (using a Jackknife procedure, see Miller 1974). Final results are presented in Table 1. All estimated coefficients are divided by the travel time coefficient, so that they can be presented in equivalent travel time minutes.

From these modelling results, we draw the following conclusions:

- The value of travel time is 6.77 minutes per euro, or 8.86 euro per hour. This is consistent with 9.25 euro per hour, which is the official value from a nation-wide value-of-travel-time survey in the Netherlands (Significance et al. 2012; Kouwenhoven et al. 2014).
- The value of one minute transfer time (above 5 minutes) is equivalent to 1.67 minutes of travel time. This is nicely within the range of 1.2 – 2.5 minutes for interchange multiplier factors used in other countries (Wardman 2014). The optimal transfer time is 5 minutes, as can be seen from Figure 1.
- Travelers have a strong preference for a trip without interchanges. A direct connection is valued at 22.63 minutes less compared to a connection with one interchange but otherwise similar characteristics. It should be noted that we assume this interchange to be cross-platform with a transfer time of 2 minutes and a possible extra waiting time of 15 minutes (when the connecting train is missed due to delays).

- Different interchange characteristics will result in a different valuation: the value of a direct connection compared to a trip with one interchange with 5 minutes transfer time and 10 minutes possible extra waiting time is only 13.36 minutes.
- One minute of possible additional waiting time is valued at 0.72 minutes of travel time, which seems reasonable.
- A cross-station interchange is valued at an equivalent of 7.22 minutes travel time increase compared to a cross-platform interchange. No significant difference was found between a cross-station interchange with and without escalators. A more precise analysis revealed that the penalty is about 6.4 minutes for people travelling without luggage or with only a small bag, and 13 minutes for people travelling with heavy luggage.

Table 1: Final model results and t-ratios. All model coefficients are expressed in equivalent travel time minutes. Note that the uncertainties in the interchange coefficients should be doubled (i.e. t-ratios should be halved) due to unclear specification of the SP, see text.

Purpose:	**ALL**		**COMM./BUS.**		**OTHER**		**EDUCATION**	
(In equivalent travel time)	Coeff.	t-ratio	Coeff.	t-ratio	Coeff.	t-ratio	Coeff.	t-ratio
TRAVEL COST								
For each Euro	6.77	(10.8)	3.83	(7.8)	11.95	(10.9)	7.64	(3.2)
TRANSFER TIME								
Transfer time = 2 minutes	0	(-)	0	(-)	0	(-)	0	(-)
For each minute between 2 – 5 min.	-1.89	(-4.4)	-0.77	(-2.5)	-4.43	(-6.6)	-1.85	(-1.3)
For each minute above 5 minutes	1.67	(9.1)	1.68	(12.9)	1.29	(5.1)	1.74	(2.9)
NUMBER OF INTERCHANGES								
0 *	-22.63	(-10.2)	-18.88	(-9.6)	-31.13	(-9.5)	-20.07	(-3.6)
1	0	(-)	0	(-)	0	(-)	0	(-)
2 *	15.62	(10.7)	13.60	(10.7)	21.15	(10.0)	14.47	(3.7)
POSSIBLE EXTRA WAITING TIME								
Possible waiting time = 15 minutes	0	(-)	0	(-)	0	(-)	0	(-)
For each minute different from 15 min.	0.72	(7.3)	0.59	(7.2)	1.03	(7.6)	0.58	(2.1)
TYPE OF INTERCHANGE								
Cross-platform	0	(-)	0	(-)	0	(-)	0	(-)
Cross-station	7.22	(6.4)	5.31	(7.4)	11.86	(7.4)	7.48	(1.9)

Compared to the previous analysis (De Keizer et al. 2012) we have combined the data from the two experiments in a different way: amongst others, we used a uniform base level for a single interchange. Previously, the travel time coefficient depended on the trip duration but the evidence for this in the data was not convincing. We included in our final model only coefficients that are significant and are relevant for the implementation (see next section), all other coefficients have been removed. These changes were made following the recommendations from the external auditor (Steer Davies Gleave).

Furthermore, we looked into the uncertainties of the final estimated coefficients. On top of the estimation error margins, we believed that the uncertainty in the transfer penalties should be doubled since some of the attributes in the SP were not clearly specified. Specifically, in the second experiment, it was not specified whether the interchange was cross-platform, or cross-station.

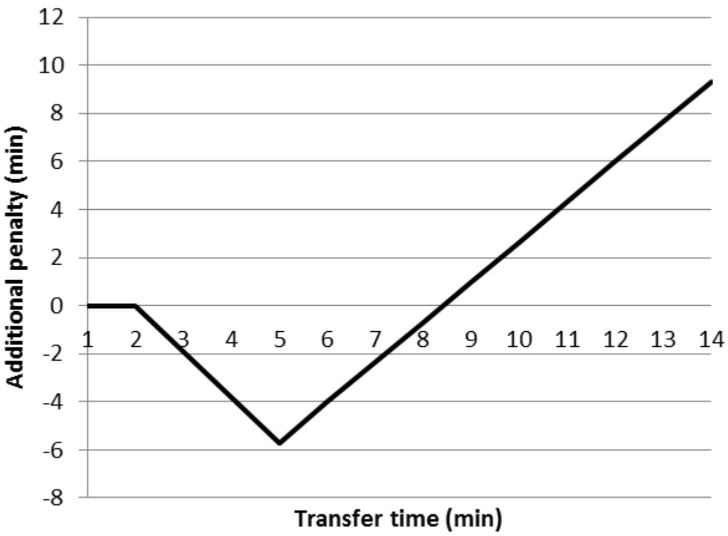

Fig. 1: Additional penalty for an interchange with a transfer time of more than 2 minutes

3. Recommended values for interchange penalties

Table 2 summarizes the set of interchange penalties in the perceived journey time. The interchange penalty has been constructed for an arbitrarily chosen case:

1. Cross-platform interchange
2. Transfer time of 2 minutes
3. "Possible additional waiting time by missing the interchange" of 15 minutes
4. Travelling with 'average' luggage

For this situation, the transfer penalty is equal to 23 minutes (including 2 minutes transfer time). For other situations, the penalty can be calculated by comparing its characteristics with these above. For every deviation of the characteristics a supplement or reduction on the value of the interchange penalty is made (see table 2). The starting value plus or minus the values of the deviations make the complete interchange penalty.

Figure 1 shows the relationship between the transfer time and the additional penalty for a transfer time of more than 2 minutes. The negative values between 2 and 8.5 minutes transfer time mean that the interchange penalty in this range is lower than for an interchange with a transfer time of 2 minutes. From a customer's point of view the optimal transfer time is 5 minutes.

Table 2: recommended values for interchange penalties

Resistance factor	Perceived journey time by trip purpose (minutes)
Interchange penalty (transfer time included) for a cross platform interchange with a transfer time of 2 minutes and a possible additional waiting time of 15 minutes	23
Cross-station interchange (instead of cross-platform)	+ 7
Travelling with heavy luggage	+ 7
Travelling with no luggage / only light luggage	-1
Transfer time	See figure 1
Possible additional waiting time by missing an interchange	See table 3

Although the model estimation did not result in a dependency because of the lack of longer transfer times in the SP design, it is very likely that the resistance for the possible additional waiting time depends on the planned transfer time of the interchange. After all, the likelihood of missing the connection decreases by the increase of the planned transfer time. Based on expert-judgment of NS and ProRail experts a dependence between the two resistance factors has been implemented in the application model: the resistance for possible additional waiting time is constant up to 8 minutes and decreases to zero between 8 and 15 minutes transfer time as is shown in Table 3.

Table 3: Dependency between 'Possible additional waiting time'- penalty and the transfer time

'Possible additional waiting time'- penalty per minute	Transfer time (minutes)
0,72	<= 8
0,72 * (15 – Transfer time) / 7	Between 8 and 15
0	>= 15

4. Comparison of the findings with international literature

We did not find any literature with a similar detailed analysis of the importance of various aspects of interchanges between trains. However, the average height of the new penalty seems to be in the range of international findings. In general, the new value corresponds better with the results from other studies than the previously used fixed value of 10 minutes penalty (excluding transfer time).

In the Passenger Demand Forecasting Handbook (PDFH) the interchange penalties are split by distance band and ticket type. An interchange in a trip with a distance of 25 km has a penalty of 15 minutes for full fare and reduced tickets and a penalty of 10 minutes for season tickets. For a distance of 160 km it increases to 40 minutes for full fare and reduced tickets and 26 minutes for seasonal tickets. The transfer time has been excluded from these numbers. The range between 10 and 40 minutes is in line with the range in our study: quite common values are between 8 and 35 minutes. The difference between the ticket types full fare/reduced and seasonal is largely consistent with the difference in trip purposes social-recreational and commuting.

In a research of MVA (1985) a cross-station interchange (instead of cross-platform) was valued at 9 minutes. That's comparable to the 7 minutes extra penalty for cross-station penalties in this study.

In Wardman, M., & Hine, J. (2000) several studies are mentioned about the impact of a guaranteed connection on the interchange penalty. A MVA study (1987) of the Network South East suburban services shows an interchange penalty of 13 minutes if the connection is guaranteed. If it is not guaranteed the penalty increases to 20 minutes if there was a chance of 10% of being delayed 5 minutes and it increases to 39 minutes if there was a chance of 10% to being delayed 30 minutes. TCI-OR (1996) found that a guaranteed connection was worth 20 minutes of journey time. In the present study delays and guaranteed connections are not presented directly to the respondents. In the experiments, respondents only got information about the frequency of the connecting service. The results showed that with a lower frequency of a connecting train, passengers experience a greater interchange resistance, because of the possible extra waiting time in case of missing the connection (see table 1 and 2). Dependence between punctuality, the connection time and the frequency of the connecting train is confirmed in all studies.

5. Comparison of the findings with real-world observations

We have studied three real cases in which direct services are replaced by services with an interchange and vice versa. We looked at the number of travelers between two stations, and corrected for effects of economic and demographic growth etc. The remaining change in number of travelers is attributed to the change in Generalized Journey Time (GJT).

We included the results of our new study in the GJT-calculation. By multiplying the different GJT-outcomes through the years with a journey time elasticity, a prediction of the growth caused by GJT changes can be made. The same can be done for a GJT-calculation with the old 10 minutes interchange penalty.

The three cases are the following ones.

Schiphol – Ede-W/Arnhem/Nijmegen

The completion of the 'Utrechtboog' near the Amsterdam ArenA soccer stadium has resulted in a direct service between Schiphol and Ede-W/Arnhem/Nijmegen in 2009. Before then, this trip could only be made with an interchange. The passenger growth caused by GJT-reduction on these relations is 23% (see Figure 2), which is twice as large as expected based on the old transfer penalty. Using the results of the new study, the GJT model predicts a growth of 21% which is much more in line with the real-world observation.

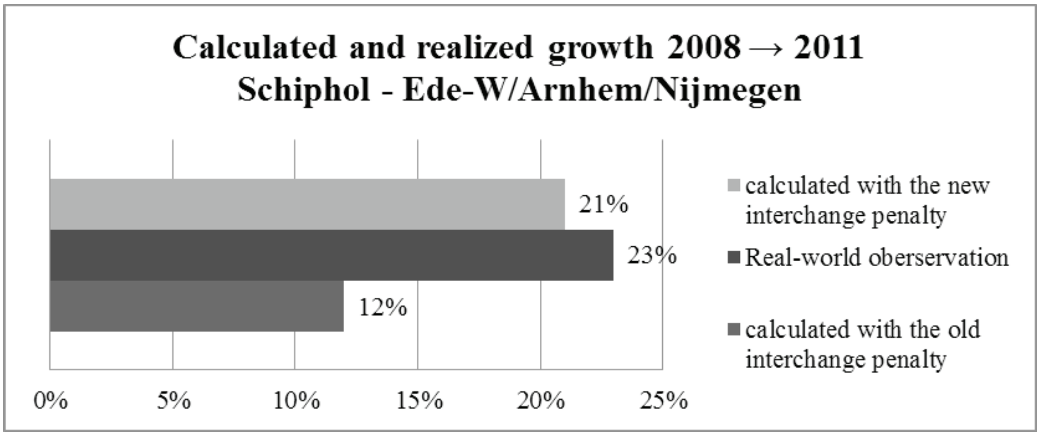

Fig. 2: Development of the number of trips on the relation Schiphol-Ede-W/Arnhem/Nijmegen. Comparison of calculated growth when applying new penalty (study outcome), old penalty (10 minutes) and real-world observation

Schiphol-Purmerend/Hoorn

In 2004 the 'Hemboog' near Amsterdam Sloterdijk was the trigger for starting up the direct service between Schiphol and Purmerend and Hoorn. A large growth in the ridership was observed. Again, this could not be explained by the GJT improvement using the old value of interchange (Figure 3). Application of the new values results in a much better correspondence between the GJT model and the actual growth.

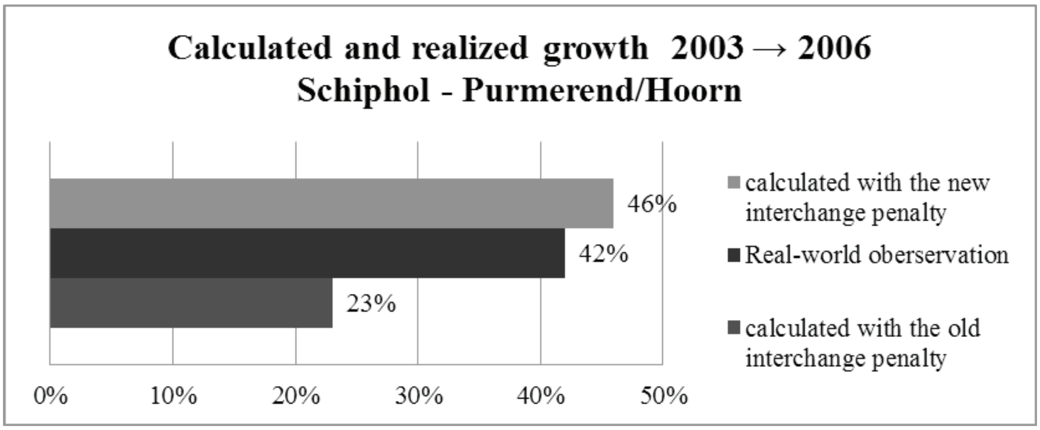

Fig. 3: Development of the number of trips on the relation Schiphol-Purmerend/Hoorn. Comparison of calculated growth when applying new penalty (study outcome), old penalty (10 minutes) and real-world observation

Den Haag Centraal - Arnhem

In another case (see figure 4) it has been decided to remove a direct service in favor of another connection. In 2009 the intercity-service between Den Haag and Arnhem has been shortened to Den Haag Centraal – Utrecht Centraal. From then onwards, travelers between Den Haag and Arnhem had to change trains in Utrecht. The drop in the number of passengers caused by a GJT-increase on this relation has been three to four times higher than expected before. If the same calculation is made by using the study results a small underestimation remains but the result is much more appropriate to the real-world observation than before.

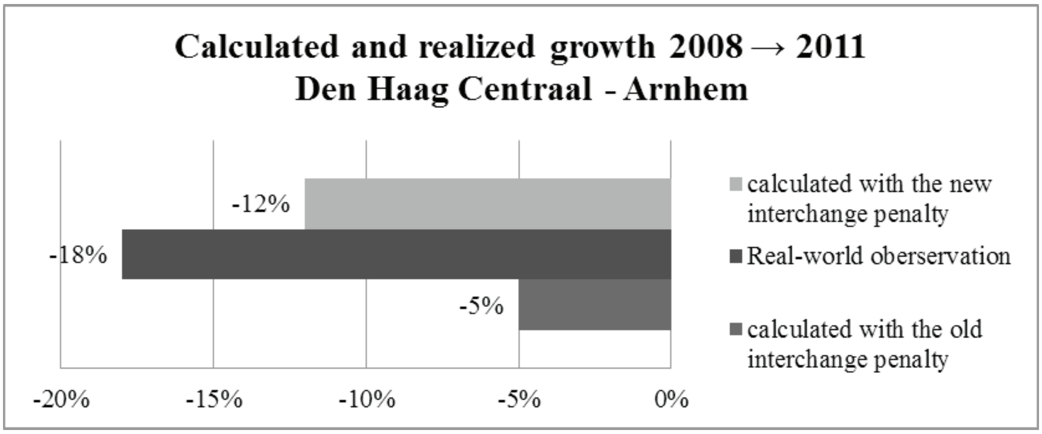

Fig. 4: Development of the number of trips on the relation Den Haag Centraal - Arnhem. Comparison of calculated growth when applying new penalty (study outcome), old penalty (10 minutes) and real-world observation

6. Conclusions

The outcome of this new analysis is a reference interchange penalty, that is twice as high as the old penalty. The analysis also shows large differences in the height of the penalty depending on the characteristics of the interchange (cross-platform, frequency of trains, waiting time etc.). For the first time, this study investigates many interchange characteristics (including their weights) together. The comparison with the real-world observations shows that the new estimated values fit better than the old ones.

It can be concluded that in public transport studies a variable interchange penalty, that takes into account the different characteristics of each interchange, is necessary to make a good forecast of travelers behavior and passenger growth.

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