Interchanges in timetable design of railways:

A closer look at customer resistance to interchange between trains

De Keizer, B

NS (Dutch Railways)

Geurs, K. T. , Haarsman, G. H.

University of Twente

1. Introduction

For a long time, railway companies have taken passengers' (train-to-train) interchange demands into consideration when organizing their timetables. With a further aim to keep passengers' transfer time to a minimum, this also means that additional travel time resulting from the transfer is limited. However, changing trains not only means a longer travel time for the passenger but also hassle. For several decades, NS has translated this in its models by awarding each transfer a penalty of a number of minutes' travel time. In prognoses, NS currently employs a transfer penalty of 10 minutes.

Although this resistance to interchange is assumed to be the same for each transfer, reality shows this not to be the case. Changing at a windy station in the flat, Dutch countryside is far more unpleasant than at the covered one at Schiphol Airport, where time can also be spent purposefully on shopping or having a bite to eat. By furnishing the environment of a transfer platform with stimuli that appeal to passengers (i.e. the correct choice of light, colour, sound and infotainment), the perceived waiting time can be reduced by more than 50% (Van Hagen, 2011). But it is not just the quality of the station and the platform that play a role. Also the way the timetable has been organized has an influence. A cross-platform transfer is more pleasant than when one has to take the stairs to another platform. To more successfully anticipate the demands of the passenger, it is necessary to incorporate these different transfer experiences in the timetable design. To this end, the generic penalty must be made situation-dependent. This means that, in order to be able to distinguish the penalties for any interchange resistance, the reasons need to be mapped and quantified.

2. Resistance factors

A potential passenger will always compare (albeit often unconsciously) the utility awaiting him at his/her destination versus the disutility of the journey. As long as the utility at the destination is more significant than the disutility of the journey, it is a trip worth making. We also have a name for this disutility: travel resistance. It influences the passenger's choice not only with regard to whether (s)he will actually make the trip but also with which mode of transport and at what time. This principle is based on the micro-economic utility theory at the heart of which is rational choice behaviour, i.e. behavioural choices made by individuals on the basis of the principle

of utility maximization. By decreasing the resistance to travel, a transport company can increase its transport demand.

When undertaking a journey, the passenger has to a certain degree three budgets at his/her disposal: time, money and effort. These components co-determine the travel resistance. If an interchange forms part of a train journey, this will impact on the time and effort budgets. If the transfer duration is short, the used time budget is limited but the effort budget remains significant. If the transfer is cross-platform, the effort with immediate transfer time is smaller than with a cross-station transfer. Besides all the exertion the transfer demands (lugging suitcases, planning the journey, climbing the stairs), the transfer time cannot be usefully spent either. Whereas one can work on one's laptop or read a book on the train, this is rarely the case (if at all) during the transfer. At such a time, the experiential value of the transfer appears to be the lowest scoring part of a train journey (Van Hagen, 2011; Steenberghen, Walle, Cornelis, Castaigne, 2005; Walle & Steenberghen, 2006).

Figure 1: Time components vis-à-vis experiential value (Van Hagen, 2011)

Although it is relatively easy to establish how much time a transfer takes, effort is more complex to determine. In the majority of studies, as with NS, there is one fixed penalty per transfer (Wardman & Hine, 2000; Wardman et al., 2001). However, a large number of resistance factors combined represent this penalty for a train-to-train transfer and it is not always clear which factors are included per study.
Table 1 shows the various (time- and effort-related) resistance factors named in the literature. The financial aspects have been disregarded here, but see for example Balcombe et al. (2004) for an overview.

Table 1: Overview resistance factors during train-to-train transfer from the literature

Factor	Findings from the literature
Waiting time	• Waiting time is experienced as being twice as long as in-vehicle time, (Wardman, 1983, in Wardman & Hine, 2000). • A longer waiting time may be construed as advantageous, because it decreases the chance of missing a connection. Naturally to a certain limit
Walking time	• The walking time is evaluated the same as the waiting time

Frequency	• The frequency influences the duration of the wait, particularly with high frequency services. For low frequency services the scheduled transfer time determines the waiting time. The frequency also determines the waiting time when one has missed a connection; it thus has an influence on the risks involved in a transfer • The frequency co-determines the transfer time. A low frequency allows for more transfer time but a high frequency may have to contend with a possible lack of transfer time (Hine & Scott, 2000).
Reliability (punctual arrival and departure of the train)	• The reliability of a service, both in the direction of and from the transfer, is relevant. In the direction of the transfer determines whether the transfer can be made on time, and from the transfer determines the extra waiting time • The reliability is an important aspect of the quality of the service but also of the transfer itself (Hine & Scott, 2000; Hutchinson, 2009). • A guaranteed transfer can reduce the transfer penalty by 45% (Wardman, Hine & Stradling, 2001).
Feeling of uncertainty (owing to possibly missing one's transfer and not having a seat on the connecting train)	• The feeling of uncertainty with regard to missing a transfer contributes significantly to the experienced disadvantage of a transfer. It moreover increases the considered minimum safe connecting time. Whether finding a seat post-connection or not also adds to the disadvantage of a transfer. • Availability of seats not important to majority (Fabel, 1996, in Wardman & Hine, 2000). • 2nd point of resistance is missing connection (25%) (MVA, 1985, in Wardman & Hine, 2000).
Transfer type (cross-platform or cross-station)	• Of importance here are the transfer types, varying from cross-platform, changing platform or changing station. The type of transfer determines the walking time and can be made easier with lifts, escalators, moving walkways and more difficult with congestion.
Walking facilities	• Wardman & Hine (2000) state that crowding at the station can also have an impact. • 3rd point of resistance is having to move (16%) (Wardman, 1983, in Wardman & Hine, 2000).
Waiting facilities 1 (physical)	• The presence and quality of facilities such as waiting rooms, eateries and shops increase the evaluation of the wait.
Waiting facilities 2 (experience)	• An important point of improvement is the waiting environment, which not only involves the aforementioned facilities but also such aspects as safety and the presence and visibility of staff (Hine & Scott, 2000).
Acquainted with transit station	• Frequent passengers will know the transit station and thus award the interchange a lower transfer penalty than less frequent passengers.
Ticket (entire journey on one ticket?)	• Integrating travel tickets into one ticket for the entire journey, including transfer, can be seen as a point of improvement. Also price-related information is seen as a possible improvement (Hine & Scott, 2000).
Customer orientation	• Customer service, basic staff training, helpfulness and reliability of policy mentioned as points of improvement (Hine & Scott, 2000). • Contact with the bus driver is really important for the quality of the service (Hutchinson, 2009).
Information (timetable, delay	• Provision of information named as important point and might include the availability of timetables and information about delays (Hine & Scott, 2000).
Safety (transit station unsafe)	Social safety at stations is difficult to evaluate but feeling unsafe can mean that certain groups (such as the elderly and women) do not dare to travel at certain times (if at all) (Balcombe et al., 2004).

Table 1 shows that many different factors can play a role with the different kinds of travel resistance. In order to identify the total resistance to interchange, we must first determine the degree to which these factors play a role and when. Factors which will

also be able to influence one another. The literature, for example, offers no insight into the relationship between the extent of transfer penalties and the duration of train journeys and the transfer type. The factors moreover depend on individual characteristics, such as age, gender and travel motive. To illustrate, British research has shown that senior citizens have greater trouble with cross-station transfers (Wardman & Hine, 2000).

What also stands out in the literature is that many studies were conducted in the 80s and 90s of the twentieth century. So the question is whether the importance of an interchange in the total travel resistance has not increased in the meantime. Under the influence of ICT (such as the use of mobile phones and wireless internet), the time spent on a train has become increasingly productive, whether for work or social networking.

This paper focuses on the functioning and degree of interchange resistance as influenced by timetable design. Factors such as social safety and acquaintance with (transit) stations have been disregarded here.

3. Choice of research method and set-up of the experiment

This study had a new empirical approach and used choice experiments in order to identify the different resistance factors pertaining to interchanges. The set-up of this study is described below.

The research focused on four factors (hereafter called attributes), which are important when changing trains:
1. Transfer time. The hypothesis is that both a very short and a very long transfer time are negatively appraised.
2. Train frequency of connecting train. This train frequency determines the possible extra waiting time when missing a connection. The hypothesis is that passengers with a lower train frequency experience a higher resistance to interchange.
3. Transfer type: (a) cross-platform (changing on same platform); (b) cross-station with escalator (one has to take escalator from platform a to platform b); or (c) cross-station without escalator (one has to take the stairs from platform a to platform b). The hypothesis is that passengers (particularly those with luggage) prefer a cross-platform transfer to a cross-station with escalator or a cross-station without escalator.
4. Number of transfers (0, 1 or 2). The hypothesis is that resistance to interchange undergoes a non-linear increase with the number of transfers, i.e. passengers find a second transfer more tiresome than the first.

Furthermore, we studied the influence of passenger characteristics (such as travel motive, travelling alone, travelling with luggage) and the passengers' estimation of the chance of making the connection.

Stated Choice experiment

A specific form of Stated Preference (SP) experiment was chosen to collect the data: Stated Choice (SC), a.k.a. conjoint analysis. This is a much-used method in traffic and transport research (see e.g. Hensher et al., 2005). As opposed to Revealed Preference (RP) research, in SC studies the contributions of the attributes to the final

choice can be clearly and easily separated. Furthermore, with SC it is possible to offer hypothetical choices and it is easier to simulate changes in several attributes. This means more information can be acquired on a larger range. Another advantage of SC is that the effects of the individual attributes can be evaluated separately, which in turn makes the analyses easier. However, by basing the choices on the passenger's most recent journey, and thus also on the estimations of its cost and travel time, the correlation between these two attributes indeed continues to exist. By letting the choice situations (SC) interconnect with the choice already made (RP), the hypothetical bias is minimized. This hypothetical bias implies that respondents might not actually make the same choice as they stated in the SC choice situations. The abovementioned pros and cons are named in various studies (Ben-Akiva, et al., 1994; Birol, Kontoleon, & Smale, 2006; Haider, 2002).

Set-up choice experiment
Ultimately, two SC choice experiments were set up for this study. The first described a journey with one interchange, whereby the focus was on the description of the transfer. The factors on which the respondent based his/her choice were travel time, transfer time and transfer type. The presented travel times ranged around the travel time of their most recent trip as stipulated by the respondents. In this experiment the respondent had to choose between two journeys with a transfer whereby the abovementioned factors differed in value.

Besides the four transfer factors, also the effective travel time (the total length of time between departure station and destination, including transfer time) and travel costs were included as attribute in the choice experiments. The effective travel time was included in order to translate the other attributes to extra travel time. Travel costs were included as 'validation' attribute to enable the calculation of a travel time assessment and a comparison with findings in the literature.
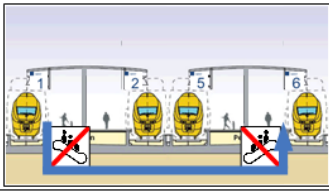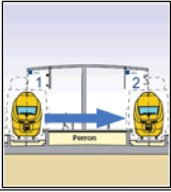

Figure 2: Example of a question in Experiment 1

The second experiment described a journey that could be made directly or include one or two transfers. In this experiment the focus was on the journey with a varied number of transfers. The factors on which the respondent based his/her choice were travel time, transfer time, costs, number of transfers and possible extra waiting time.

The respondent had to choose between three options. Two options were travelling with zero or one transfers, and the third option was a non-choice. This non-choice enabled respondents to indicate they were no longer travelling (by train). This non-choice was included to give the respondents a way out and thus not force them to choose between either of the two trips.

Option 1		Option 2		Option 3
Travel time from station to station	40 minutes	Travel time from station to station	48 minutes	I am no longer travelling (by train).
Of which travel time	6 minutes	Of which travel time	8 minutes	
Cost of single journey	€ 5.00	Cost of single journey	€ 4.50	
Number of transfers	2	Number of transfers	1	
Extra waiting time due to missed connection	15 minutes	Extra waiting time due to missed connection	10 minutes	
O		O		O
Which option do you choose?				

Figure 3: Example of a question in Experiment 2

Owing to the small number in the first experiment, several attributes can be considered across a broader range, which is the added value of this experiment. Furthermore, the two experiments are linked, allowing the coefficients to be estimated on the basis of more data. This yields a model with a broader range of the attributes and a more complete utility function.

On designing the experiments, orthogonality, dominant choices and the number of choice sets were taken into consideration. On designing the choice experiments, the aim was an orthogonal design, meaning that in the analysis the effects of the attributes can be seen separately from one another whereby the effect indeed originates from that one attribute and not from a combination of two or more. Finally, and taking the dominant choices into consideration, the choice experiments are (almost) completely orthogonal. A dominant choice is a one that scores higher on all attributes. In order not to overload respondents, each was presented with a limited albeit varied number of choices.

NS Customer Panel
The study was conducted via the internet among members of the NS Customer Panel (which consists of approximately 110,000 NS passengers).
In total, 4,700 panel members were approached by email. Ultimately, 795 questionnaires were filled in completely (a net response rate of 17%). Of these, 580 appeared suitable after several were excluded in order to have a reliable dataset. Exclusions comprised, inter alia, a minimum length of time for filling in the questionnaire and maximum deviations from estimated as opposed to actual travel times.

Preceding the choice experiments, respondents were asked after personal characteristics such as age and travel motive. Also specific characteristics of their last journey, such as luggage and duration of journey. In the final dataset the

proportions of the travel motive, age, education and travel frequency were disproportionate to reality. Generally speaking, the distribution in the sample is quite similar to the distribution in the NS population. However, this was not the case for the travel motive (underrepresentation of commuters), the travel frequency (underrepresentation of frequent passengers), age (underrepresentation of young people), and, to a lesser degree, the education of the respondents.

In this study the data were weighted according to the proportion of travel motives (commuter versus social-recreational) of the total NS population. This also corrects for many other characteristics that generally correlate with the travel motive.

4. Model estimates

In order to describe a passenger's choice process, this study made use of the Multinomial Logit Model. The reason for choosing this model was because it is often used in other studies of choice behaviour (Wardman & Hine, 2000; Wardman et al., 2001; Uenk, 2009; Tillema, 2009). In the event of a choice between several alternatives, the Multinomial Logit Model expresses the chance that an individual will opt for alternative 'i' as:

$$P_{iq} = \frac{\exp(V_{iq})}{\sum_{j=1}^{J} \exp(V_{jq})}$$

Here, Viq is the utility and is determined by the utility function. In previous studies, the linear form was chosen for the utility function (Wardman & Hine, 2000). Moreover it appears in practice that this can quite adequately determine choice behaviour. That is why this study also opted for a linear utility function. The utility function comprises attributes and coefficients.

$$V_{iq} = \gamma RT_{iq} + \alpha OT_{iq} + \ldots + \ldots$$

The coefficients (γ,α, etcetera) are estimated and the attributes are determined by resistance factors and individual and trip characteristics. These coefficients are estimated for different motives (commuter and social-recreational). The coefficient values in the models for the different motives result (after weighting) in a general model for all motives combined.

The model is basically expressed as a utility function. By including the travel time (in minutes) in the experiments, the disutility can be expressed in travel minutes.

5. Results

It appears from the model estimates that a transfer is an important resistance factor when determining one's choice of train travel. Below we will discuss the influence of interchange resistance on travel time, transfer time, frequency of connecting train, number of transfers and transfer type.

Travel time

In accordance with our hypothesis, the interchange resistance is dependent on the total travel time. With journeys shorter than 60 minutes, the resistance is approximately 50% higher than with journeys longer than 120 minutes. This is independent of the absolute resistance which increases linearly with travel time when relative resistance remains the same.. Furthermore, commuters react more strongly, i.e. with short trips they experience more and with longer trips less disutility than social-recreational passengers do.
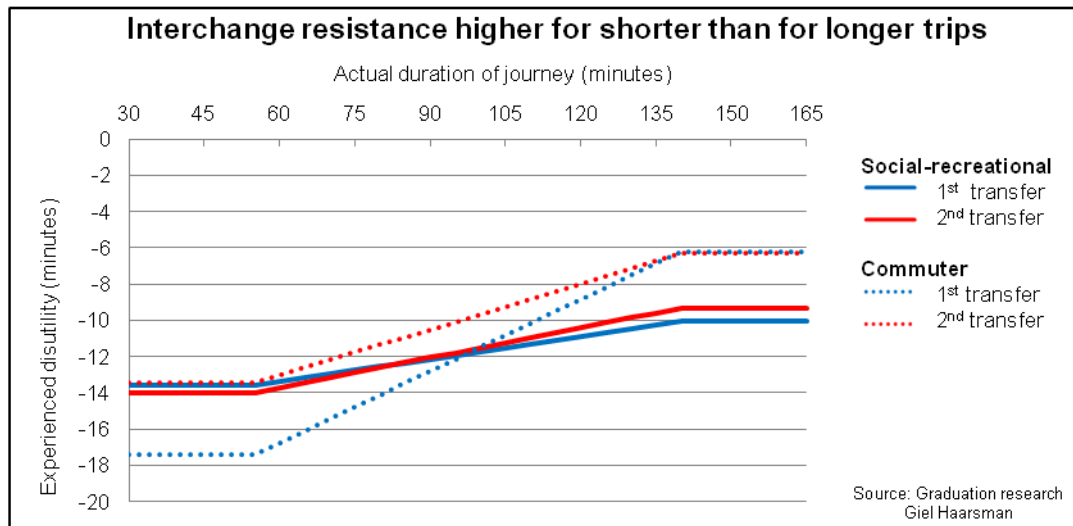

Interchange resistance higher for shorter than for longer trips

Figure 4: Interchange resistance vis-à-vis travel duration

Transfer time

An extremely short and extremely long transfer time is negatively appraised. This confirms the a priori expectations. Social-recreational passengers prefer to avoid short transfers and commuters experience particularly the longer transfer times as more negative.

An important finding of the model estimates is that there would seem to be an 'ideal' transfer time of 4 minutes (see figure 5). Short transfers are particularly negatively appraised by social-recreational passengers. An obvious reason for this is that a short transfer induces stress. Stress that can originate from either having to hurry or possibly from missing a connection. In the literature, there were no significant findings on short transfer times, although there were suspicions which this study has now corroborated. The disutility of a short transfer time for cross-platform connections is lower than for cross-station.

A *transfer* time longer than 4 minutes becomes *waiting* time and causes all types of passengers to feel increased resistance. This is less so for those with a large amount of luggage as opposed to those with none.
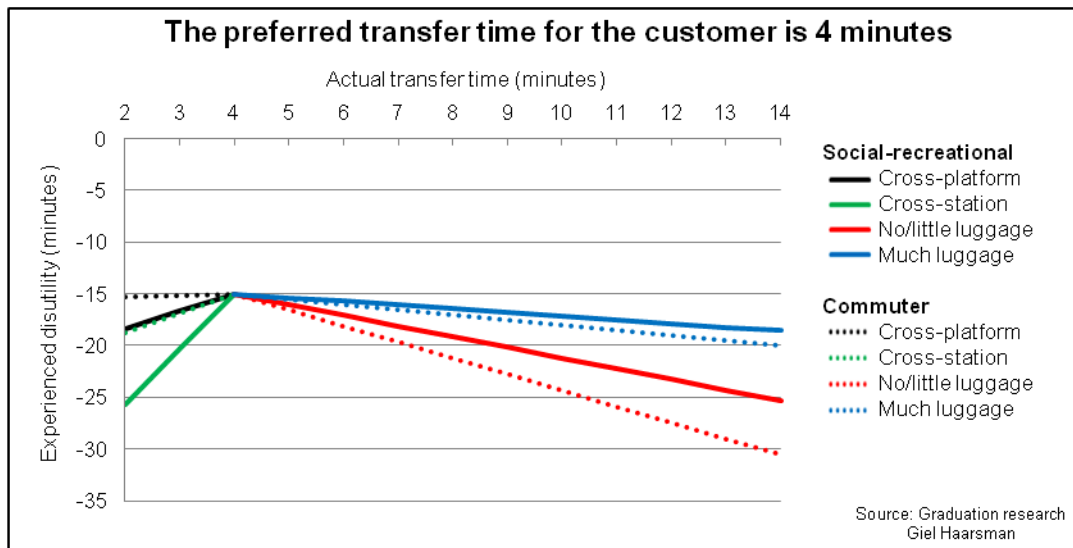
Figure 5: Actual transfer time vis-à-vis experienced transfer time

Possible extra waiting time

Despite train companies endeavouring to realize (train-to-train) connections as often as possible, there are no guarantees. The passenger assimilates this uncertainty in his/her appraisal. Our a priori expectation was that with a lower frequency of a connecting train, passengers would experience a greater interchange resistance. This suspicion was confirmed in the study's appraisal of possible extra waiting time.

- With one transfer of a train sequence with a *high* frequency to a train sequence with a *low* frequency, the interchange resistance will be higher than vice versa.
- *Example:* When the frequency of the connecting train is reduced from 6 to 2 x per hour, the interchange resistance increases by 14 minutes.

One or two transfers

With two transfers passengers experience a greater interchange resistance than with one. Although we also expected the second transfer to be experienced as more negative, our study did not demonstrate this. The second transfer can be modelled in the same way as the first. With two identical transfers this means that the interchange resistance is experienced twice as heavily as the resistance with the same journey with one transfer.
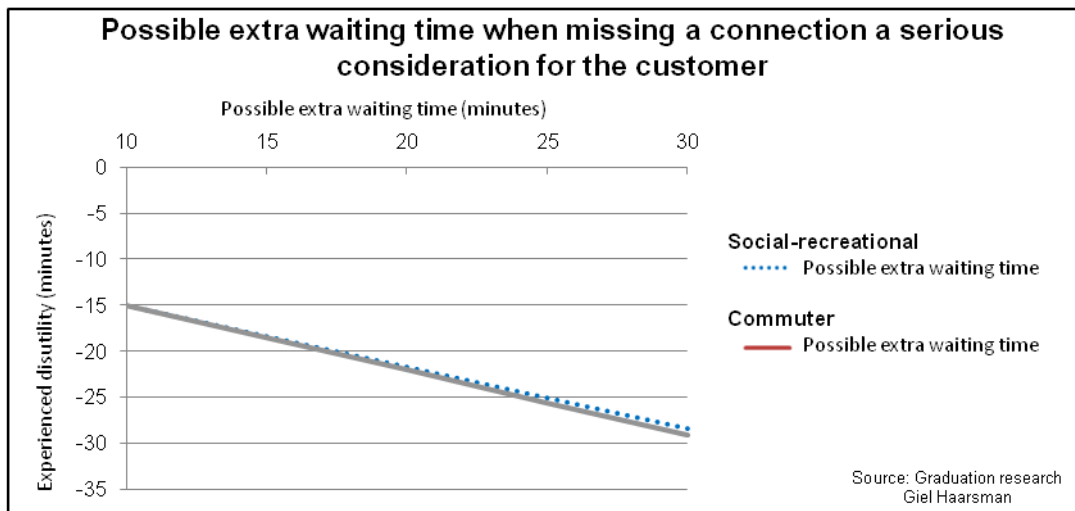
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Figure 6: Possible extra waiting time vis-à-vis experienced travel time penalty

Transfer type

As expected, the transfer type shows that passengers prefer a cross-platform transfer the most and then a cross-station transfer with escalator. Social-recreational customers attach more value to a cross-platform transfer than commuters. The difference is slightly bigger for passengers with much luggage than for those with little to none. The findings showed no significant differences between with or without escalators.
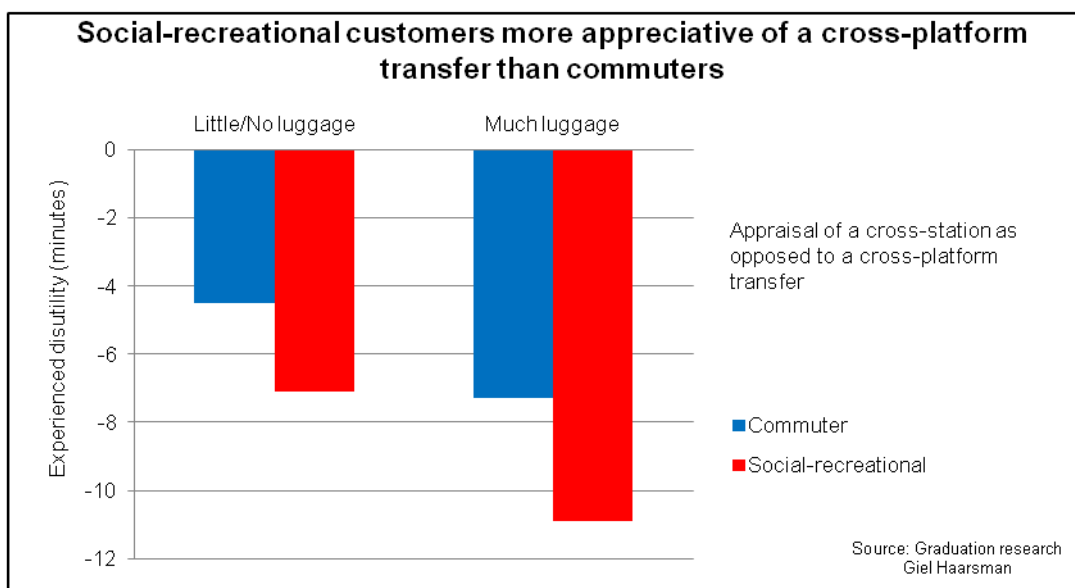

Figure 7: Experienced extra transfer resistance (in minutes) with luggage

Formerly direct

Passengers that currently have a direct connection are not at all pleased when the through train is withdrawn and replaced with a train journey that includes a transfer. Long distance passengers (>80 minutes' travel time), who can currently still travel direct, but who soon will not be able to, experience a greater transfer resistance than customers who now also have to change trains with an identical travel duration. With one transfer the resistance to this increases with circa 13 minutes extra.

6. Impact for NS

The findings show a much greater transfer resistance than NS accounted for in its prognosis models. In the Netherlands, an average journey plus transfer lasts 60 minutes, 10 of which is transfer time. An interchange is furthermore characterized by a cross-station transfer and a possible extra waiting time of 17 minutes. Prognoses currently allow for a transfer penalty of 10 experienced travel minutes (ETM), whereas for an average journey plus transfer this study has calculated a penalty of 25 ETM.
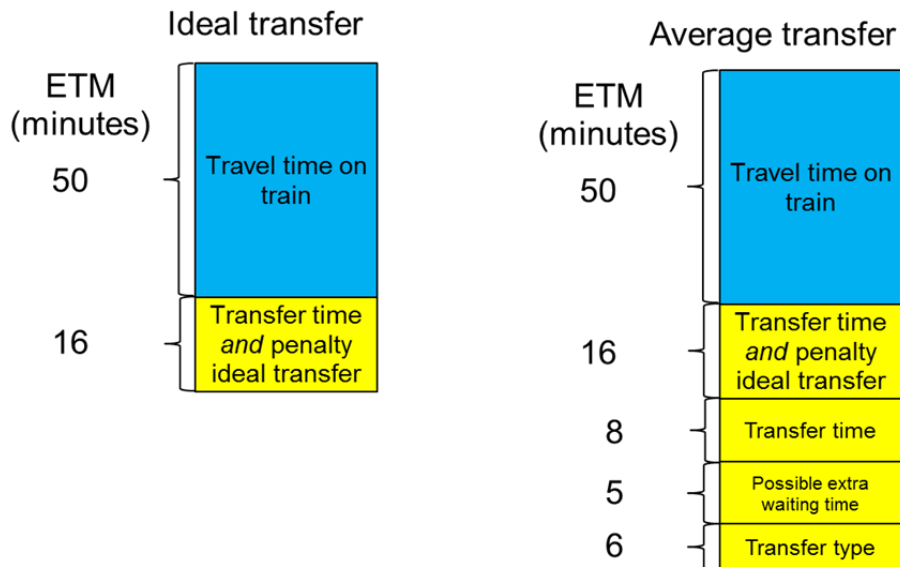
Figure 8: Build-up Transfer Penalty with ideal and average transfer

Even in the most ideal situation of a cross-platform connection with 4 minutes' transfer time and a frequency of 6 x per hour of the connecting train, the 12-minute penalty is still higher than was originally assumed.

In order to substantiate the findings of this research, the development of the number of trips over the years was addressed for several travel relations. A number of ODs were picked out that used to be with one transfer but are now direct, and a number whereby the direct connection has been replaced by one with a transfer. The analysis shows that the new, direct connections show considerably higher growth figures than could be expected on the basis of the old prognosis methods. Various new connections with Schiphol Airport, for example, show a growth rate of over 40% in a two-year period.

For NS this calls for adapting the prognosis models and changing the policy. More focus is needed on offering direct connections and the concentration of transfers where cross-platform is possible.

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