Value of crowding in front of vertical infrastructure

Towards a cost-benefit analysis framework of crowd management measures at railway stations

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Preface

This thesis discusses the evaluation of crowding management measures at railway stations. It explores the evaluation aspects and their importance in cost-benefits analysis and how crowding in front of station vertical infrastructure is measured in monetary terms. This thesis is the final project of the master program Transport, Infrastructure & Logistics at Delft University of Technology. It is also a 8 month practical work placement in Royal Haskoning DHV.

I want to thank Prof. Serge Hoogendoorn and Eelco Thiellier for offering this opportunity in the beginning. I’m grateful to Winnie Daamen for her critical comments and weekly supervision. She teaches me to think independently and critically. I also want to thank Rik Schakenbos, John Baggen and Jeroen van den heuvel for their support and feedbacks. Finally, I am very grateful for those who fill in my survey. Your feedbacks give me insights into the stated preference experiment. This thesis would not have been completed without your help!

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Summary

Transfer is critical for a public transport trip. Previous studies show that the disutility of transfer time is the highest considered by passengers among the segments of travel time. Implementing crowd management measures at large railway stations is complex because multiple stakeholders with different interests are involved. Crowd management measures aim at improving transfer process in advance. The problem owner, the government, needs to balance the interests and let all stakeholders agree on same crowding management measures. Therefore, a decision support framework is required. According to literature, the government prefers cost-benefit analysis (CBA) to decide which measure is most cost-efficient for the whole society. However, the evaluation framework of crowding management measures by using cost-benefit analysis is not well studied, especially in the evaluation aspects and the ways to measure the aspects in monetary terms. In this thesis, the important evaluation aspects are identified and the monetary value of crowding in front of station vertical infrastructure (stairs or escalators) is selected to be investigated. Crowding in front of station vertical infrastructure is chosen for monetizing study because it is an important unknown aspect. The literature also indicates that it is feasible to measure crowding in monetary terms. As a result, the general objectives of this thesis are to

Identify important evaluation aspects of crowd management measures at railway stations.

Determine the monetary values which can measure crowding benefits and costs

The first part of this thesis meets the first objective. Stakeholder analysis of station transfer process is performed. The aim of stakeholder analysis is to derive potential evaluation aspects in a checklist. The government can uses that checklist to balance the conflicts among stakeholders by finding their common interests and considers its own budget as well. Seven stakeholders are identified. They are rail infrastructure operator, station operator, passenger, train operator, metro & tram & bus operator, municipalities, and the government. Each stakeholder’s interest can be considered as an evaluation aspect for the government. After an analysis of their interests, it is found that conflicts of interests exist, even within a same company. However several common interests are shared by many stakeholders, such as safety, security. A real case is given to show how conflicts can be managed by finding common interests. The thesis also discusses the importance of stakeholders. The government, rail infrastructure operator, station operator, municipalities, and passenger are considered more important than train and other public transport operators with respect to transfer process. The importance of aspects to the government depends on the importance of their related stakeholders.

Literature is reviewed to know importance of aspects to the related stakeholders. Based on the importance of stakeholders and their priorities, the importance of evaluation aspects can be determined. After a selection of aspects according to the importance and definition, 11 aspects and their importance are determined in an evaluation checklist in Table 1.
<table>
<thead>
<tr>
<th>Aspect</th>
<th>Passenger</th>
<th>Station operator</th>
<th>Rail infrastructure operator</th>
<th>Local municipalities</th>
<th>Train, Metro, Tram and Bus operators</th>
<th>The government</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1. Safety in normal pedestrian flow</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>A2. Safety under emergency</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>A3. Security</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>A4. Transfer time</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>A5. Reliability</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>A6. Comfort</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>A7. Way-finding</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>A8. Easy management (maintenance costs)</td>
<td></td>
<td>1</td>
<td>2</td>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>A9. Retail</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>A10. Accessibility for area around station</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>A11. Investment costs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

Very important (1)  Medium important (2)  Not important (3)  Not related (blank)

Literature is also reviewed about whether they have suitable indicator for cost-benefit analysis and methods to translate that indicator into money. 4 evaluation aspects are not yet able to be quantified by monetary terms. Safety under normal condition and way-finding are the two aspects that cannot be quantified by an indicator for ex-ante evaluation. Security and comfort lack a value to convert the unit into money.

Comfort in terms of crowding at stations is selected for monetizing study because it is an important unknown aspect for CBA. Moreover, it already has a suitable indicator for CBA and the existing studies of crowding in vehicles indicate its possibilities to be monetized. The approach to determine the monetary value of crowding can also be viewed as an example to measure security and other aspects of comfort in cost-benefit analysis.

The second part of this thesis determines the values of crowding by conducting a stated preference experiment. Stated preference experiment is chosen because flexible variation in attribute levels is required for knowing the values of crowding and it is possible in stated preference experiment. Stated preference experiment can also avoid the mix influence of several attributes by excluding unnecessary attributes in a hypothetical alternative.

The experiment consists of four components: survey design, data collection, model estimation, and results interpretations. Survey design includes: choice situation, attributes and their levels, utility function, experiment design, a pilot and the format of survey. The choice situation is designed so that it allows respondents to make a trade-off between walking time and crowding conditions on the route choice level. From the trade-off, the disutility of crowding is converted to a generalized walking time and it can be further
transformed to the monetary value of crowding via the value of walking time in literature. In order to and make people feel a significant difference between two levels, only four levels of crowding are distinguished based on whether overtaking can happen and the length of queue. They are \(0.5p/m^2\) (easy overtaking) of a 2.5meter length region, \(1p/m^2\) of a 2.5meter length region (overtaking difficult but possible), \(1.5p/m^2\) with 2.5meter queue (impossible to overtake and a small queue), \(1.5p/m^2\) with 5meter queue (impossible to overtake and a large queue). Because it is believed that crowding perception is not linear over all range of crowding conditions, the values of crowding in this thesis are based on these four discrete crowding levels. An exponential function or different linear relations for different segments of crowding condition performs better than the discrete levels. However, these functions would require more advanced estimation tool and data which is limited in this research. Three levels of extra walking time are determined based on a pilot survey: 1, 2 and 3 minutes. Efficient experiment is designed in software Ngene.

In total 222 respondents are recruited through internet. 11 of them are excluded from the sample data because they made inconsistent choices in their responses. Finally, the distribution of respondents’ social-demographic characteristics is analysed. The populations of non-work, infrequent traveller, young people and male are overestimated. This helps to explain whether the sample creates a selection bias after understanding which characteristics have impacts on the values of crowding.

After that, a generic MNL model is estimated and the values of crowding are determined as shown in Figure 1. From the results, crowding disutility increases sharply from crowding level 1 to crowding level 2 and there is a bigger jump from crowding level 2 to level 3. It can be concluded that queue has large impacts on crowding perceptions. What is more, specific models with a distinction of social-demographic characteristics are also estimated. It is found that individuals with work and business motives are more reluctant to spend time to avoid crowding than other motives. Frequent travellers have lower value of crowding compared to infrequent ones. Age and gender do not have significant impacts on the values of crowding according to the analysis.

Finally the applications of findings and results in the experiment are discussed. Values of crowding are successfully applied in cost-benefit analysis as one aspect of evaluation. The
results can also be used on the crowding aspect evaluation in multi-criteria analysis. Companies such as NPC can also benefit from the results of the stated preference experiment. For example, the fact that queue size has strong impacts on passengers crowding perceptions suggests larger size of study region in bottleneck analysis. For station operators such as NS Station, realizing that passengers are willing to spend significant amount of time to avoid crowding can help it take actions to improve its operation. Signs can be used to indicate the alternative route to leave the station or make the alternative route visible. For train operators, understanding the importance of crowding at stations to passengers can make them change their train operation to improve customer satisfaction, such as changing the timetable or the stop location of trains.

Several issues regarding to the validity of the results are discussed. First of all, people may have different choice behaviour when they are asked on the paper than the real situation. For example, the disutility of the walking time might be underestimated because no walking effort is made when they make route choice virtually. This could lead to an overestimation of the values of crowding. Secondly, to reduce the complexity of choice situation, not all attributes which influence route choice are described. Noise among the sample data would occur when respondents interpret un-described attributes differently. Thirdly, although extra waiting time is excluded from disutility of crowding in the survey, people who do not read the text carefully would still think that the less crowded route leads to lower transfer time.

In the future, the method to quantify safety can be discussed because it is a very important aspect in transfer. Moreover, the results of cost-benefit analysis can be incorporated into multi-criteria analysis so that the problems of CBA, such as inability to measure qualitative aspects and equity problems, can be solved. The results of passenger crowding perceptions in this research are purely based on stated preference data. In the future, revealed preference experiment can be performed to validate the results.
1 Introduction

This chapter presents the background and the reason of this thesis study. It defines the research scope and questions. Finally, the adopted research approaches and thesis structure are discussed in this chapter.

1.1 Problem analysis

Transfers are essential in public transport systems. Passengers usually need to transfer between different modes in order to reach their destinations, especially in large multimodal networks. It was found that 70% of underground trips in London involve at least one transfer (Transport for London, 2001). Whether there is a smooth transfer connection between different modes of transport highly affects the mode choice of a traveller. Van Hagen (2011) found out that the time spent on the transfer link has the lowest value for train passengers, which means transfer time is perceived longer than other travel time. For public transport operators and infrastructure operators, a good transfer process contributes to a high ridership and an efficient use of infrastructures respectively. For retail shops at stations a good transfer process means high revenues. Therefore, transfer is a critical link for multiple parties.

Despite the importance of the transfer process, it appears to be overlooked during station design and operation. There are two reasons to explain this indifference. Firstly, the quality of the public transport service is the main focus of the operators because it is more intuitively connected to the ridership (Iseki & Taylor, 2009). As a result, public transport operators focus on their own service but not transfer, especially for the transfer between modes. Secondly, organizational difficulties in practice pose a huge barrier for changing the infrastructure in transfer process. A complex structure of stakeholders exists in station area and sometimes multiple stakeholders are responsible for a single facility (Verhoeff, 2014).

Crowd management measure aims at prevent pedestrian congestion from happening. Those measures can be part of stations redesign or station operational improvement. Examples of the crowd management measures are changes in the locations of ticket gates, the width of the stairs, and the stop locations of the trains. Before undertaking a transfer improvement project, the government who invests in the stations would like to know which measure can most cost-efficiently improve the overall transfer function of the station.

To know the effects of crowd management measures, changes in station performance after implementation should be known. Therefore, it is necessary to understand what transfer performance includes. However, few scientific studies have conducted transfer evaluation on a full station scale and the evaluation aspects are limited. Transfer time is the most popular aspect for transfer evaluation (Van den Heuvel & Hoogenraad, 2014) (Hoogendoorn & Daamen, 2004). Transfer time reliability is also an important aspect to consider when assessing the pedestrian function of a station (Van Oort, 2011) (Li, Hensher, & Rose, 2010). There are also other aspects to consider in terms of passenger perception of the transfer process. Because a station area is a complex environment with many stakeholders involved, passenger needs in the transfer process, such as less transfer time, are often constrained by the interests of other stakeholders (for example the investment/maintenance costs from station operators’ side). As a result, when the government wants to invest a station, it is good to think from a multiple stakeholders’ perspective because different stakeholders are involved at railway stations and all stakeholders should agree on the same measures to
implement. An evaluation framework is desired to translate the performance in all aspects to a recommendation to the decision maker.

Social cost benefit analysis is an important evaluation approach that can be used to support policy making (Brinke & Faber, 2011). It lists the benefits and costs of a certain investment for society as a whole. In order to be objective, all benefits and costs are converted into monetary terms. The analysis result then shows whether the potential project/alternative leads to a higher increase in social welfare which considers the overall public interest. This thesis mainly discusses the evaluation through cost-benefit analysis because such method is objective and the government has been putting greater emphasis on using cost-benefit analysis for transport terminal capital investment (Landau, Weisbrod, Gosling, Williges, Pumphrey, & Fowler, 2015) (Eijgenraam, Koopmans, Tang, & Verster, 2000) (Brinke & Faber, 2011).

However it is not easy to evaluate crowd management measures on a full station scale through cost-benefit analysis. Although there are studies about value of travel time and reliability (Significance & VU University Amsterdam, 2012), many qualitative aspects in transfer process are hard to be transferred to money or even quantified. Crowding at railway station is one of the qualitative aspects. The most severe crowding usually occurs in front of vertical infrastructure at Dutch railway stations (this will be explained further in Chapter 4). However, during the evaluation of a transfer project, the monetary benefits of a decrease in crowding condition in front of vertical infrastructure are unknown.

Not all stations are within the study scope of this research. As shown in Table 2, 6 types of stations in the Netherlands are classified. This thesis only explores existing railway stations for type 1 and 2 in the Netherlands because transfer problem usually occurs at big stations.

<table>
<thead>
<tr>
<th>Station type</th>
<th>Description</th>
<th>Number of stations in the Netherlands</th>
<th>Number of stations operated by NS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Very large station in the center of a big city</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>Large station in medium-sized city</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>3</td>
<td>Suburban station with hub function</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>4</td>
<td>Station at center of small city/town</td>
<td>147</td>
<td>95</td>
</tr>
<tr>
<td>5</td>
<td>Suburban station without hub function</td>
<td>108</td>
<td>85</td>
</tr>
<tr>
<td>6</td>
<td>Station in outer area of small city/town</td>
<td>95</td>
<td>51</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>397</td>
<td>278</td>
</tr>
</tbody>
</table>

A study done by Givoni & Rietveld (2007) shows that in the Netherlands both the quality of the station and access/egress facilities to/from railway station have important effects on the general perception of rail travel and therefore on railway ridership. As a result, the access and egress journeys to/from the railway are also considered as part of transfers at stations.
The whole process of train trips in the Netherlands is shown in Figure 2. In the figure, possible access and egress modes are listed in black texts and the corresponding facilities are identified in blue circles. The transfer process which is interested in this thesis is in red.

Figure 2 Train trips in the Netherlands

1.2 Problem statements

Although multiple stakeholders are involved in the transfer process at stations (stakeholders will be further analysed in the Chapter 2), the problem owners of this study is the government. The government represents passengers’ interests theoretically, but it also needs to balance the interests of other stakeholders at railway stations so that an agreement on transfer intervention can be reached. Because the government needs to allocate its limited public funds wisely, it is important to choose the most cost-efficient crowd management measure to implement. A decision support framework is therefore required to provide a recommendation to the decision maker. However, the first step of building such a decision support framework is to have a checklist which specifies all the important aspects that need to be considered. As a result, the first general problem statement of this thesis is summarized as below:

A decision support checklist is needed to identify all important evaluation aspects the government needs to consider when approving a transfer project

Because cost-benefit analysis is chosen as the approach for evaluation, the methods to monetize important aspects identified in the checklist should be known. With those methods, decision maker can calculate total monetary net value and draw a conclusion based on it. This thesis chooses to focus on measuring one of the qualitative aspects (comfort in terms of crowding) in monetary terms because it is an important and unknown aspect. Therefore, the second problem is stated below:

There is no existing method of monetizing crowding benefits/costs in the evaluation of a railway station transfer project
1.3 Objectives
In general, there is no cost-benefit analysis framework to support the government in deciding which crowd management measures to implement at railway stations. To build such a framework, it is necessary to first identify all the evaluation aspects and then measure the benefits and costs of those aspects in money.

As a result, the general objectives of this thesis are to

Identify important evaluation aspects of crowd management measures at railway stations.
Determine the monetary values which can measure crowding benefits and costs

1.4 Research questions
Following the problem statement and objective, the first main research question is formulated as:

Which aspects are important when evaluating the crowd management measures through cost-benefit analysis?

In order to answer the first main research question, several sub-research questions need to be answered. Firstly, stakeholders need to be analysed because the transfer performance of a station is concerned by multiply stakeholders. A stakeholder analysis can help to understand which evaluation aspects are concerned by which stakeholders. After that, all possible evaluation aspects are identified. And the first sub-question is formulated:

(1) Which evaluation aspects can be considered during an evaluation from a multiple stakeholders’ perspective?

Literature shall be reviewed to know the importance of the evaluation aspects to each stakeholder. Combined with the importance of stakeholders, the importance of transfer aspects can be determined. After that, the feasibility of the aspects in terms of cost-benefit analysis is reviewed based on two criteria: a suitable indicator and a method to convert indicator into monetary unit. Finally the reason for choosing crowding aspect for monetization analysis can be explained and scope of crowding aspect is defined.

Therefore, following research questions are listed:

(2) What is the importance of transfer aspects according to literature?

(3) What is the feasibility of transfer aspects to be measured in money according to literature?

To monetize the crowding aspect in the evaluation of a railway transfer project, the second main research question needs to be answered:

How to evaluate crowding in front of station vertical infrastructure in cost-benefit analysis?

The first step to answer it is to determine and design the approach to collecting passenger value of crowding. Therefore, the eighth sub-research question is formulated.

(4) Which methodology should be used to determine the value of crowding in front of station vertical infrastructure?
After conducting the experiment based on the determined methodology, behaviour models are estimated. The results of model estimation need to be interpreted. The sub-research questions should be answered:

(5) How to interpret the resulted values of crowding?

Finally, how various stakeholders related to passenger crowding can use the results are discussed:

(6) How can the values of crowding be applied in transfer evaluation and practice?

1.5 Societal and scientific contribution
There are also two parts of the contribution of this thesis: societal and scientific

1.5.1 Societal contribution
For the government in general, using this checklist could lead to better policy decisions. To be more specific, this checklist identifies all the important aspects and their importance. This is helpful for the government to balance the different interests among stakeholders and get agreement on transfer interventions. Other stakeholders can realize how their actions influence others by using this checklist.

The values of crowding found in the second part of this research shows crowding at station is of great importance for passengers. This implies that station operators should take actions to encourage people to avoid crowding for a better transfer. For train operators, the findings are also important because they want to offer passenger a high quality trip overall.

1.5.2 Scientific contribution
The developed method for measuring crowding in front of station vertical infrastructure can be viewed as a reference approach for measuring other qualitative aspects in transfer process. This step is critical because the major obstacle of cost-benefits analysis is to measure qualitative benefits/costs by money. By using this approach, most important aspects for transfer evaluation can be integrated into the cost-benefit evaluation. Moreover, the findings in the use of the approach to determining the monetary values of crowding are also useful for future research.

1.6 Research approaches
In this thesis, stakeholder analysis, literature study, checklist study, and stated preference study are used to achieve the research objective.

To answer the first main research question as below, stakeholder analysis is employed to know the evaluation aspects and the literature review is used to determine the importance.

Which aspects are important when evaluating the crowd management measures through cost-benefit analysis?

- Stakeholder analysis

In order to know what evaluation aspects are important, a stakeholder analysis is performed. The outcomes of the analysis are the interests of stakeholders and their importance. The importance of aspects can then be derived from the importance of related stakeholders.

- Literature review
Because it is not the first study about station transfer evaluation, literature is reviewed to know current evaluation aspects and the possibilities to measure those aspects in money. After literature review, the characteristics of aspects with respect to the cost-benefit analysis can be determined, which means whether the potential benefits/costs of an aspect can be quantified by an objective indicator and whether the unit of the indicator can be converted into money are known.

To answer the second main research question as below, a stated preference experiment is carried out.

**How to evaluate crowding in front of station vertical infrastructure in cost-benefit analysis?**

- Stated preference experiment

In order to evaluate crowding benefits/costs by the cost-benefit tool, monetary value of crowding should be determined. There are two methods to collect the data of travel behaviour: stated preference experiment and revealed preference experiment. Because stated preference experiment is flexible for controlling attributes and their levels, it is suitable for measuring the value of crowding. The experiment consists of four steps: survey design, data collection, model estimation, and results interpretation.

### 1.7 Research Structure

After the introduction of the main research approaches, the structure of this thesis is visualized in Figure 3. As shown in the figure, chapter 1 states the problems need to be solved, research objectives and questions of this thesis. In chapter 2, a stakeholder analysis is performed to know what transfer aspects should be evaluated from a multiple stakeholders’ point of view. The importance of transfer evaluation aspects, evaluation indicators and ways to translate indicator units into money are reviewed in chapter 3. An evaluation checklist which includes aspects and their importance is developed.

A stated preference experiment which aims at determining the monetary value of crowding for cost-benefit analysis is performed and analysed in chapter 4 and 5. Firstly, the scope of crowding aspect is defined so that it will not overlap with other aspects. Based on the definition, a survey is designed and performed to collect passengers’ value of crowding. It is done by asking people to make tradeoff between crowding and walking time. Multiplying the existing value of walking time, the monetary values of crowding for cost-benefit analysis are known. Finally possible applications of the experiment results are shown in chapter 7 and conclusions and recommendations for future study are discussed in chapter 8.
Figure 3 Research structure
2 Stakeholder analysis of the transfer process

A station, especially a multi-modal station, is a complex and collaborative public service environment with multiple stakeholders involved. Various stakeholders have different interests regarding to the transfer. In order to let all stakeholders agree on certain transfer interventions, their interests should be analysed. To know the interests of stakeholders, important stakeholders should be first identified. It is followed by the analysis of their interest. From the interests of stakeholders, the possible evaluation aspects are known. The stakeholder analysis is also useful for managing the stakeholders in practice. A real case of crowd management with multiple stakeholders involved is introduced.

The second part of this chapter is to analyse the importance of the stakeholders. This is useful to know the importance of their related aspects.

The first sub-research question listed below is answered in this chapter.

(1) What evaluation aspects can be considered during an evaluation from a multiple stakeholders’ perspective?

2.1 Stakeholder identification

A station has several functions as a public infrastructure and for each the involved stakeholders are different. Therefore it is necessary to clarify what functions a railway station has and then determine which one is within the scope of this study. Juchelka (2002) concludes that a railway station has three general functions. The primary function is to connect multiple transport modes from only transport point of view. Secondly, a station performs as a commercial, leisure and cultural place where people can shop and meet. The last function represents the synergistic effects of a station to its surrounding area. For example, the station can perform like a city centre. In this study, only the transport function that covers the transfer process within a station will be investigated. This transfer process includes not only transfers between trains but also between other modes and trains. Therefore, the geographic scope of this study is all the identified space of a railway station in Figure 4.
Five stakeholder functions which are related with pedestrian function have been classified. They are platform infrastructure operator, station operator, commercial service provider, passengers, train operator and other public transport operators. The specific stakeholders in the Netherlands are also listed in Table 3. In the Netherlands, the station facilities are operated by two companies, ProRail and NS Stations. ProRail functions as an operator of rail infrastructure. It is also responsible for the non-commercial space at the stations. ProRail (re)builds the stations and provides operation and maintenance of platforms, tunnels, platform bridges, stairs, escalators, lifts as well as the route information within stations (ProRail, 2015). Another station operator, NS Station, not only operates the station halls in the Netherlands but also owns the land near stations and develops and operates these areas (NS, 2015). One branch of NS Stations, NS Stations Retailbedrijf, is responsible for all the commercial real estates in the station hall and on the platform. As for transfer passengers, a station provides them a transition point between trains and other modes. Three groups of transfer passengers are classified according to their different access and egress modes. Through passengers and local citizens who only want to shop at stations are excluded here. The three groups of transfer passengers within the study scope are shown in Figure 5:

1. Transfer passengers between trains
2. Transfer passengers between metro, tram, bus and trains
3. Transfer passengers between walking, biking, car and trains
Train operator (NS Reizigers) and metro, tram & bus operators (GVB for instance) are also interested in passenger transfer process. Finally, local municipalities who own some public facilities around the station, for instance the bus platforms, have almost daily contact with station area and rail infrastructure operators on mobility related projects. These projects could be Park&Ride facilities, bike racks and so on (Bruin, 2013). Table 3 concludes all the stakeholders identified in this research.

Table 3 Stakeholder identification

<table>
<thead>
<tr>
<th>Stakeholder functions</th>
<th>Specific Stakeholders in the Netherlands</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rail infrastructure operator (tracks, platforms, vertical infrastructure, tunnels etc.)</td>
<td>ProRail</td>
</tr>
<tr>
<td>Station operators (station hall, real estate and land)</td>
<td>NS Station, ProRail</td>
</tr>
<tr>
<td>Transfer passengers</td>
<td>All passengers at the station whose origins or destinations are trains</td>
</tr>
<tr>
<td>Train operator</td>
<td>NS Reizigers*</td>
</tr>
<tr>
<td>Metro, Tram &amp; Bus operator</td>
<td>Urban and regional public service operators</td>
</tr>
<tr>
<td>Municipalities</td>
<td>Local municipalities</td>
</tr>
<tr>
<td>The government</td>
<td>Ministry of Transport or Provincial governments</td>
</tr>
</tbody>
</table>

*Other train operators are not considered because only major big railway stations in the Netherlands are considered

2.2 Stakeholders’ interests

The interests of all key stakeholders are summarized based on literature and expert opinions. They are shown in Table 4, and it is followed by the explanations of the interests.
<table>
<thead>
<tr>
<th>Stakeholder functions</th>
<th>Interests</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rail infrastructure operator</strong></td>
<td>Ensure safety and security of infrastructure</td>
</tr>
<tr>
<td></td>
<td>Efficient use of infrastructure, no congestion on its infrastructure</td>
</tr>
<tr>
<td></td>
<td>Easy management of infrastructure</td>
</tr>
<tr>
<td></td>
<td>Low investment &amp; maintenance costs</td>
</tr>
<tr>
<td></td>
<td>Provide a high quality of transfer service for passenger</td>
</tr>
<tr>
<td><strong>Station operator</strong></td>
<td>Ensure safety and security of infrastructure</td>
</tr>
<tr>
<td></td>
<td>Efficient use of infrastructure, no congestion on its infrastructure</td>
</tr>
<tr>
<td></td>
<td>Easy management of infrastructure</td>
</tr>
<tr>
<td></td>
<td>Low investment &amp; maintenance costs, Higher revenues</td>
</tr>
<tr>
<td></td>
<td>Provide a high quality of transfer service for passenger</td>
</tr>
<tr>
<td></td>
<td>Earn more revenues through : Enough waiting time of passengers, More space</td>
</tr>
<tr>
<td></td>
<td>for advertisement at station and Location with high passenger flow</td>
</tr>
<tr>
<td><strong>Passengers</strong></td>
<td>A safe and secure transfer</td>
</tr>
<tr>
<td></td>
<td>High reliability of transfer walking time</td>
</tr>
<tr>
<td></td>
<td>Low transfer walking time</td>
</tr>
<tr>
<td></td>
<td>Shorter walking distance</td>
</tr>
<tr>
<td></td>
<td>Difficulty of transfer walking (level of changes, number of conflict points)</td>
</tr>
<tr>
<td></td>
<td>Good transfer information provision</td>
</tr>
<tr>
<td></td>
<td>Comfortable physical waiting environment</td>
</tr>
<tr>
<td></td>
<td>Better transfer experience with more light, smell and music</td>
</tr>
<tr>
<td><strong>Train operator</strong></td>
<td>A safe, fast &amp; comfort transfer corridor for a higher ridership</td>
</tr>
<tr>
<td></td>
<td>Ensure punctuality of operation</td>
</tr>
<tr>
<td><strong>Metro, Tram &amp; Bus operators</strong></td>
<td>A safe, fast &amp; comfort transfer corridor for a higher ridership</td>
</tr>
<tr>
<td></td>
<td>Ensure punctuality of operation</td>
</tr>
<tr>
<td><strong>Local municipalities</strong></td>
<td>High accessibility for residents nearby</td>
</tr>
<tr>
<td></td>
<td>A good inter-district connection</td>
</tr>
<tr>
<td><strong>The government</strong></td>
<td>Improve the overall social benefits and reduce costs</td>
</tr>
</tbody>
</table>
2.2.1 Rail infrastructure operator
Generally, the rail infrastructure operator has three objectives which are related to the transfer process:

a) High operational performance of its infrastructure
b) Low costs
c) Satisfy passenger needs during transfer

Within all the operational aspects, the safety of transfer process is perceived as the most important one by the infrastructure operator of the station according to (van den Heuvel, 2015). Moreover, it is interesting for infrastructure operator to keep the operation performance of its infrastructure at a higher level in a way that is easy to manage. Secondly, rail infrastructure operator would prevent itself from unnecessary investment cost of infrastructure. Finally, it is necessary for the operator to satisfy passengers’ needs because station is a public facility and everybody who pays the tax indirectly owns the station. Those needs include higher total capacity to accommodate growth in passenger number, removal of bottlenecks and so on.

2.2.2 Station operator
In the Netherlands, the facilities and retails in the station hall and surrounding area are all possessed by NS Stations. Besides the similar interests it has with the infrastructure operator, the station operator would like to grow revenues by using station spaces for retail.

2.2.3 Passengers
Van Hagen (2011) ranked five different passenger needs according to their importance in the shape of a pyramid. They are safety & reliability, speed, ease, comfort, and experience, from bottom to top. The ranking of needs reflects the perception of the quality offered by train service operator, which means passengers’ first need for travelling is a safe and reliable trip. Passengers would never take a trip which is unsafe. Safety, which is perceived more subjective, becomes especially important if any accident happened before. With respect to transfer within a station, walking time reliability is perceived directly by passengers because unreliable walking time would lead to a high possibility of missing a train. It is also supported by the interview done by (Schaar & Lance, 2010), which indicates that ensuring reliable travel time has been raised as the most important need of passengers in the aviation field.

Hoogendoorn-Lanser et al. (2006) listed all stages of passengers during the transfer process. Only two of those stages are relevant to railway station: walking and waiting. That is because transfer time mainly consists of walking time and waiting time. As a result, the five basic needs can also be divided according to which stage they can be applied. When passengers are walking, the first three needs (safety & reliability, speed, ease) are crucial aspects to consider, while comfortable waiting facilities and friendly transfer experience are demanded by passengers during waiting phase.

2.2.4 Train operators
The train operators have two interests when it comes to the passenger movement in stations. Firstly, in order to attract more passengers, train operators would demand station operators to provide a high level of transfer service to passengers. The second interest for train operators is to minimize the negative transfer impact on its timetable, which means less passenger transfer time at stations. It is unacceptable for the train operators to allow the transfer process to affect the punctuality of the timetables.
2.2.5 Metro, Tram & Bus operators
In general, metro, tram and bus operators have the same interests as train operators. They want to have safe, fast and comfortable transfer corridors between their services and trains which would contribute to a higher ridership.

2.2.6 Local municipalities
Local municipalities in general would devote to developing an accessible, safe and attractive station and a well inter-district connection between two sides of the station at the same time. They mainly represent the opinions from local residents who do not want to let station to be a barrier between districts in the city.

2.2.7 The government
The government aims at improving the overall transport system in the country. It needs to consider and coordinate the interests from all stakeholders so that the overall social benefits can be achieved.

Moreover, the government considers the externality effects to the whole society caused by the project. Externality means the cost or benefit that affects a party who did not choose to incur that cost or benefit. The externalities of a transport project could be the changes in accident numbers, noise and air pollution brought by the modal shift (Delft, C.E., & Infras, F.I., 2011).

2.3 Real crowd management case regarding stakeholders’ interests
From the last section, an organization barrier can be found in the crowd management at railway station. Those interests that are only concerned by few stakeholders are possible to conflict with others. For example, in the Netherlands, the station operator (NS Stations) relies on the revenues of its retail shops at stations. In general, it wants to locate retail at the most crowed location so that more passengers can visit the shop. But when it is crowed, transfer safety can be an issue. Therefore, the rail infrastructure operator ProRail whose main concern is safety would like to keep clear of the crowded area. This means ProRail rather have less shops in the transfer process.

Even though for those interests that are shared by stakeholders, conflicts also exist because different stakeholders have different priority levels regarding the same interests. For example, station operator (NS Station) wants to reduce the congestion on the stairs/escalators as much as possible so that they can offer a comfortable transfer experience to passengers. However, the rail infrastructure operator (ProRail), who is responsible for the stairs/escalators, would not invest in an uncomfortable situation as long as there is no safety issue. This is because its main concern is safety and it cares much less about comfort than NS Station.

Despite the conflicts, the different interests can still be managed by finding their common interests or finding a balanced point. Below is a real crowd management case regarding to different stakeholders’ interests that happened in the Netherlands.

Removing tracks for widen platforms in Amsterdam
At Amsterdam central station, crowding platforms happen routinely thanks to the narrow platforms and high number of passengers. This leads to a large delay on transfer time as well...
as safety problems. Because the rail infrastructure operator (ProRail) is responsible for managing the platforms and rail tracks, it wants to remove one of the tracks which is used for overtaking trains so that the platforms are widened and congestion can be solved. However, for the train operator (NS Reizigers), taking out the track means less flexibility in running trains. Therefore, it has a negative effect on travel time, which conflicts with its interest.

The government can balance these interests by making the train operator realize that transfer time at station, which is valued even higher than in-train time for passengers, is also an important component of travel time. The decrease in transfer time can offset increases in in-train time. Moreover, removing the track also means less track switches. This improves the reliability of the network which is good for running the trains.

### 2.4 Evaluation aspects and the relevant stakeholders

Each stakeholder’s interest stated in Table 4 can be considered as an evaluation aspect for crowd management measure. However, conflicts also occur among those interests as stated in last section. As a result, a framework is needed to support the government to make decisions under such complex environment. All possible evaluation aspects are listed along with their relevant stakeholders in Table 5. Identifying these aspects is the first step of building the decision support framework because the problem owner, the government in this case, needs to understand the common or conflict interests of stakeholders so that actions can be taken to balance them.

#### Table 5 A list of possible evaluation aspects

<table>
<thead>
<tr>
<th>Evaluation aspects</th>
<th>Relevant stakeholder functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety in normal pedestrian flow</td>
<td>All stakeholders except local municipalities</td>
</tr>
<tr>
<td>Safety under emergency</td>
<td>All stakeholders except local municipalities</td>
</tr>
<tr>
<td>Security</td>
<td>All stakeholders except local municipalities</td>
</tr>
<tr>
<td>Walking time</td>
<td>All stakeholders except local municipalities</td>
</tr>
<tr>
<td>Waiting time</td>
<td>All stakeholders except local municipalities</td>
</tr>
<tr>
<td>Reliability</td>
<td>All stakeholders except local municipalities</td>
</tr>
<tr>
<td>Comfort</td>
<td>All stakeholders except local municipalities</td>
</tr>
<tr>
<td>Walking distance</td>
<td>All stakeholders except local municipalities</td>
</tr>
<tr>
<td>Way-finding</td>
<td>All stakeholders except local municipalities</td>
</tr>
<tr>
<td>Easy management (Infrastructure</td>
<td>Station operator; Rail infrastructure operator; The government</td>
</tr>
<tr>
<td>maintenance)</td>
<td></td>
</tr>
<tr>
<td>Revenues of shops</td>
<td>Station operator; The government</td>
</tr>
<tr>
<td>Accessibility for area around station</td>
<td>Local municipalities; The government</td>
</tr>
<tr>
<td>Ridership changes</td>
<td>Train, bus, metro, and tram operators</td>
</tr>
<tr>
<td>Externalities</td>
<td>The government</td>
</tr>
<tr>
<td>Investment costs</td>
<td>The government</td>
</tr>
</tbody>
</table>

### 2.5 Power-interest matrix

After identifying all the stakeholders and their interests, it is necessary to analyse the power and level of interest of each stakeholder in an existing railway station. This is because the importance of the stakeholder decides the importance of their interests. The importance of a stakeholder depends on how it can influence the transfer process. The ways how different stakeholders in the Netherlands influence the transfer process are first discussed in Table 6.
Table 6 The influence ways of stakeholders to transfer performance

<table>
<thead>
<tr>
<th>Specific Stakeholders</th>
<th>Influence ways</th>
</tr>
</thead>
<tbody>
<tr>
<td>ProRail</td>
<td>Change its infrastructure (stairs, lifts, information panel)</td>
</tr>
<tr>
<td></td>
<td>Change route information</td>
</tr>
<tr>
<td>NS Stations</td>
<td>Change its infrastructure (ticket gates, benches, information panel)</td>
</tr>
<tr>
<td></td>
<td>Change route information</td>
</tr>
<tr>
<td></td>
<td>Determine the type of use of station space (retail or walking space)</td>
</tr>
<tr>
<td>Transfer passengers</td>
<td>Choose which transport mode to take</td>
</tr>
<tr>
<td></td>
<td>Vote the government</td>
</tr>
<tr>
<td>NS Reizigers</td>
<td>Change operation timetable (has impact on passenger transfer time)</td>
</tr>
<tr>
<td>Metro, Tram &amp; Bus operators</td>
<td>Change operation timetable (has impact on passenger transfer time)</td>
</tr>
<tr>
<td>Local municipalities</td>
<td>Determine the use of area near stations</td>
</tr>
<tr>
<td>The government</td>
<td>Decide the overall transport policy</td>
</tr>
</tbody>
</table>

The power and interest levels of stakeholders are determined indicatively in Figure 6 according to the reasons below:

The government has the greatest power and it concerns a lot about transfer process since it is in charge of the transfer project. NS Station and ProRail have equal interests and power because they are all operators of station infrastructure and thus directly related to the transfer process. Local municipalities show much less concerns towards station transfer as long as it does not affect the accessibility of its city. Passengers are considered to have less power because although a station as a public facility is indirectly owned by all citizens and they also have vote powers towards the decision makers, it takes time to reveal their indirect impacts on the transfer process. However, transfer is of great concern to the passengers because they experience it every day. The train service operator concerns less about transfer process compared to station infrastructure operators. It also has less power because what it is not directly related to the crowd management at stations. Other transport services operators have even less impact than the train operator, because the train operator has a stronger connection with the station operator.
2.6 Conclusions

From this chapter, transfer process is found to be a complex area. Station and rail infrastructure operators, passenger, local municipalities, separate operators that run different transport modes and the government are involved. Different interests and priorities exist among them. As a result, a decision support framework is needed to balance all these differences.

The analysis of stakeholders’ interests provides the basis for deriving transfer evaluation aspects. Identifying these aspects can help the government evaluate the crowd management measure on a full scale while for individual stakeholders they would have a better idea about how to improve their own infrastructure performance and how their actions would affect the overall transfer performance.

Identifying stakeholders’ interests also helps to better manage the stakeholders so that an agreement on transfer intervention can be reached. This is because although conflicting interests exist among stakeholders, it can still be managed by finding common interests or a balanced point. A real case of such stakeholder management given in this chapter verifies this.

Stakeholders’ influence and their interest level are studied as well. It is found that the government, station and rail operators, passengers have both high interest and influence in transfer while the local municipals have less interest compared to them. Public transport operators related the station have less interest and lower power compared to others. Analysing the importance of stakeholder helps to determine the importance of evaluation aspects in the next chapter.
3 Literature review

In this chapter, literature is reviewed in order to answer the following sub-research questions:

(2) What is the importance of transfer aspects according to literature?

(3) What is the feasibility of transfer aspects to be measured in money according to literature?

The first step is to summarize the importance of transfer aspects that have been discussed in literature. After that, a checklist with evaluation aspects (identified in the last chapter) and their importance can be derived.

It is followed by the investigation of aspects feasibility in cost-benefit analysis. In order to be measured by monetary units, an objective and predicable indicator and a method to translate the indicator unit into the monetary term are required. Therefore, literature is studied on both two sides. From the feasibility, the reason why crowding is chosen for monetizing study can be explained. Finally, the components of

3.1 The importance of transfer aspects

Many researchers considered the transfer process from only passenger point of view. As shown in Figure 7, NS Stations (Van den Heuvel, Dekker, & De Vos, 2012) classified the needs of passengers in the transfer process into five categories according to Maslow’s hierarchy of needs (Maslow, 1943). The importance of each category is expressed in the shape of pyramid. From the pyramid, we can see that safety and reliability are among the most important aspects for passengers. Besides safety and reliability, ease and speed are also dissatisfiers which means passengers would not take that trip if a station performs poorly in these aspects. Experience and comfort are the two main satisfiers in transfer process. High qualities in these two aspects would lower the perceived transfer time but they are not necessary for passengers. This concept is also adopted by NS for practical analysis according to Van den Heuvel & Hoogenraad (2014).

![Figure 7 Pyramid of Customer Needs (van Hagen, 2011)](image)

Some researchers have done studies about transfer performance aspects in large terminals also from passenger point of view. Iseki & Taylor (2009) believed that transfer performance
is reflected by transfer penalty in passenger trip choice. They illustrated how different aspects in the transfer process are related to the transfer penalty. Transfer penalty consists of several cost items. Through the amount of costs perceived by passengers, transfer performance of the stations can be known. Transfer penalty was divided into three parts shown in the equation below, namely walking costs, waiting costs and a constant transfer penalty value.

\[
TP_b = (Walk_{tt} \cdot \text{Walk}_{tt}) + (Wait_{tt} \cdot \text{Wait}_{tt}) + TP
\]  

(1)

\(TP_b\): Broad sense of transfer penalty  
\(Walk_{tt}\): Walking time at transfer station  
\(Wait_{tt}\): Waiting time at transfer station  
\(TP_w\): Passenger valuation of walking time at transfer station  
\(TP_{tt}\): Passenger valuation of waiting time at transfer station  
\(TP_n\): Narrow sense of transfer penalty excluding transfer walking and waiting

The ways different aspects affect each part of transfer penalty are elaborated in Figure 8. From the figure, it is shown how different factors affect different parts of the transfer penalty. The perceptions of transfer process are reflected by passenger valuations of waiting and walking time. Through the significant variations of the wait and walk time valuations across stations, the authors were clear that improving transfer facilities have great impact on the perceived penalty of transfer.

Taylor & Miller (2009) considered transfer performance from managers’ perspective. The importance of evaluation aspects was also examined. It was found that safety and security are the most important for station managers, followed by the ease of transferring.

Figure 8 A conceptual framework for determining the generalized cost of transfer (Iseki & Taylor, 2009)
The importance of current evaluation aspects to their related stakeholders are listed in Table 7. In general, evaluation aspects from passenger perspective have already been well discussed in literature. However, the importance of aspects to other stakeholders is not completely identified.

### Table 7 Transfer evaluation aspects in literature

<table>
<thead>
<tr>
<th>Aspects</th>
<th>Importance to related stakeholders</th>
<th>Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety</td>
<td>Very important for passengers, Rail &amp; Station operators</td>
<td>(Taylor &amp; Miller, 2009)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Iseki &amp; Taylor, 2009)</td>
</tr>
<tr>
<td>Security</td>
<td>Very important for passengers, Rail &amp; Station operators</td>
<td>(Taylor &amp; Miller, 2009)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Iseki &amp; Taylor, 2009)</td>
</tr>
<tr>
<td>Transfer time</td>
<td>Very important for passengers</td>
<td>(Iseki &amp; Taylor, 2009)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(van Hagen, 2011)</td>
</tr>
<tr>
<td>Reliability</td>
<td>Very important for passengers</td>
<td>(Iseki &amp; Taylor, 2009)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(van Hagen, 2011)</td>
</tr>
<tr>
<td>Comfort</td>
<td>Medium important for passengers</td>
<td>(Iseki &amp; Taylor, 2009)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(van Hagen, 2011)</td>
</tr>
<tr>
<td>Walking distance</td>
<td>Medium important for Passengers</td>
<td>(Iseki &amp; Taylor, 2009)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(van Hagen, 2011)</td>
</tr>
<tr>
<td>Way-finding</td>
<td>Medium important for Passengers</td>
<td>(Iseki &amp; Taylor, 2009)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(van Hagen, 2011)</td>
</tr>
</tbody>
</table>

#### 3.2 Evaluation checklist

In section 2.4, 15 possible evaluation aspects are identified in total. However, in practice, the government prefers less evaluation aspects and it is also important to make sure that two evaluation aspects in cost-benefit analysis do not have an overlapping part. As a result, the relations between the evaluation aspects are analysed and unnecessary evaluation aspects are excluded from the checklist.

Walking distance is highly related to the walking time. A long walking distance can lead to long walking time. However it does not hold vice versa because walking time depends on not only walking distance but also the pedestrian flow condition at railway station. In this logic, an evaluation of walking time includes the evaluation of walking distance. Moreover, passengers do not care that much about distance as time. Therefore, walking distance is excluded from the evaluation checklist.

Ridership changes of public transport operators and externalities aspects are also excluded because they are indirect effects and the least important for the government economical appraisal.

Finally, 11 aspects are included in the checklist presented in Table 8. The importance of each aspect to different stakeholders is represented by rankings in the table. The blank cells in the table represent that the stakeholder does not concern about that specific aspect. Such importance is determined according to literature review and common sense. The importance of each aspect to the problem owner (the government) is determined by the importance of that aspect to the related stakeholder and the importance of the related stakeholders. The determination is explained below:
Safety under normal and emergency situations and security are the most important for passenger, station operator and rail infrastructure operator according to the literature and medium important for public transport operators. As a result, they are the top needs for the government. Transfer time and reliability are not the top needs for rail infrastructure operator because its main responsibility is safety. However, they are still the top needs for important stakeholders like passengers and station operator. Therefore, they are also considered as the most important aspects to the government.

Although comfort and way-finding are important for passengers, they are not the priority needs. They are the least important aspect to station operators, rail infrastructure operators and public transport operators. However, they are still ranked as medium important to the government because most of stakeholders care about them. Easy management is the top need for station and rail infrastructure operators. However, because other stakeholders are not interested in it, it is only considered as medium important for the government.

Retail and accessibility for area around station are also considered as the least important because they are only very important for a single stakeholder.

Finally, the investment cost is naturally the priority for the government with respect to a station improvement project.

Table 8 Evaluation checklist

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Stakeholder Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Passen-</td>
</tr>
<tr>
<td>A1. Safety in normal pedestrian flow</td>
<td>1</td>
</tr>
<tr>
<td>A2. Safety under emergency</td>
<td>1</td>
</tr>
<tr>
<td>A3. Security</td>
<td>1</td>
</tr>
<tr>
<td>A4. Transfer time</td>
<td>1</td>
</tr>
<tr>
<td>A5. Reliability</td>
<td>1</td>
</tr>
<tr>
<td>A6. Comfort</td>
<td>2</td>
</tr>
<tr>
<td>A7. Way-finding</td>
<td>2</td>
</tr>
<tr>
<td>A8. Easy management (maintenance costs)</td>
<td>1</td>
</tr>
<tr>
<td>A9. Retail</td>
<td>1</td>
</tr>
<tr>
<td>A10. Accessibility for area around station</td>
<td></td>
</tr>
<tr>
<td>A11. Investment costs</td>
<td></td>
</tr>
</tbody>
</table>

Very important (1); Medium important (2); Not important (3); Not related (blank)

This resulted aspects in the checklist can be used in cost-benefit analysis to know what benefits/costs should be calculated. The total sum of the benefits and costs tells whether the project is profitable or not. The importance of the aspects is useful for determining the weights during the evaluation. The checklist developed here functions as a preliminary step towards a complete decision support framework which can transfer the objective measures to a recommendation to decision makers.
NPC develops a concept of ‘Transfer Solution’ which clearly elaborates the process of a station transfer project. As shown in Table 9, this concept divides the transfer project into three phases: ex-post analyse, proposing solutions and ex-ante testing. For each phase, there are several vital instruments to address the problem.

This thesis focuses on evaluating crowding management measures, which is closely related to phase 1 and 3 of the ‘Transfer Solution’ concept. After proposing solutions for the transfer problems, an ex-ante evaluation framework should be applied to systematically test the solutions. As a result, the checklist which functions as the first step of building an evaluation framework will be helpful for the problem analysis and solution test.

<table>
<thead>
<tr>
<th>Phases</th>
<th>Instruments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Ex-post analyse</td>
<td>Actual measurement; Customer survey &amp; interview</td>
</tr>
<tr>
<td>2. Proposing solutions</td>
<td>Redesign or Operational changes</td>
</tr>
<tr>
<td>3. Ex-ante test</td>
<td>Simulations</td>
</tr>
</tbody>
</table>

### 3.3 Evaluation aspects regarding cost-benefit analysis

Different evaluation aspects appear to have different characteristics. In order to be evaluated by cost-benefit analysis, two elements are required for each evaluation aspect: a suitable indicator and a value to translate indicator unit into money. A suitable indicator for cost-benefit analysis should be an objective and able to be predicted.

#### 3.3.1 Objective indicators

Two types of indicators are distinguished in literature: subjective and objective. Subjective indicators appear as rankings in questionnaires. NS is currently measuring the overall performance of their stations from a passenger point of view by using a survey tool called the “Stations Experience Monitor”. The indicators it uses are all in forms of stated preference questions which reflect the satisfaction levels of the passenger needs. The dataset of the “Stations Experience Monitor” not only shows the performance of stations but also allows the determination of correlations between transfer aspects and the overall station experience (Van den Heuvel, Dekker, & De Vos, 2012).

However, because this thesis focus on applying cost-benefit analysis on transfer evaluation, an objective and predicable indicator for each aspect is required. Transfer time is the most commonly used objective indicator in literature (Van den Heuvel & Hoogenraad, 2014) (Landau, Weisbrod, Gosling, Williges, Pumphrey, & Fowler, 2015) (Correia, Wirasinghe, & de Barros, 2008) (Hoogendoorn & Daamen, 2004). Van den Heuvel and Hoogenraad (2014) indicated that station transfer time, which contains walking and waiting time, is valued importantly by passengers. In their research, they examined both walking and waiting time by using automatic fare collection data in two cases studies conducted at Dutch railway stations. It was assumed that people check in and out at the time they enter or leave the platform. One case studied the walking time of arrival passenger to leave the station so that the bottlenecks at the railway station can be identified. Another case calculated the waiting time changes when a new train schedule was introduced. The waiting time, affected by headways between timetables, is regarded as a very important aspect in transfer penalty. Both long and short transfer times are perceived negatively by passengers (Schakenbos , 2014).
Level-of-service described by Fruin (1971) was also often adopted as the criterion to assess congestion level and comfort in practice and research (Daamen, 2004) (Verhoeff, 2015). As shown in Figure 9, common level-of-service consists of six levels (from A to F) in terms of pedestrian density, speed and flow. Values are set to distinguish each level.

![Figure 9 Level of service (Fruin, 1971)](image)

Although updates of level-of-service have been performed by other researchers (Milazzo, Roupail, Hummer, & Allen, 1999) (Soligo, Irwin, Williams, & Schuyler, 1998), NS and Prorail still use the level-of-service standard developed by Fruin and it has different level-of-service standards for different types of pedestrian flows and different parts of infrastructure (Daamen, 2004). All the standards are summarized in Table 10.

<table>
<thead>
<tr>
<th>Infrastructure</th>
<th>Pedestrian flow</th>
<th>Level-of-service</th>
</tr>
</thead>
<tbody>
<tr>
<td>Platform</td>
<td>Walking</td>
<td>D</td>
</tr>
<tr>
<td></td>
<td>Waiting</td>
<td>C</td>
</tr>
<tr>
<td></td>
<td>Boarding passengers</td>
<td>E</td>
</tr>
<tr>
<td>Stairs</td>
<td>Walking</td>
<td>E</td>
</tr>
<tr>
<td>Tunnel</td>
<td>Walking</td>
<td>D</td>
</tr>
<tr>
<td>Hall</td>
<td>Walking</td>
<td>C</td>
</tr>
<tr>
<td></td>
<td>Waiting</td>
<td>C</td>
</tr>
</tbody>
</table>

Walking distance is the indicator used to reflect the ease of transfer in many previous evaluation studies (Correia, Wirasinghe, & de Barros, 2008) (Hoogendoorn & Daamen, 2004). Usually, the norms of maximum distances transferring passengers have to walk are defined by the station owner (Daamen & Hoogendoorn, 2002). In the station transfer evaluation study of Chen et al. (2014), walking distance is calculated by the equation below:

$$D_{transfer} = H_{transfer} + kV_{transfer}$$  \(2\)

Where \(H_{transfer}\) and \(V_{transfer}\) respectively mean the horizontal and vertical average walking distance, \(k\) is the extended factor for stairs or escalators. Long walking distance directly leads to long walking time, but the relation does not hold in a reverse way. Long walking time of passengers can happen because of either long walking distance or low walking speed (congestion) or both.

Reliability of travel time expresses whether the actual passenger transfer time meets the expected one. There are various ways to define the travel time reliability in the vehicular traffic (Li, Hensher, & Rose, 2010). A common one is the standard deviation of actual
transfer time for identical trips. Therefore, the indicator would be the transfer time variance. However, this definition implicitly assumes travel time to be normally distributed and it can be predicted by plus or minus a factor times the standard deviation which is not the case in reality (Van Lint, Van Zuylen, & Tu, 2008). While some researches assumed travel time variability causes negative utility, others considered that the loss of utility happens when not arriving at the preferred arrival time (Bates, Polak, Jones, & Cook, 2001) (Small, The scheduling of consumer activities: work trips, 1982). Therefore, late arrival and early arrival are distinguished since passengers may have different perceptions about those two scenarios (Small, The scheduling of consumer activities: work trips, 1982). The preferred arrival time theory fits passenger behaviour better but the variation expression is easier to implement.

Correia, Wirasinghe, and de Barros (2008) developed two orientation indicators in the definition of the overall level of service for airport passenger terminals. They are the ratio between actual walking distances and minimum walking distances and tardity-differential which consists of number of decision points and number of level changes. However, such orientation indicators may not be applicable for a cost-benefit analysis because it is difficult to predict those indicators in future.

Besides the performance of pedestrian flow under a normal situation, safety in case of emergency situations was also assessed in their study and it was quantified by the evacuation time of all passengers to exit the station (Hoogendoorn & Daamen, 2004). When calculating the safety under normal situation, although it is related density, there is no objective indicator that can quantify safety benefits under normal condition. It is necessary to measure safety in other ways.

The indicators above are all related to the passenger perceptions while the performance indicators from the perspectives of other stakeholders are few mentioned. The retail shops on the platforms are fully dependent on the pedestrian flow at the platform. Therefore, Van den Heuvel et al. (2012) assessed the performance of Kiosks on the platforms through the number of passengers using the platform during different period of the day.

Some qualitative aspects can also be evaluated by using objective indicators as proxies. In the transit service evaluation study of Eboli & Mazzulla (2011), security against crimes is quantified by the number of complaints registered. However, such an indicator can only be used during ex-post evaluation because the future number of crime complaints can not be accurately predicted. For ex-ante evaluation, indicators like the availability of CCTV and lighting condition are adopted.

Comfort is also a rather qualitative aspect. Comfort is a complex experience including crowding, stability of the vehicle, seat comfort, temperature, smells, cleaningness, and so on (Kroes, Kouwenhoven, Debrincat, & Pauget, 2013). Comfort in terms of crowding is linked to density at stations. For cleanliness aspect of comfort, Eboli & Mazzulla (2011) believed that the cleanliness of the stations can be represented by the frequency of interior cleaning and exterior washing. In Table 11, all the suitable indicators for cost-benefit analysis in literature are summarized.
### Table 11: Indicators in literature

<table>
<thead>
<tr>
<th>Suitable indicators for CBA</th>
<th>Related transfer aspect</th>
<th>Related stakeholder(s)</th>
<th>Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed</td>
<td>Walking speed</td>
<td>Passenger; Station operators;</td>
<td>(Correia, Wirasinghe, &amp; de Barros, 2008) (Van den Heuvel &amp; Hoogenraad, 2014)</td>
</tr>
<tr>
<td>Transfer time</td>
<td>Waiting and walking time</td>
<td>Public transport operators;</td>
<td>(Hoogendoorn &amp; Daamen, 2004)</td>
</tr>
<tr>
<td>Level-of-service (flow)</td>
<td>Speed</td>
<td>The government</td>
<td>(Daamen &amp; Hoogendoorn, 2002)</td>
</tr>
<tr>
<td>Level-of-service (density)</td>
<td>Comfort (crowding)</td>
<td></td>
<td>(Hoogendoorn &amp; Daamen, 2004)</td>
</tr>
<tr>
<td>Transfer time variance</td>
<td>Reliability</td>
<td></td>
<td>Landau et al. (2015)</td>
</tr>
<tr>
<td>Evacuation time</td>
<td>Safety in emergency</td>
<td></td>
<td>(Hoogendoorn &amp; Daamen, 2004)</td>
</tr>
<tr>
<td>Frequency of interior cleaning and exterior washing</td>
<td>Comfort (cleanliness)</td>
<td></td>
<td>(Eboli &amp; Mazzulla, 2011)</td>
</tr>
</tbody>
</table>

Some of the suitable indicators are correlated with each other. In Figure 10, the causal relations among correlated indicators are shown. The arrows in the figure mean the influence direction. For example, density at station is influenced by the interaction of station capacity and demand flow. Capacity is in circle in the picture because it alone is not listed as an indicator for evaluation. The plus in the below means transfer time consists of walking time and waiting time.
3.3.2 Methods to translate indicator units into money
As for the methods to translate indicator units into money, four aspects have already been investigated in transfer or other transport studies. They are introduced below:

**Value of time**
Landau et al. (2015) performed an ex-ante study to support the terminal investment decisions by using the cost-benefit analysis tool. They developed a guidebook which focused on analysing the transfer time reduction benefits in cost-benefit analysis for airport capital investment. Value of time which means the amount of money a passenger wants to pay to save a certain amount of time is used to monetize transfer time reduction benefits. Such a relation can also been observed in passenger utility function for a trip (Significance & VU University Amsterdam, 2012):

\[ U = \beta_C \cdot C + \beta_T \cdot T \quad (3) \]

where:
- \( \beta_C \): Cost parameter
- \( C \): Travel cost
- \( \beta_T \): Time parameter
- \( T \): Travel time

The value of time can be calculated by dividing the time parameter by cost parameter:

\[ VOT = \frac{\beta_T}{\beta_C} \quad (4) \]

Kouwenhoven et al. (2014) updated the official values of time for the Netherlands. It was found that the value of general in-train travelling time is 9.25 euro/hour. The value also differs among different trip motives. The value of time for commute in the Netherlands is 11.5 euro/hour while it is 7 euro/hour for non-working purpose.

Value of walking time can be derived from value of in-train time by applying a multiplier. According to a meta-analysis (Abrantes & Wardman, 2011), walking time is weighted as 1.65 times the in vehicle time, which means the value of walking time at railway station is 15.26 euro/hour for the Netherlands.
Value of reliability

Travel time reliability has been heavily evaluated by cost-benefit analysis in other transport projects (Den Boer, van Essen, Brouwer, Pastori, & Moizo, 2011) (Li, Hensher, & Rose, 2010). There are two popular models to value reliability of travel time: the mean-dispersion approach and scheduling approaches (Significance & VU University Amsterdam, 2012). In the mean-dispersion model, the utility function includes a parameter of the dispersion of the travel time distribution which is shown in the function below.

\[ U = \beta_c \cdot C + \beta_T \cdot T + \beta_R \cdot \sigma \]  

(5)

\( \beta_R \): Reliability parameter  
\( C \): Standard deviation  

The value of reliability can be calculated by dividing the reliability parameter by cost parameter.

\[ VOR = \frac{\beta_R}{\beta_C} \]  

(6)

VOR: value of reliability

The scheduling model is another way to model travel time reliability, taking into account the consequences of unreliable travel time (Li, Hensher, & Rose, 2010). In this model, passengers are assumed to have desired arrival time at destination. Disutility would occur when they arrive earlier or later than the desired time. This model reflects more realistic travel behaviour but it requires more data. A utility function is proposed by Small (1982) to reflect the departure time choices of passengers who want to arrive on-time.

\[ U = \alpha \cdot T + \beta \cdot SDE + \gamma \cdot SDL + \theta \cdot D_L \]  

(7)

\( T \): Travel time  
\( SDE \): Schedule delay early  
\( SDL \): Schedule delay late  
\( D_L \): Dummy variable, it equals to 1 when there is a SDL and 0 otherwise. This reflects a discrete penalty for missing a train that departs at a specific time  
\( \beta, \gamma, \theta \): Cost values that are estimated

Value of life

Although it is difficult to measure safety in money, value of life is developed to describe the benefit of saving a human life. This monetary value can be calculated by determining the willingness to accept payment for bearing additional risk of life or foregone earnings (Viscusi & Aldy, 2003).

Value of crowding

In terms of measuring qualitative aspects in cost-benefit analysis, only crowding inside public transport vehicles are studied before. Li and Hensher (2011) reviewed public transport crowding valuation and identified the ways to value crowding in the utility function: (1) a travel time multiplier, (2) a monetary value per trip.

Kroes et al. (2013) and Hurtubia (2015) have studied the value of crowding in vehicles. They both adopt the values of crowding in the form of travel time multipliers. These multipliers can be interpreted as a measure of how crowding would be translated into disutility by increase in travel time, which can be further translated into monetary units by value of time.
3.3.3 Feasibility of aspects in cost-benefit analysis

Combined with the review of suitable indicators for cost-benefit analysis and the ways to translate indicator units into money, the feasibility of important aspects in cost-benefit analysis are determined. The reason for choosing value of crowding in front of station vertical infrastructure for further investigation can also be explained in this section.

The feasibility of each evaluation aspect in CBA is summarized in Table 12.

<table>
<thead>
<tr>
<th>Aspects</th>
<th>A suitable indicator for ex-ante evaluation</th>
<th>A value to translate the unit into money</th>
<th>Feasible for CBA</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1. Safety in normal pedestrian flow</td>
<td>Not yet</td>
<td>Yes, Value of stochastic life</td>
<td>Not yet</td>
</tr>
<tr>
<td>A2. Safety under emergency</td>
<td>Evacuation time</td>
<td>Yes, Value of stochastic life &amp; Standard evacuation time</td>
<td>Yes</td>
</tr>
<tr>
<td>A3. Security</td>
<td>The availability of CCTV; Lighting condition; Etc.</td>
<td>Not yet</td>
<td>Not yet</td>
</tr>
<tr>
<td>A4. Transfer time</td>
<td>Time</td>
<td>Yes, Value of time</td>
<td>Yes</td>
</tr>
<tr>
<td>A5. Time reliability</td>
<td>Time variation</td>
<td>Value of reliability</td>
<td>Yes</td>
</tr>
<tr>
<td>A6. Comfort</td>
<td>Density; Frequency of cleaning; Etc.</td>
<td>Not yet</td>
<td>Not yet</td>
</tr>
<tr>
<td>A7. Way-finding</td>
<td>Not yet</td>
<td>Not yet</td>
<td>Not yet</td>
</tr>
<tr>
<td>A8. Easy management</td>
<td>Money</td>
<td>Yes, Already in money</td>
<td>Yes</td>
</tr>
<tr>
<td>A9. Revenues of shops</td>
<td>Money</td>
<td>Yes, Already in money</td>
<td>Yes</td>
</tr>
<tr>
<td>A10. Travel time changes for through passenger flow</td>
<td>Time</td>
<td>Yes, Value of time</td>
<td>Yes</td>
</tr>
<tr>
<td>A11. Investment costs</td>
<td>Money</td>
<td>Yes, Already in money</td>
<td>Yes</td>
</tr>
</tbody>
</table>

A1. Currently, there is no indicator for quantifying pedestrian safety under normal condition yet. However, the relation between safety and monetary costs is well developed in other transport study through value of stochastic life and it is also clear that high density would lead to unsafe condition. Therefore, it needs an objective indicator to reflect the relation between density and safety.
As for the safety under emergency situation, evacuation time is a way to quantify it. In order to express this aspect in money, a standard evacuation time and a value of life should be adopted.

Passengers’ perception of security can be expressed by some proxies, for example, the availability of CCTV and the lighting condition at night. However, passenger values of these proxies are not known yet.

Transfer time is already an objective indicator and value of time can be adopted to convert walking time saving into monetary term.

Standard deviation of transfer time is a way to quantify reliability and the value of reliability can convert it into monetary terms.

Comfort is a qualitative aspect which can be quantified by several proxies like density, seat numbers or the frequency of station cleaning. Currently, the value to convert the changes in those proxies into monetary terms is not available yet. Comfort during transfer covers a wide range of aspects including crowding in front of station vertical infrastructure, cleanliness, seats availability, smells, noise and so on. However, crowding at station can already be quantified for ex-ante evaluation and the studies of values of crowding in vehicles discussed in literature indicate its possibilities to be monetized.

Way-finding performance is dependent on passenger perception. Although the walking time deviation can tell the current performance, it is hard to predict the changes in way-finding before the measures. Therefore, a proper indicator for ex-ante evaluation should be developed.

Management costs of stations can be estimated in money from station operators.

One important performance indicator of retail is revenues per passenger. However, waiting time is also an important variable affecting the revenue of retails. The relation between waiting, number of passengers and the revenue can be investigated through existing data of stations.

The travel time for inter-district connection is considered as an indicator for evaluating the accessibility of station nearby area. Combined with value of time, it can be incorporated into cost-benefit analysis.

Investment costs are already in form of monetary costs.

From the analysis, it is concluded that crowding at station is an important unknown so far. It already has a suitable indicator for CBA while literature suggests measuring crowding in money is feasible through value of time. Moreover, the method to measure crowding at station in monetary term can also be used to measure other qualitative aspects.

### 3.4 Influence factors of crowding

Crowding is part of comfort. It overlaps with many other aspects such as safety, security, transfer time and reliability. Such correlation exists because these aspects are all influenced by density, as shown in Figure 11. When density is high, crowding would appear and there will be extra walking time (aspects of time and reliability), increasing possibilities of accidents (safety aspect) and crimes (security aspect). The overlapping part should be defined clearly before performing an evaluation. In this thesis, the disutility of extra walking time and accidents caused by crowding are not included in crowding. However, the perceptions of risks to security and safety and the anxiety of propensity to be delayed under dense area are included in crowding disutility.
The fact that crowding decreases the level of comfort has been recognized by many researchers in the appraisal of public transport services (Cheng, 2010) (Mahudin, Cox, & Griffiths, 2012) (Cox, Houdmont, & Griffiths, 2006). Density is often used as a proxy to reflect comfort levels in terms of crowding. However, high density is not necessarily equal to low comfort because the discomfort in crowd is caused by several factors. Density is only one of them, while comfort is a passenger perception originating from an interaction among cognitive, social and environmental factors (Cox, Houdmont, & Griffiths, 2006). As a result, it is necessary to know what factors mainly influence the passengers’ stress in crowding. In general, there are three types of factors that influence the crowding perceptions. They are the characteristics of crowds, the characteristics of railway stations and the characteristics of individual passengers.

In Figure 12, the main aspects are given and each aspect is linked with the factors which cause that stress aspect. As stated before, the disutility of extra walking time and accidents due to crowding are not included in crowding disutility and the perception of risk to security under dense area is included in crowding. Under this scope, crowding disutility consists of two parts: mental and physical stress. Mental stress includes stress from the perception of risks to safety and security, the propensity to be delayed and the invasion of privacy while physical stress means that passengers need to put more effort in transfer.

Passengers would perceive a risk to safety (fall down or stampede) when density is high and the high dense area is located near the rail track or stairs/escalators. Therefore, the density together with the location of crowded area is the factor causing this stress aspect. Although some other factors, for example the shape of the bottleneck or high speed trains passing through, would increase passengers’ anxiety of falling down, they are considered as the characteristics of station and these characteristics differ across stations.

The relation between crowding and personal security is contingent on crime type. When the station is too crowded, pick pocketing would arise. On the other hand, passengers would feel a risk to be mugged when there is barely anyone at station. Since this thesis only explores the disutility of crowding, the first type of crime applies. Therefore high density is the factor causing the perception of a risk to security.

When passengers see that an area in the station becomes too crowded and a queue is formed, they would feel anxiety because there is a propensity to be delayed. People usually estimate extra walking time by the amount of people in front of the bottleneck, which
depends on density and the size of queue. As a result, density and the size of the queue are sufficient to represent this stress aspect.

People prefer to have enough space around them for the sake of privacy. Crowding creates a dense area where passengers’ personal space is violated and they might feel uncomfortable about that. For this stress aspect, the density of the area where people walks has impacts.

Two aspects of discomfort contribute to physical stress: pushing and the efforts to avoid collision. In very crowded areas, people are forced to have physical contact with others and they might be pushed by people behind them. Moreover, passengers have a preference of maintaining their desired walking speed and direction (Kretz, 2014). However, in a dense area, it is highly possible to have collision with others. Therefore, passengers need to change their walking speed and direction frequently to avoid collision, which can cause physical stress for passengers. Both two stress aspects can be represented by density.

Finally, because stress is a subjective perception, it is also dependent on the characteristics of each individual passenger, such as mood.

![Diagram showing the relationship between main aspects of crowding stress and factors affecting them.](Figure 12 Passenger perceptions of crowding)

Although the characteristics of people and stations would have impacts on the crowding perceptions, only the characteristics of crowding (shown in green rectangular in Figure 12) are considered in this thesis. This is because the characteristics of people and stations vary a
lot and the goal of this survey is to derive a generic perception towards crowding. The characteristics of crowding are density, the size of queue and the location of dense area.

3.5 Conclusion

In this literature review, the importance of evaluation aspects to stakeholders is studied. It is found that passenger perceptions of aspects are well studied while it does not hold for other stakeholders. An evaluation checklist which includes 11 aspects and their importance can be then. The importance of an aspect is determined by the importance of this aspect to its related stakeholders and the importance of the related stakeholders. The checklist functions as a preliminary step for calculating the costs and benefits of crowd management measures at railway stations in cost-benefit analysis.

From the overview of the aspect feasibility in cost-benefit analysis, 4 evaluation aspects are not yet able to be quantified by monetary terms. Safety under normal condition and way-finding are the two aspects that cannot be quantified by an indicator for ex-ante evaluation. Security and comfort lack a value to convert the unit into money.

Comfort in terms of crowding at stations is selected for monetizing study because it is an important unknown from the CBA feasibility analysis. Moreover, it already has a suitable indicator for CBA and the existing studies of crowding in vehicles indicate its possibilities to be monetized. The approach to determine the monetary value of crowding can also be viewed as an example to measure security and other aspects of comfort in cost-benefit analysis.

Finally, the components of crowding disutility are listed and three characteristics of crowding are defined. They are density, the size of queue and the location of dense area. In the next chapter, these three characteristics are used to describe the crowding condition in the survey which aims at determining the values of crowding.
4 Survey design and data collection

In the last chapter, crowding at railway station is selected to be investigated how it can be measured by monetary terms in evaluation. The location of crowding, which is one of the crowding characteristics, is first determined in this chapter.

Because it is hard to measure the existing passenger behaviour in terms of crowding responses, stated preference experiment is chosen as the approach to determine the value of crowding. The experiment includes four steps (survey design, data collection, model estimation and results interpretation). This chapter is to design a survey which can let respondent make a trade-off between crowding and a reference variable. To be more specific, the choice situation, utility function, attributes, attribute levels, and the choices combination should be designed. In general, the sub-question below can be answered in this chapter:

(4) Which methodology should be used to determine the value of crowding in front of station vertical infrastructure?

After designing the survey, data needs to be collected. This chapter presents the social-demographic characteristics distribution of sample data. It also shows the approach to eliminating respondents with low quality responses.

4.1 Chosen crowding location: in front of vertical infrastructure

The area in front of vertical infrastructure is selected as the crowding study region because station congestion mainly occurs at specific bottlenecks during peak hours in the Netherlands and most station improvement projects aim at solving those bottlenecks. Vertical infrastructure (stairs and escalators) and gates are the bottlenecks of pedestrian flow at railway stations and the areas upstream are the most crowded locations. As a result, when transfer quality is evaluated in consultancies, such as NPC, only three critical regions are analysed. They are the regions in front of stairs and escalators and the regions in front of gates. As shown in Figure 13, the study region in red is defined to represent the condition on platform and density is calculated each minute for that region.

![Figure 13 An example of density analysis of platform](image)
Considering vertical infrastructure is easier to become a bottleneck for Dutch stations compared to ticket gates since the flow often exceeds the capacity on vertical infrastructure than that of gates because not all stations are gated. As a result, the upstream of the vertical infrastructure is chosen to represent crowding conditions at Dutch railway stations. In terms of crowding on vertical infrastructure and its upstream region, there is no clear evidence from literature showing that people have different perceptions for crowding on different types of vertical infrastructure (stairs or escalators) or the directions of flow. Therefore, differences between stairs and escalators and between going up and down are not considered in this survey.

**4.2 Stated preference & discrete choice modelling**

There are two main types of data collection methods in the analysis of travel behaviour: revealed preference and stated preference. Revealed preference experiment uses existing choice data to estimate a travel behaviour model while stated preference data arises from the experiment where a respondent has to choose among hypothetical alternatives (Wardman, Hine, & Stradling, 2001b).

Although revealed preference approach has high validity since it is based on real choice data, stated preference experiment is chosen for this research because of following reasons:

The goal of this thesis is to let people make trade-offs between crowding conditions and time so that the disutility of crowding can be converted to the generalized time unit. This would require variations in attribute values which is hard to be fulfilled by revealed preference approach (Louviere, Hensher, & Swait, 2000). On the contrary, it is easy to control attribute values in the stated preference experiment because it is hypothesized.

Moreover, it is hard to derive solely passengers’ perceptions towards crowding from revealed preference data because many other attributes besides crowding are involved. For example, in reality, not all passengers will know that another route to leave the station is less crowded. As a result, they would probably stay in the queue although they are willing to take another route if they can clearly see it. Uncertainty about the total walking time and the crowding level of another route are also the factors that prevent passengers to reveal their perceptions through their existing choices. Arising from experiments where a respondent has to choose among hypothetical alternatives, stated preference experiment can avoid these problems by excluding unnecessary attributes in a hypothetical alternative.

Utility maximization theory is the most common travel behaviour theory used in both practice and research. It means individuals will select the alternative with maximum benefit or minimum cost (Fishburn, 1970). Another two common theories are prospect theory and regret theory. Prospect theory captures the behaviour of loss aversion, risk aversion and risk seeking. It is suitable for the situation where uncertainty exists. And the added value of regret theory lies with its possibility of capturing regret aversion (de Moraes Ramos, 2015).

However, both prospect and regret theory do not add extra value in this experiment because such risks and regret are not important in this route choice. The utility theory is the most efficient one since it is the simplest one. Moreover, the validity of utility theory has been acknowledged by both the research and practice while prospect and regret theory require more experiment to improve their validity (de Moraes Ramos, 2015). Finally, the utility maximization theory forces respondents to consider trade-offs solely between
attributes, which is the goal of this experiment. Therefore, passengers are assumed to act according to the utility theory in this experiment.

Random utility maximization (RUM) which is based on utility theory is adopted to capture passengers’ behaviour. It is the most commonly used non-deterministic approach for route choice models and traditionally estimated in the framework of discrete choice analysis (Train K. E., 2009). In RUM, the utility ($U_i$) people perceive consists of two parts: a systematic component $V_i$ and a random component $\varepsilon_i$ (McFadden, 1974). The systematic component includes objective attributes of a trip, such as time, cost and crowding condition which can be measured by observers. The random component reflects the particular taste of each individual. The random part does not suggest that individuals make choices in some random fashion. Instead, it implies that important but unobserved factors on choice exist and can be characterised by a distribution in the sampled population, though we do not know where any particular individual is located on the distribution. Hence we assign this information to that individual stochastically (Train, 2009). Finally, an individual would choose option $i$ instead of $j$ if (Louviere, Hensher, & Swait, 2000)

$$U_i > U_j = (V_i + \varepsilon_i) > (V_j + \varepsilon_j)$$

Where $i$ and $j$ are two alternatives.

### 4.3 Survey description

The section first presents the aim and the overview of the survey. Then it discusses the utility function and the form of crowding penalty. It is followed by the introduction of choices situations and adopted attributes and attributes levels. Finally, the design of attributes combination is introduced.

#### 4.3.1 Survey aim and overview

The survey aims at determining the value of crowding in front of vertical infrastructure for the cost-benefit analysis of transfer process. It consists of three parts:

1. An introduction of the survey
2. A stated preference experiment (time versus crowding condition in front of vertical infrastructure)
3. Questions about personal information and characteristics of train travelling

#### 4.3.2 Choices situation

There are two levels of choices for a train traveller with respect to crowding at railway station as shown in Figure 14.
On the strategic level, they choose which train to take. The trip of a certain train includes characteristics like total travel time and crowding condition at station. If he/she experiences crowding once at station, in the next trip he/she might choose another departure time with another train to avoid congestion at railway stations. This is their reaction in a long term. On the tactical level, when passengers arrive at the station and see congestion in front of them, they could choose another route to avoid crowding. This decision can be made during the trip. This thesis adopts the second one as the hypothetic choice situation in the survey because walking time attribute is on the same tactical level with crowding. It is easier for respondents to understand and make realistic choices. Two routes introduced in survey are shown in Figure 15.

4.3.3 Attributes
Respondents are asked to make a hypothetical route choice so that the value of crowding can be determined. The aim of this survey study is to know the amount of walking time people would sacrifice to avoid crowding. Therefore, not all influence factors of route choice
behaviour are included in the survey, such as the type of vertical infrastructure or even the moods of passenger. Walking time is included because it is the most important aspect for passengers when they make route choices for walking (Bovy & Stern, 1990). Moreover, the goal of including walking time as an attribute is to let people make a trade-off between time and crowding condition. From the trade-off, the disutility of crowding can be expressed by the amount of walking time which can be further translated into monetary terms by value of time (value of time is a known value in literature). Another attribute of the stated preference experiment is naturally crowding condition because the aim of this experiment is to know the value of crowding.

Adopted attributes are shown in the example of choice sets in Figure 16. In this example, people need to choose between route 1 and 2. Route 1 is very crowded and route 2 is medium crowded but it has 1 minute extra walk towards a same destination.

Real photos taken in Leiden Central Station are used to reflect the crowding conditions. Use of photos has shown to facilitate the description of complex choice scenarios, where an exhaustive text-based description of attributes would over-complicate the choice task (Hurtubia & Donoso, 2014). Real photos give more direct description than texts and screenshots in pedestrian simulation. What is more, the photos are taken from passenger’s viewing angle. The chosen angle clearly presents the crowding condition a passenger would see when he/she wants to leave the platform. With real photos and viewing angle, it can better remind respondents of real situations at railway stations and thus help them to make more realistic choices.

4.3.4 Attributes levels
Because in the logit model only difference between two values has impact on the results, extra walking time is presented in the survey. And the disutility of time is assumed to be linear with time. People’s acceptations of extra time to avoid crowding are first collected in a pilot survey so that the range of walking time attribute can be assured. From a pilot, the maximum extra walking time is kept as 3 minutes. 3 levels of walking time are then determined as 1, 2, 3 minutes. Arrival scenario is set because this experiment only investigates the crowding aspect and it does not want to let respondents be affected by other factors, such as time restriction.
It is possible that passengers with long travel time would perceive less disutility of an extra 3 minute than those with short travel time. However, the base walking time is not stated in the survey because testing the perceptions of another base time would double the number of choice questions in this survey. This would add a lot of burden to the respondents. As a result, the influence of base time on the willingness of spending time to avoid crowding cannot be discussed in this thesis.

The characteristics of crowding identified in section 3.4 are location, density and the length of queue. Location is defined as the area in front of vertical infrastructure. Another two characteristics (density and queue length) together describe the levels of crowding condition. The number of presenting crowding levels is important for the survey design. Excess number of crowding levels would increase the complexity of survey and the burden of respondents while insufficient number of crowding levels would not cover the all perceptions of crowding. 4 levels of crowding are defined in this experiment based on whether passenger can overtake and the length of queue. The first level is not crowded (0.5p/m² of a 2.5m length area). In this level, passenger can easily overtake another passenger. The second level is medium crowded (1p/m² of a 2.5m length area), where overtaking becomes difficult but still possible. The third level is crowded (1.5p/m² with 2.5meters queue). In this level, a queue arises and overtaking is impossible. The last level is very crowded (1.5p/m² with 5meters queue), where there is a severe congestion with long queue. With this classification, respondents can perceive the difference between two levels and all walking behaviour under different crowding conditions can be covered at the same time. Perceptions of crowding conditions between these levels are assumed to be similar because the possibility of overtaking and of standing still does not differ a lot.

4.3.5 Utility function: expression of crowding disutility

Two components of the systematic utility are identified in this survey: walking time, crowding conditions. Walking time included in the utility function so that crowding parameters can be generalized as walking time which can be further translated into money. Walking time instead of travel cost is chosen because passengers will pay the same ticket costs no matter how crowded the station is. On the other hand, walking time is closely related to crowding and the value of walking time is known and studied by many researchers (Wardman, Hine, & Stradling, 2001b). An alternative-specific constant is added to represent the systematic factors that are not able to be captured by the two variables (walking time and crowding condition).

As for the crowding condition, there are two possible formats to express each crowding condition in a utility function: a monetary value per time unit (a travel time multiplier) or constant monetary value per trip (Li & Hensher, 2011). The first type assumes that the discomfort of crowding is proportional to the travel time while the second one assumes that effect is irrelevant of travel duration. The second one (constant penalty) is preferred in this experiment because it is easy for respondents to make a trade-off between time and crowding conditions in the experiment when the time in the crowding is not stated. Moreover, because crowding in front of vertical infrastructure does not last for a long time at Dutch stations, it is assumed that passengers perceive a certain amount of crowding penalty if that crowding situation occurs no matter how long it lasts. Discrete parameters are adopted to express different levels of crowding perception instead of a continuous one as shown in the equation below. This is because passenger can only perceive different disutility when the difference in crowding level is large enough. It is also possible that there is a threshold in crowding level that passengers start to perceive larger crowding disutility.
over a same increase. Therefore, the utility function which expresses the crowding and time aspect in the route choice is formulated as below:

\[ U = \beta_{\text{Time}} \cdot \text{WT} + \beta_{CL0} \cdot CL_0 + \beta_{CL1} \cdot CL_1 + \beta_{CL2} \cdot CL_2 + \beta_{CL3} \cdot CL_3 + \text{ASC} \quad (9) \]

Where:
CL\(_i\): Crowding Level \(i\)
WT: Walking time
ASC: A constant value which represents un-captured factors
\(\beta_{CLi}\): Parameters to be estimated

### 4.3.6 Experimental design

Software Ngene is deployed to design the combinations of choice levels. An efficient design of experiment is chosen to be generated by Ngene because the utility function contains dummy variables. Efficient design means it does not merely try to minimize the correlation in the data for estimation purposes, but also aims to result in data that generates parameter estimates with as small as possible standard errors. Several efficient designs are generated by Ngene and the one with the lowest D-error is chosen. The final experiment design for choice situations is listed in Appendix A.

### 4.3.7 Pilot

Pilot survey is conducted via interviews with a small amount of people to know how much time they would be willing to spend to avoid crowding. The largest extra time is believed to be 3 minutes based on the outcomes of pilot survey. Prior for the parameter values are determined by the pilot. It also corrects the ambiguous texts in the survey from the feedbacks of interviewees.

### 4.3.8 The format of survey

Restricted by the regulations, the format of survey is electronic and is made in Google form. It is distributed via internet.

### 4.4 Data collection

In the section, the ways to collect respondents are introduced. After that, the quality of data sample is improved by eliminating inconsistent choices. Finally, the social-demographic characteristics of sample population are shown.

#### 4.4.1 Recruitment of respondents

In total, 222 people joined this stated preference experiment. There are two sources of the respondents: social media and email. Invitations are sent only through Internet.

#### 4.4.2 Exclusion of inconsistent choices

All 222 respondents are asked to make 8 basic choices. Therefore, in total there are 1776 original choice data in this experiment. To ensure the quality of the data, criteria are developed to eliminate inconsistent choices between two choice sets. For example, when two choices sets are presented like “C1” row in Table 13, inconsistency would occur when a respondent choose to take an extra walk in choice set 1 but still stay in the crowding in choice set 2. Six possible inconsistent choice pairs are summarized in Table 13 and checked in consecutive order. If one respondent makes an inconsistent choice pair, all the choices made by that respondent will be removed from the sample.
<table>
<thead>
<tr>
<th>Choice set 1</th>
<th>Choice set 2</th>
<th>Inconsistent choice pair</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1 A: Crowded V.S. B: Medium crowded+ 2mins</td>
<td>A: Crowded V.S. B: Not crowded+ 2mins</td>
<td>Set1: Choice B Set2: Choice A</td>
</tr>
<tr>
<td>C2 A: Very crowded V.S. B: Medium crowded+ 3mins</td>
<td>A: Very crowded V.S. B: Not crowded+ 3mins</td>
<td>Set1: Choice B Set2: Choice A</td>
</tr>
<tr>
<td>C3 A: Crowded V.S. B: Medium crowded+1mins</td>
<td>A: Crowded V.S. B: Medium crowded+2mins</td>
<td>Set1: Choice A Set2: Choice B</td>
</tr>
<tr>
<td>C4 A: Crowded V.S. B: Not crowded+ 2mins</td>
<td>A: Crowded V.S. B: Not crowded+ 3mins</td>
<td>Set1: Choice A Set2: Choice B</td>
</tr>
<tr>
<td>C5 A: Very crowded V.S. B: Not crowded+ 2mins</td>
<td>A: Crowded V.S. B: Not crowded+ 3mins</td>
<td>Set1: Choice B Set2: Choice A</td>
</tr>
<tr>
<td>C6 A: Very crowded V.S. B: Not crowded+ 3mins</td>
<td>A: Crowded V.S. B: Not crowded+ 3mins</td>
<td>Set1: Choice A Set2: Choice B</td>
</tr>
</tbody>
</table>

In total, 11 respondents made inconsistent choice pair and therefore they are removed from sample data. Finally, the sample size of survey remains at 211 respondents.

4.4.3 Distribution of social-demographic characteristics

In the last part of the survey, the social-demographic characteristics of the respondent which includes common trip motives, trip frequency, age and gender are collected.

Common trip motive is asked because it is assumed that passengers behave similar when they always travel on one motive. Seven motives are distinguished in the survey so that people can easily identify their own common motives. They are work (commute), business, study, visit family/ friends, sport and hobby, shopping, and vocation & outing. Visit family/ friends, sport and hobby are classified as social while shopping and vocation & outing are regarded as recreational. Since the number of business trips is low and there is no big difference between work and business trip, business trip motive is combined with work.

Schakenbos (2014) indicates that Dutch Railway company (NS) conducts research on large scale every few years to obtain the characteristics of Dutch train travellers. The real-life distribution of trip motives from NS is referred to and listed together with sample distribution in Table 14. After comparing sample and NS population, it is clear that trip motives “Study” is underestimated in the sample while “Social” and “Recreational” are overestimated. The percentage of trip motives “Work” and “Business” is similar to the real situation. In the results interpretation phase, only groups with enough population are segmented for specific analysis.

<table>
<thead>
<tr>
<th>Trip motives</th>
<th>Sample population (people)</th>
<th>NS population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work + Business</td>
<td>80 + 21 (47.8%)</td>
<td>45%</td>
</tr>
<tr>
<td>Study</td>
<td>26 (12.3%)</td>
<td>31%</td>
</tr>
<tr>
<td>Social</td>
<td>39 (18.5%)</td>
<td>11%</td>
</tr>
<tr>
<td>Recreational</td>
<td>45 (21.3%)</td>
<td>13%</td>
</tr>
</tbody>
</table>

Four levels of trip frequency are defined in the survey. They are shown in Table 15. The sample and real-life distributions of trip frequency are compared as well. The share of people who travel less than 1 day per month is similar to the real situation. However, the
share of frequent passengers who travel more than 1 day per week is underestimated while the share of passengers who travel 1-3 days per month are overestimated.

Table 15 Sample and real-life distributions of trip frequency

<table>
<thead>
<tr>
<th>Trip frequency</th>
<th>Sample population (people)</th>
<th>NS population</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 days per week and more</td>
<td>75 (35.5%)</td>
<td>77%</td>
</tr>
<tr>
<td>1-3 days per week</td>
<td>56 (26.5%)</td>
<td></td>
</tr>
<tr>
<td>1-3 days per month</td>
<td>56 (26.5%)</td>
<td>10%</td>
</tr>
<tr>
<td>Less than 1 day per month</td>
<td>24 (11.4%)</td>
<td>13%</td>
</tr>
</tbody>
</table>

Table 16 shows the age distribution of sample population. The sample lacks people under 18 and above 64 because there is no access to those people in this survey. Group between 25 and 34 has the largest population while other age groups have similar shares as real situation except that age group between 18 and 24 is underestimated.

Table 16 Sample and real-life distributions of age

<table>
<thead>
<tr>
<th>Age</th>
<th>Sample population (people)</th>
<th>NS population</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;18</td>
<td>0</td>
<td>5%</td>
</tr>
<tr>
<td>18-24</td>
<td>58 (27.5%)</td>
<td>37%</td>
</tr>
<tr>
<td>25-34</td>
<td>93 (44.1%)</td>
<td>21%</td>
</tr>
<tr>
<td>35-44</td>
<td>22 (10.4%)</td>
<td>14%</td>
</tr>
<tr>
<td>45-54</td>
<td>26 (12.3%)</td>
<td>12%</td>
</tr>
<tr>
<td>55-64</td>
<td>10 (4.7%)</td>
<td>6%</td>
</tr>
<tr>
<td>&gt;64</td>
<td>2 (0.9%)</td>
<td>4%</td>
</tr>
</tbody>
</table>

As for the gender, there are more male in the sample than in the real population.

Table 17 Sample and real-life distributions of gender

<table>
<thead>
<tr>
<th>Age</th>
<th>Sample population (people)</th>
<th>NS population (percentage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>129 (61.1%)</td>
<td>51%</td>
</tr>
<tr>
<td>Female</td>
<td>82 (38.9%)</td>
<td>49%</td>
</tr>
</tbody>
</table>

After testing the effects of social-demographic characteristics in the next chapter, the characteristics distribution can indicate whether the sample of respondents creates a selection bias towards to final results.

4.5 Conclusion

In this chapter, area in front of vertical infrastructure is chosen as the crowding study area. Stated preference experiment with discrete choice modelling is determined as the approach to know the monetary values of crowding. As a result, a survey is designed: choice on the route level is used in the survey to let people make a trade-off between crowding and time. 4 crowding levels are classified based on whether overtaking can happen and the length of queue. Levels of extra walking time are determined based on a pilot. Ngene software is deployed to design the combinations of choice sets.

After designing the survey, the survey is distributed through internet and data are collected. In total, 214 people completed the survey. The quality of dataset is improved by excluding
inconsistent choices. Finally, the distribution of respondents’ social-demographic characteristics is analysed. This helps to explain whether the sample creates a selection bias during results interpretation. In the next chapter, models will be estimated based on the sample data and results will be interpreted.
5 Model estimation & Results interpretation

This chapter discusses the third and fourth step of the stated preference study: model estimation and result interpretation. It answers the sub-research question below:

(5) How to interpret the resulted values of crowding?

First of all, the statistical analysis of choice data is given so that a general picture of how people choose between two routes under different scenarios is clear. Then a generic multinomial logic model is estimated and the results are interpreted. It is followed by the tests of social-demographic characteristics on the values of crowding. To know their impacts, required tests and approach are introduced. The results of various values of crowding are presented in the end along with the interpretations.

5.1 Analysis setup

The model estimation starts with an overview of statistical analysis of choice data. The percentage of choosing two routes in each choice set is presented. Then, a basic multinomial (MNL) model is estimated with generic parameters. Although there are several models available to estimate passengers’ travelling choices under utility maximization theory, multinomial model is the most convenient and most popular practical discrete choice model so far (Train, 2009). It is chosen because it requires the lowest computation effort while the assumption of the model is fulfilled. MNL assumes that the unobserved factors are uncorrelated over alternatives and are independent and identically distributed extreme value. Because in the choice situation of this experiment, the ratio of choosing one route over another is unaffected by the presence of any additional alternative in the choice set, the assumption of MNL model correspond to the choice behaviour. MNL model is therefore considered as the most efficient model for the purpose of the value of crowding determination.

After the estimation of a generic model, the effects of social-demographic characteristics on the values of crowding are tested. This can be done by replacing the generic parameters in the basic MNL model by specific ones. Because the sample does not fully represent the real population at station, understanding the effects of social-demographic characteristics gives indication about whether the sample population has created a bias to the general values of crowding. Finally, models with a segmentation of significant influencing characteristics are estimated. As a result, values of crowding by the significant characteristics are determined.

To summarize, four analysis steps are listed below:

• Statistical analysis of choice data
• Estimation of a basic MNL model
• Test the effects of trip motive, travel frequency, age and gender.
• Estimation of MNL models with a segmentation of significant influencing characteristic

5.2 Statistical analysis of choice data

Table 18 presents all the choice sets in the survey. They are presented to every respondent. The percentages of respondents choosing each route are shown in Table 19. The largest
percentage of respondents choosing route 2 (a detour to avoid crowd) exists in the seventh choice set while the least percentage of respondents choosing route 2 exists in the fifth choice set. Because the only difference between fifth and seventh choice set is the crowding condition on route 1. In the fifth choice set, route 1 is crowded while it is very crowded in the seventh. Therefore, a large gap in crowding perceptions between “very crowded” and “crowded” is identified, which means people dislike the “very crowded” condition much more than “crowded” condition. What is more, more people choose route 2 than 1 only when “very crowded” condition is presented in the choice set. This could indicate the disutility of “very crowded” condition is much higher than others. These findings can be further validated by the resulted values of crowding.

<table>
<thead>
<tr>
<th>Choice set</th>
<th>Route 1</th>
<th>Route 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Very crowded</td>
<td>Crowded + 2mins</td>
</tr>
<tr>
<td>2</td>
<td>Very crowded</td>
<td>Medium crowded + 3mins</td>
</tr>
<tr>
<td>3</td>
<td>Crowded</td>
<td>Medium crowded + 1mins</td>
</tr>
<tr>
<td>4</td>
<td>Medium crowded</td>
<td>Not crowded + 1mins</td>
</tr>
<tr>
<td>5</td>
<td>Crowded</td>
<td>Not crowded + 3mins</td>
</tr>
<tr>
<td>6</td>
<td>Crowded</td>
<td>Medium crowded + 2mins</td>
</tr>
<tr>
<td>7</td>
<td>Very crowded</td>
<td>Not crowded + 3mins</td>
</tr>
<tr>
<td>8</td>
<td>Crowded</td>
<td>Not crowded +2mins</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Choice set</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage of respondents choosing Route 1</td>
<td>48.9%</td>
<td>49.3%</td>
<td>53.6%</td>
<td>76.3%</td>
<td>79.6%</td>
<td>74.9%</td>
<td>37.0%</td>
<td>67.8%</td>
</tr>
<tr>
<td>Percentage of respondents choosing Route 2</td>
<td>51.10%</td>
<td>50.70%</td>
<td>46.40%</td>
<td>23.70%</td>
<td>20.40%</td>
<td>25.10%</td>
<td>63.00%</td>
<td>32.20%</td>
</tr>
</tbody>
</table>

5.3 Estimation of a generic model

In this section, a model with generic parameters is estimated. In the beginning, the selected type of the model is introduced. The results of model estimation are given and the meanings of statistics in the output are explained.

5.3.1 Multinomial model

In the multinomial model, the choice possibility of an individual to choose one alternative equals to

\[
P_{iq} = \frac{e^{V_{iq}}}{\sum_{j=1}^{N} e^{V_{ij}}} \quad (10)
\]

Where i means one alternative, N means the total number of alternatives

The MNL in this thesis includes two attributes which have been determined in the survey design: walking time and crowding condition. Crowding conditions are modelled with dummy variables because crowding perceptions are considered to be discrete in section 4.3.5. Walking time is modelled as a linear function since it is continuous. Moreover, the
alternatives are labelled because choice 1 represents the short but crowded route and choice 2 represents the detour. As a result, the conditions in choice 1 (CL 1-3) can only be more crowded than that of choice 2 (CL 0-2) and an alternative specific constant (ASC) is used in the utility function of choice 2 to reflect the disutility of extra walking distance. To conclude the utility functions used to represent two choices in this survey are listed below:

\[
U_1 = \beta_{CL3} * CL_{13} + \beta_{CL2} * CL_{12} + \beta_{CL1} * CL_{11} \\
U_2 = \beta_{CL2} * CL_{22} + \beta_{CL1} * CL_{21} + \beta_{CL0} * CL_{20} + \beta_{Time} * WT + ASC
\]  

(11)

Where \(U_1\) represents the choice 1 and \(U_2\) represents the choice 2. CL\(ij\) are dummy variables representing crowd level j in alternative i, \(\beta_{CLi}\) are the parameters of crowd level i, CL3 means the most crowded level while CL0 means the lowest level. \(WT\) is the value of walking time, \(\beta_{Time}\) is the parameter of walking time.

Biogeme software is used to estimate the model from the data collected from the survey. A generic MNL model with all sample data is generated below. In the output file of Biogeme software, the characteristics of the model estimation are given. ‘Observations’ represents the number of choice sets included in the data. Statistical values which are related to the quality of the model which are given. The outcomes of model estimation include the parameter values of the utility function identified in section 4.3.5. They are \(\beta_{CLi}\), \(\beta_{Time}\) and ASC in this model. For each parameter, their mean value, standard error t-value and p-value (the meaning of t-value and p-value are introduced in the next section) are given. Moreover, the parameters of non-time attribute are all translated into generalized walking time (in minutes) since the final goal of the estimation is to determine value of crowding.

5.3.2 Goodness of fit

The rho-square is a measure for the goodness of fit of the model. It tells how good the model fits the data. It can be calculated as below (Train, 2009)

\[
\rho^2 = 1 - \frac{LL(\hat{B})}{LL(0)}
\]  

(12)

where \(LL(\hat{B})\) is the final log-likelihood, \(LL(0)\) is the trivial log-likelihood (trivial log-likelihood is the log-likelihood of all parameters equal to zero).

This value always increases when more parameters are added to the model. However, adding more parameters makes the model more complex and thus could also lead to overfitting. The adjusted rho-square takes these considerations into account by adjusting the rho-square for the number of parameters. It can be calculated by the equation below:

\[
\bar{\rho}^2 = 1 - \frac{(LL(\hat{B}) - K)}{LL(0)}
\]  

(13)

Where K is the total number of estimated parameters, a higher adjusted rho-square means an improvement in model fit.

In theory \(\bar{\rho}^2\) varies between 0 and 1. The best \(\bar{\rho}^2\) value a model can get is 1. However, values of \(\bar{\rho}^2\) between 0.2 and 0.4 are considered to indicative of extremely good model fits in practice. (Louviere, Hensher, & Swait, 2000).
5.3.3 Significance values
To test the significance of the estimated parameters, the t-value is calculated for each parameter as the ratio of its mean value to its standard error (Louviere, Hensher, & Swait, 2000). The null hypothesis of the t-test is that the possibility of an individual choosing an alternative is independent of the attribute in the MNL function. If the hypothesis is retained, then the parameter of that crowding condition attribute is set to zero which means people perceive no disutility for that crowding condition level. Biogeme automatically performs t-test for all parameters in the utility function. When the absolute t-value is higher than 1.96, it is considered significant based on 95% confidence. The significance level is at 1.65 when confidence level is set at 90%.

The reported p value is calculated as: \( p = 2(1 - \Phi(t)) \), where \( \Phi(t) \) is the cumulative distribution function of a standardized normal random variable, estimated at the value t. P-value represents the possibility of that parameter to be insignificant.

5.4 Outcomes of generic model estimation
The outcomes of model estimation demonstrated in Table 20 consist of two parts: values of crowding and the statistic performance of the model estimation.

5.4.1 Values of crowding
Generated from the model estimation, crowding parameters can first be transformed to the generalized walking time by dividing the parameter value of time in this model. After that, monetary values of crowding can be determined by multiplying value of walking time. The equation for calculating the values of crowding is listed as below:

\[
VOC = GWT \times VOT \times M_{WT}
\]  \( (14) \)

Where VOC means value of crowding, GWT means generalized walking time, VOT means value of time and \( M_{WT} \) means walking time multiplier.

Based on the literature review, the value of walking time is 15.26 euro/hour. The resulting values of crowding are shown in Table 20 and Figure 17.
Table 20 Results of generic model estimation

<table>
<thead>
<tr>
<th>Basic MNL Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observations</td>
</tr>
<tr>
<td>Null log-likelihood</td>
</tr>
<tr>
<td>Final log-likelihood</td>
</tr>
<tr>
<td>Rho-square</td>
</tr>
<tr>
<td>Adjusted rho-square</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
<th>Std-error</th>
<th>Robust t-value</th>
<th>P-value</th>
<th>Generalized walking time (minutes)</th>
<th>Value of crowding (VOC) (euros/p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASC</td>
<td>-0.511</td>
<td>0.160</td>
<td>-3.21</td>
<td>0.00</td>
<td>0.65</td>
<td></td>
</tr>
<tr>
<td>$\beta_{CL3}$</td>
<td>-3.36</td>
<td>0.409</td>
<td>-8.14</td>
<td>0.00</td>
<td>4.28</td>
<td>1.09</td>
</tr>
<tr>
<td>$\beta_{CL2}$</td>
<td>-1.35</td>
<td>0.249</td>
<td>-5.42</td>
<td>0.00</td>
<td>1.72</td>
<td>0.45</td>
</tr>
<tr>
<td>$\beta_{CL1}$</td>
<td>-0.293</td>
<td>0.126</td>
<td>-2.35</td>
<td>0.02</td>
<td>0.37</td>
<td>0.10</td>
</tr>
<tr>
<td>$\beta_{CL0}$</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\beta_{Time}$</td>
<td>-0.785</td>
<td>0.130</td>
<td>-5.94</td>
<td>0.00</td>
<td>1</td>
<td>0.25</td>
</tr>
</tbody>
</table>

From the results, it is clear that there is a jump in the disutility of crowding when a queue is presented (queue starts to appear in crowding level 2). Moreover, the value of crowding increases more than double when the queue grows to its double size. These findings suggest that queue plays an important role in crowding perception levels. When density is low and queue is not formed, the value of crowding is much lower. The ASC equals to 0.65 generalized walking time from the estimation, which means when the detour can save more than 0.65 minute, people are willing to walk further.

5.4.2 Statistic performance
This adjusted rho-square of the generic model (0.095) is not high. This can be caused when the underlying behaviour differs a lot among individuals and the current sample size is not
enough to derive a significant relation from the differences. Besides the sample size, it could also because that some other important attributes are not observed in the behaviour model. Another explanation of the low adjusted rho-square is the noise of survey data. Different interpretations of the choice situation and attributes might appear. For example, some of respondents may have unrealistic perceptions of walking time since it is only reflected on paper instead of real experiences. This can lead to difference in the responses among individuals.

However, the robust t-values and p-values of all parameters turn out to be significant, which means the observed attributes are all important for the choice. The low adjusted rho-square means other important attributes are not captured in the model. However, since the goal of this experiment is to derive values of crowding for social-economic appraisal instead of behaviour prediction, the estimated model with its results is still useful.

5.5 Estimation of specific models

It is possible that individuals with different social-demographic characteristics have different values of crowding. To test the effects of social-demographic characteristics on the values of crowding, generic parameters in the original utility function are replaced by specific ones which represent population with specific social-demographic characteristics. Below is an example of the gender segmentation. In the utility function, the parameter in generic model, for example  is replaced by  and  .

\[
U_1 = \beta_{CL,3\text{male}} \cdot CL13 \cdot \text{Male} + \beta_{CL,3\text{female}} \cdot CL13 \cdot \text{Female} + \beta_{CL,2\text{male}} \cdot CL12 \cdot \text{Male}
\]

\[
+ \beta_{CL,2\text{female}} \cdot CL12 \cdot \text{Female} + \beta_{CL,1\text{male}} \cdot CL11 \cdot \text{Male} + \beta_{CL,1\text{female}} \cdot CL11 \cdot \text{Female}
\]

\[
U_2 = \beta_{CL,2\text{male}} \cdot CL22 \cdot \text{Male} + \beta_{CL,2\text{female}} \cdot CL22 \cdot \text{Female} + \beta_{CL,1\text{male}} \cdot CL21 \cdot \text{Male}
\]

\[
+ \beta_{CL,1\text{female}} \cdot CL21 \cdot \text{Female} + \beta_{CL,0\text{male}} \cdot CL20 \cdot \text{Male} + \beta_{CL,0\text{female}} \cdot CL20 \cdot \text{Female}
\]

\[
+ \beta_{\text{Time}} \cdot WT + ASC
\]

Where  represents the choice 1 and  represents the choice 2

\( CLij \) are dummy variables representing crowding level  in alternative  

\( \beta_{CLi\text{female}} \) are the parameters of crowding level  for female group

\( \beta_{CLi\text{male}} \) are the parameters of crowding level  for male group

\( WT \) is the value of walking time

\( \beta_{\text{Time}} \) is the parameter of walking time

ASC is alternative specific constant

5.5.1 Test of significant difference

To determine whether the difference between the parameters specified for different social-demographic characteristics on the same crowding level is significant, t-test is performed. T-value can be calculated by using the formula below

\[
t = \left( \frac{X_1 - X_2}{S_1^2 + S_2^2} \right) \left( \frac{1}{N_1} + \frac{1}{N_2} \right)^{-1}
\]
Where $\bar{X}_1$ and $\bar{X}_2$ are the means of two parameter, $S_1$ and $S_2$ mean the standard deviation of two parameters, $N_1$ and $N_2$ are the sample size for two group.

A high absolute t-value means the difference is significant. The thresholds for the T-value under large sample size are shown in the table below. For example, as shown in Table 21, when the confidence level is set at 90%, a significant relation only holds when t-value is higher than 1.645.

<table>
<thead>
<tr>
<th>Confidence interval</th>
<th>90%</th>
<th>95%</th>
<th>98%</th>
<th>99%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Threshold values</td>
<td>1.645</td>
<td>1.96</td>
<td>2.326</td>
<td>2.578</td>
</tr>
</tbody>
</table>

5.5.2 Test of model improvement

The Chi-square test is used to check whether replacing generic parameters can significantly improve the adjusted rho-square and thus the quality of the model. Naturally, a model will perform better when more specific parameters are included to describe the relation. However, when a model becomes excessively complex with too many parameters, over-fitting of the sample data would occur, which means the estimated model describes random error or noise instead of the underlying relationship. The null hypothesis of the Chi-square is that extra parameters are equal to generic ones, which means the quality of original model is not improved. The first step of the Chi-square test is to estimate two models with the same data. Then the generalized likelihood ratio can be calculated as below (Louviere, Hensher, & Swait, 2000):

$$L = L(\omega) / L(\Omega)$$  \hspace{1cm} (17)

Where $L$ is the likelihood ratio, $L(\omega)$ is the likelihood of original model while $L(\Omega)$ is the likelihood of new model with more parameters.

The next step is to see if the quantity $-2 \ln L$ is greater than a critical value of $\chi^2$ from a predefined significance level. The test is passed if the equation below is fulfilled:

$$-2 \ln L > \chi^2_{(1-\alpha),df}$$  \hspace{1cm} (18)

Where $\alpha$ is the level of significance (in this case $\alpha = 0.05$), df means degrees of freedom which equals the number of extra parameters added.

Finally if the test is passed, null hypothesis is rejected and the parameter values from the new model should be adopted since the new model has a better fit of the sample data.

5.5.3 Approach to determine the impacts of social-demographic characteristics

Before determining characteristic specific values of crowding, it is necessary to first identify whether there are differences in crowding perceptions for different characteristic and on which crowding level. Because the survey collects four social-demographic characteristics: passengers’ trip motive, trip frequency, age and gender, each one of them is selected and tested to see the impacts on crowding perceptions. It is done by replacing generic parameters of all attributes (crowding condition levels) by characteristic specific parameters. After estimating the specific model, insignificant parameters (high p-value) are set to 0. Then the new model is estimated and the generated social-demography specific parameters of same crowding condition are compared by t-test. Only if there are significant differences among those specific parameters under one crowding level, then that characteristic is
considered to have impacts on the perceptions of this crowding condition. The same t-test applies for three crowding conditions while the last one is set as reference level.

Generic parameter of each crowding condition is replaced by specific ones only when social-demographic characteristic has impacts on that. Then a new model with specific parameters is generated and estimated. If it has a larger adjusted rho-square, it means the model has been approved, while chi-square test checks if such improvement is significant. If both criteria are met, the specific values of crowding from the new model are adopted. Otherwise, the generic values from the original model are adopted.

The approach to determine the impacts of social-demographic characteristics and the specific values of crowding are summarized in Figure 18.
Replace all generic parameters by social-demography specific parameters

Estimate the model

Significant p-value of all parameters?

Yes  

Significant t-test of specific parameters between groups?

Yes  

This social-demographic characteristic has impacts on the perception of this crowding level

No  

This social-demographic characteristic has no impact on the perception of this crowding level

Set that parameter to 0

Replace the generic parameter on this crowding level by specific parameters

Higher Adjusted rho-square?

Yes  

Pass the chi-square test?

Yes  

Use values from the specific model on this crowding level

No  

Use the value from the generic model on this crowding level

Results of Chapter 6.5

Figure 18 Flowchart for determining the impacts of characteristics and the specific values of crowding
5.6 Social-demographic impacts

Whether the four social-demographic characteristics have impacts on crowding perceptions are analysed based on the approach developed in the last section. This helps to know whether the unrepresentativeness of sample population in terms of each social-demographic characteristic would create a bias to the final results.

5.6.1 The impacts of trip motives

The impacts of trip motives on passengers’ crowding perceptions are first examined. Although five motive categories are identified in the survey design, two motive categories are distinguished here because of limited number of respondents. Work and business trips are combined while non-work (study, social and recreational) trips are combined. Such a combination can assure the sample size and decrease the parameters added to the model. Moreover, from the behavioural point of view, working and business people behave similar since they are all constrained by time and have higher values of time than other motives (Significance & VU University Amsterdam, 2012). After adding specific parameters on all crowding levels, values of the specific parameters are estimated. The mean values and standard errors which are required for calculating the t-values are shown in Table 22. The differences on the perceptions of each level by trip motives can be determined by performing T-test between two specific parameters. The outcomes are listed in Table 23. From the results, differences between two groups are significant on all levels and therefore trip motive is considered to have impacts on the perceptions of all crowding levels.

<table>
<thead>
<tr>
<th>Crowding level</th>
<th>Parameter value of working</th>
<th>Standard error</th>
<th>Parameter value of non-working</th>
<th>Standard error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very crowded (CL3)</td>
<td>-2.92</td>
<td>0.338</td>
<td>-3.83</td>
<td>0.389</td>
</tr>
<tr>
<td>Crowded (CL2)</td>
<td>-0.977</td>
<td>0.195</td>
<td>-1.70</td>
<td>0.244</td>
</tr>
<tr>
<td>Medium crowded (CL1)</td>
<td>0</td>
<td>0</td>
<td>-0.535</td>
<td>0.151</td>
</tr>
</tbody>
</table>

Table 23 The impacts of trip motive on the perceptions of crowding levels

<table>
<thead>
<tr>
<th>Crowding level</th>
<th>T-values of the parameter differences by working or non-working</th>
<th>Confidence level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very crowded (CL3)</td>
<td>1.76</td>
<td>90%</td>
</tr>
<tr>
<td>Crowded (CL2)</td>
<td>2.3</td>
<td>95%</td>
</tr>
<tr>
<td>Medium crowded (CL1)</td>
<td>3.54</td>
<td>99%</td>
</tr>
<tr>
<td>Not crowded (CL0)</td>
<td>Reference level (Parameter is set to 0)</td>
<td></td>
</tr>
</tbody>
</table>

5.6.2 The impacts of trip frequency

To ensure a reasonable sample size, respondents are divided into two trip frequency groups (frequent and infrequent) during the analysis of its impacts on crowding perceptions. Frequent people are defined as the people who travel 4 days per week and more while infrequent people travel less than 4 days per week. Important parameter values and their standard error from the estimation of frequency specific model are presented in Table 24 and Table 25 shows that trip frequency has strong impacts on the perceptions of all crowding levels.
Table 24 Frequency specific parameter values and their standard error

<table>
<thead>
<tr>
<th>Crowding level</th>
<th>Parameter value of frequent</th>
<th>Standard error</th>
<th>Parameter value of infrequent</th>
<th>Standard error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very crowded (CL3)</td>
<td>-2.69</td>
<td>0.357</td>
<td>-3.76</td>
<td>0.395</td>
</tr>
<tr>
<td>Crowded (CL2)</td>
<td>-0.764</td>
<td>0.210</td>
<td>-1.65</td>
<td>0.245</td>
</tr>
<tr>
<td>Medium crowded (CL1)</td>
<td>0</td>
<td></td>
<td>-0.418</td>
<td>0.141</td>
</tr>
</tbody>
</table>

Table 25 The impacts of trip frequency on the perceptions of crowding levels

<table>
<thead>
<tr>
<th>Crowding level</th>
<th>T-values of the differences by frequent or infrequent</th>
<th>Confidence level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very crowded (CL3)</td>
<td>2</td>
<td>95%</td>
</tr>
<tr>
<td>Crowded (CL2)</td>
<td>2.74</td>
<td>99%</td>
</tr>
<tr>
<td>Medium crowded (CL1)</td>
<td>2.96</td>
<td>99%</td>
</tr>
<tr>
<td>Not crowded (CL0)</td>
<td>Reference level (Parameter is set to 0)</td>
<td></td>
</tr>
</tbody>
</table>

5.6.3 The impacts of age

Three age groups are segmented in this analysis. They are 18-24 years, 25-54 year, and larger than 54 years. People between 18 and 24 are usually students. They tend to behave similar. Respondent older than 54 is considered as old people because there are few above 64 in this survey. Table 26 presents the results of age specific model estimation. After performing t-tests, age is found to have no significant influence on the perceptions of crowding on all levels as shown in Table 27.

Table 26 Age specific parameter values and their standard error

<table>
<thead>
<tr>
<th>Crowding level</th>
<th>Parameter value of 18-24</th>
<th>Standard error</th>
<th>Parameter value of 24-54</th>
<th>Standard error</th>
<th>Parameter value of above 54</th>
<th>Standard error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very crowded (CL3)</td>
<td>-2.86</td>
<td>0.318</td>
<td>-2.60</td>
<td>0.291</td>
<td>-2.86</td>
<td>0.448</td>
</tr>
<tr>
<td>Crowded (CL2)</td>
<td>-0.997</td>
<td>0.196</td>
<td>-0.840</td>
<td>0.168</td>
<td>-1.34</td>
<td>0.316</td>
</tr>
<tr>
<td>Medium crowded (CL1)</td>
<td>0</td>
<td></td>
<td>0</td>
<td></td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

Table 27 The impacts of age on the perceptions of crowding levels

<table>
<thead>
<tr>
<th>Crowding level</th>
<th>T-values of the differences by age</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>18-24/25-54</td>
</tr>
<tr>
<td>Very crowded (CL3)</td>
<td>0.6 (*)</td>
</tr>
<tr>
<td>Crowded (CL2)</td>
<td>0.6 (*)</td>
</tr>
<tr>
<td>Medium crowded (CL1)</td>
<td>0(*)</td>
</tr>
<tr>
<td>Not crowded (CL0)</td>
<td>Reference level (Parameter is set to 0)</td>
</tr>
</tbody>
</table>

(*) insignificant relation with 90% confidence
5.6.4 The impacts of gender

It is also checked whether female and male have different crowding perceptions. The results in Table 28 and Table 29 show that they only differ in the perceptions of medium crowded condition while share similar perceptions on the other crowding levels.

Table 28 Gender specific parameter values and their standard error

<table>
<thead>
<tr>
<th>Crowding level</th>
<th>Parameter value of Male</th>
<th>Standard error</th>
<th>Parameter value of Female</th>
<th>Standard error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very crowded (CL3)</td>
<td>-2.86</td>
<td>0.320</td>
<td>-3.48</td>
<td>0.378</td>
</tr>
<tr>
<td>Crowded (CL2)</td>
<td>-1.01</td>
<td>0.183</td>
<td>-1.45</td>
<td>0.244</td>
</tr>
<tr>
<td>Medium crowded (CL1)</td>
<td>0.0</td>
<td>0</td>
<td>-0.437</td>
<td>0.167</td>
</tr>
</tbody>
</table>

Table 29 The impacts of gender on the perceptions of crowding levels

<table>
<thead>
<tr>
<th>Crowding level</th>
<th>T-values of the differences by gender</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very crowded (CL3)</td>
<td>1.25 (*)</td>
</tr>
<tr>
<td>Crowded (CL2)</td>
<td>1.44 (*)</td>
</tr>
<tr>
<td>Medium crowded (CL1)</td>
<td>2.62 (99% confidence)</td>
</tr>
<tr>
<td>Not crowded (CL0)</td>
<td>Reference level (Parameter is set to 0)</td>
</tr>
</tbody>
</table>

(*) insignificant relation with 90% confidence

5.7 Values of crowding by social-demographic characteristics and their interpretations

Based on the understanding of social-demographic impacts on crowding perceptions, it is possible to decide whether specific parameter values should be adopted for each characteristic. The determination of specific parameter values are performed according to the approach developed in section 5.5.3. From last section, age is found to have no impacts on all crowding levels. Therefore it is not discussed in this section.

5.7.1 Values of crowding with a distinction by trip motive

As the impacts of two trip motives are significant on all three crowding levels from Chapter 5.6.1, there are three more parameters in the new model than the original one. The adjusted rho-square is improved by 0.01. The chi-square test which checks the significance of the improvement is performed and passed with a 95% confidence interval. This means that adding the motive specific parameters can significantly improve the quality of the model.

The results of model estimation with a distinction by trip motives are shown in Table 30. From the generalized walking time, it is clear that people with work motive are not willing to sacrifice as much time as those of non-working people to avoid crowding. The difference on the “most crowded level” is the largest. This can be interpreted as people who travel on work purpose are more likely to be constraint by time and they are not willing to sacrifice too much time for less crowding. However, after considering different values of time for different trip motives, such gaps are narrowed and value of crowding for working is even higher that those with other purposes. This is because those with work motives have higher...
value of time than social and leisure. Kouwenhoven et al. (2014) indicate that the value of
time for working in the Netherlands is 11.5 euro/hour while it is 7 euro/hour for non-
working. Finally the monetary values of crowding with a distinction by trip motive are
demonstrated in Figure 19.

The small differences in monetary values of crowding by trip motive indicate that
unrepresentativeness in trip motive would not lead to a bias to the general values of
crowding.

<table>
<thead>
<tr>
<th>Table 30 Results of specific model by trip motive</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Observations</strong></td>
</tr>
<tr>
<td><strong>Null log-likelihood</strong></td>
</tr>
<tr>
<td><strong>Final log-likelihood</strong></td>
</tr>
<tr>
<td><strong>Rho-square</strong></td>
</tr>
<tr>
<td><strong>Adjusted rho-square</strong></td>
</tr>
<tr>
<td><strong>ASC</strong></td>
</tr>
<tr>
<td>-0.513</td>
</tr>
<tr>
<td>βCL3_Work</td>
</tr>
<tr>
<td>βCL3_NonWork</td>
</tr>
<tr>
<td>βCL2_Work</td>
</tr>
<tr>
<td>βCL2_NonWork</td>
</tr>
<tr>
<td>βCL1_Work</td>
</tr>
<tr>
<td>βCL1_NonWork</td>
</tr>
<tr>
<td>βCL0</td>
</tr>
<tr>
<td>βTime</td>
</tr>
</tbody>
</table>
5.7.2 Values of crowding with a distinction by trip frequency

Trip frequency is proved to have significant impacts on all levels of crowding perceptions in 5.6.2. Generic parameters are replaced by specific ones which results in three more parameters in the new model. Adjusted rho-square is improved by 0.014 and chi-square test is passed with 95% confidence interval. This means adding the frequency specific parameters of those two attributes can significantly improve the quality of the model.

The values of crowding with a distinction of trip motives are shown in Figure 19.
Table 31 and Figure 20. Values of crowding for frequent travellers are 0.8 minute less than those of infrequent travellers on crowding level 1 and 2. It is 1.3 minutes less than that of infrequent travellers.

It can be concluded that frequent travellers do not consider crowding as seriously as infrequent travellers because either they are used to crowding every day or they have many experiences in the crowding in front of vertical infrastructure so that they know the queue will dissolve in a short time. The significant differences in monetary values of crowding by trip frequency indicate that unrepresentativeness in trip frequency would lead to a bias to the general values of crowding.
### Table 31 Results of specific model by trip frequency

<table>
<thead>
<tr>
<th></th>
<th>Observations</th>
<th>Null log-likelihood</th>
<th>Final log-likelihood</th>
<th>Rho-square</th>
<th>Adjusted rho-square</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1688</td>
<td>-1170.032</td>
<td>-1035.509</td>
<td>0.115</td>
<td>0.109</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
<th>Robust Std-error</th>
<th>Robust t-value</th>
<th>P-value</th>
<th>Generalized walking time (minutes)</th>
<th>Value of crowding (VOC) (euros/p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASC</td>
<td>-0.507</td>
<td>0.160</td>
<td>-3.18</td>
<td>0.00</td>
<td>0.64</td>
<td></td>
</tr>
<tr>
<td>$\beta_{CL3, Frequent}$</td>
<td>-2.69</td>
<td>0.358</td>
<td>-7.51</td>
<td>0.00</td>
<td>3.37</td>
<td>0.86</td>
</tr>
<tr>
<td>$\beta_{CL3, Infrequent}$</td>
<td>-3.76</td>
<td>0.399</td>
<td>-9.42</td>
<td>0.00</td>
<td>4.71</td>
<td>1.20</td>
</tr>
<tr>
<td>$\beta_{CL2, Frequent}$</td>
<td>-0.764</td>
<td>0.206</td>
<td>-3.70</td>
<td>0.00</td>
<td>0.96</td>
<td>0.25</td>
</tr>
<tr>
<td>$\beta_{CL2, Infrequent}$</td>
<td>-1.65</td>
<td>0.245</td>
<td>-6.74</td>
<td>0.00</td>
<td>2.07</td>
<td>0.53</td>
</tr>
<tr>
<td>$\beta_{CL1, Frequent}$</td>
<td>0</td>
<td>0.120</td>
<td>-0.76</td>
<td>0.00</td>
<td>0.13</td>
<td></td>
</tr>
<tr>
<td>$\beta_{CL1, Infrequent}$</td>
<td>-0.418</td>
<td>0.142</td>
<td>-2.93</td>
<td>0.00</td>
<td>0.52</td>
<td>0.13</td>
</tr>
<tr>
<td>$\beta_{CL0}$</td>
<td>0</td>
<td>0.140</td>
<td>-0.41</td>
<td>0.00</td>
<td>0.96</td>
<td></td>
</tr>
<tr>
<td>$\beta_{Time}$</td>
<td>-0.798</td>
<td>0.127</td>
<td>-6.27</td>
<td>0.00</td>
<td>0.25</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 20 Values of crowding with a distinction by trip frequency**

5.7.3 Values of crowding with a distinction by gender

From section 5.6.4, it is found that there are different perceptions of “medium crowded” condition by men and women. However, replacing the generic parameters of that parameter by specific ones, the adjusted rho square is not improved. This means the model quality is
not improved by the segmentation of gender on “medium crowded” condition. As a result, the specific values of crowding by gender are not investigated. The insignificant differences in monetary values of crowding by age and gender indicate that unrepresentativeness in these two characteristics would not lead to a bias to the general values of crowding.

5.8 Conclusions

In this chapter, the distributions of choice are given for each choice set. It is followed by the estimation and analysis of a basic MNL model with generic parameters. The general values of crowding are determined as 0, 0.1, 0.45, 1.09 euro per person for the four distinguished crowding levels. From the values, it is found that crowding perception increases a lot when a queue is formed and when queue grows. However, although the parameters are significant from the model estimation, the model has lower explanatory power. Small sample size, important but not captured attributes and noise in the survey data can contribute to the low explanatory power.

After the segmentation of the generic model by social-demographic characteristics, trip motives and frequency are found to have impacts on the amount of time people would spend to avoid crowding. People with work and business motives are not willing to sacrifice time to avoid crowding compared to those with non-working motives. However, the difference is offset by the difference in value of time when calculating the monetary value of crowding. As for the effects of trip frequency, frequent traveller’s monetary value of crowding is significantly lower than infrequent travellers.

In the next chapter, how the results and findings can be applied in evaluation and practical operation is discussed.
6 Applications of the values of crowding in evaluation and practice

Values of crowding are determined in the last chapter. It also identifies the impacts of trip motives and frequency on the values of crowding. In this chapter, the applications of those results and findings in cost-benefit analysis and other evaluation approaches are explored. As a result, the last sub-research question is answered.

(6) How the values of crowding can be used in the evaluation of crowding management measures?

6.1 Application in cost-benefit analysis

The direct application of the values of crowding is for cost-benefit analysis of crowding management measures at railway station, which is the goal of this study. The application involves two issues: the calculation of costs and benefits, and correction for unrepresentative distribution.

6.1.1 The calculation of benefits and costs

The resulting values of crowding as demonstrated in Figure 17 are applied to a hypothetical project in this section as an example of real application. The background of the hypothetical is introduced as below:

Assume the width of one stair at railway station is extended. It is required to calculate the benefits of stair extension in terms of crowding for cost-benefit analysis.

To calculate the monetary benefits of the stair extension, it is necessary to determine the amount of people who experience certain level of crowding before and after the extension every day. This can be known by performing micro-simulation of pedestrian flow at railway station. An example of daily pedestrian flow before and after extension with their experienced crowding levels are shown in Table 32.

| Table 32 Daily pedestrian flow with their experienced crowding conditions before and after extension |
|--------------------------------------------------|-------------------|-------------------|
| The amount of people before extension            | The amount of people after extension |
| Very Crowded (CL3)                               | 2,000              | 1900              |
| Crowded (CL2)                                    | 2,000              | 1900              |
| Medium Crowded (CL1)                             | 3,000              | 3100              |
| Not Crowded (CL0)                                | 5,000              | 5100              |

With pedestrian volume of different crowding conditions, the monetary benefits of this project are calculated using the formula:

$$
Benefits = VOC_{CL3} \Delta N_{CL3} + VOC_{CL2} \Delta N_{CL2} + VOC_{CL1} \Delta N_{CL1} + VOC_{CL0} \Delta N_{CL0}
$$

(19)

Where $VOC_{CLi}$ is the value of crowding on i crowding level, it should be negative because crowding is a disutility.
\( \Delta N_{CLi} \) is the change in the amount of people who experience the crowding level \( i \) after extension.

The calculation results of the example project are shown in Table 33. From the table, the benefits of stair extension in the crowding aspect are 144 euro per day based on the assumed pedestrian flow. The results of crowding aspect can be incorporated into the benefits/costs of other aspects, such as time.

**Table 33 Calculation of crowding benefits**

<table>
<thead>
<tr>
<th>Crowned level (CL)</th>
<th>The amount of people before extension</th>
<th>The amount of people after extension</th>
<th>VOC</th>
<th>Monetary benefits (euros)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Crowded (CL3)</td>
<td>2,000</td>
<td>1,900</td>
<td>-1.09</td>
<td>109</td>
</tr>
<tr>
<td>Crowded (CL2)</td>
<td>2,000</td>
<td>1,900</td>
<td>-0.45</td>
<td>45</td>
</tr>
<tr>
<td>Medium Crowded (CL1)</td>
<td>3,000</td>
<td>3,100</td>
<td>-0.1</td>
<td>-10</td>
</tr>
<tr>
<td>Not Crowded (CL0)</td>
<td>5,000</td>
<td>5,100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td>144</td>
</tr>
</tbody>
</table>

### 6.1.2 Correction for unrepresentative distribution

From chapter 5, it is found that trip motives and frequency have impacts on the values of crowding. It is possible to adjust the generic values of crowding according to the real distribution of trip characteristics. The adjustment can be achieved by weighting the specific parameters by the percentages of population within that characteristic. The equation for the weighting is shown below:

\[
CL_{new} = \sum_{i=1}^{n} CL_i \times P_i
\]

(20)

Where \( CL_i \) is the specific value for the characteristic group \( i \) and \( P_i \) is the share of population of that group.

For example, when there are 80% frequent travellers and 20% frequent travellers during peak hour, the new values of crowding for three levels can be calculated as shown in Table 34:

**Table 34 Example of adjusting generic values**

<table>
<thead>
<tr>
<th>Crowned level (CL)</th>
<th>VOC for specific population (euros/person)</th>
<th>Percentage of the population</th>
<th>VOC for generic population (euros/person)</th>
<th>Original VOC (euros/person)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CL3_Work</td>
<td>0.86</td>
<td>80%</td>
<td>0.93</td>
<td>1.09</td>
</tr>
<tr>
<td>CL3_NonWork</td>
<td>1.20</td>
<td>20%</td>
<td>1.20</td>
<td>1.20</td>
</tr>
<tr>
<td>CL2_Work</td>
<td>0.25</td>
<td>80%</td>
<td>0.31</td>
<td>0.45</td>
</tr>
<tr>
<td>CL2_NonWork</td>
<td>0.53</td>
<td>20%</td>
<td>0.53</td>
<td>0.53</td>
</tr>
<tr>
<td>CL1_Work</td>
<td>0</td>
<td>80%</td>
<td>0.03</td>
<td>0.1</td>
</tr>
<tr>
<td>CL1_NonWork</td>
<td>0.13</td>
<td>20%</td>
<td>0.13</td>
<td>0.1</td>
</tr>
</tbody>
</table>
6.2 Application in multi-criteria analysis

Besides cost-benefit analysis, the values of crowding can also be used for other evaluation method, such as multi-criteria analysis (MCA). MCA explicitly considers multiple criteria in decision-making environments. Unlike CBA, the indicators in MCA do not need to be in monetary unit or even quantitative. Therefore, it is possible for MCA to take into account of the aspects that cannot be valued in monetary terms.

A second feature of MCA is that the importance of criteria is indicated by policy makers and can express political priorities. This is different from CBA as the importance in CBA depends on the preferences of consumers. CBA is often criticized for ignoring equity issues such as distribution effects (Thomopoulos, 2009). Multi-criteria analysis can overcome equity problems in CBA by modifying the weights.

The indicator of crowding criteria will be scores. It is predefined for each MCA study. For example, crowding at station is ranked based on 4 identified levels in this research. Based on the ratios of values of crowding found in this thesis, scores for different crowding levels are determined by normalization. Another element of multi-criteria analysis is the weight of this crowding criterion. This can be determined according to the generalized walking time of crowding conditions. For example, the weight of crowding aspect can be kept as 0.4, which means the scores of crowding should times 0.4 when comparing with walking time.

6.3 Practical implications

The values of crowding results are meaningful for NPC in the analysis of pedestrian flow at railway station. Currently, a study area with 2meters length is selected as the study region during the simulation of pedestrian flow. However, according to the final values of crowding in this thesis, it is found that passengers consider crowding condition with 5 meters queue much more severe than the condition with a same density but 2.5meters queue. As a result, the study region with 2 meters length cannot well reflect the crowding condition. It is recommended to consider a region with 5 meters length during pedestrian flow analysis.

For NS station or ProRail, the jumps in value of crowding suggest that passengers are willing to walking longer to avoid crowding especially when they see a queue. The finding corresponds to the behaviour Voskamp (2012) found in his research that many people would choose to avoid crowding in front of bottleneck even when the total walking time is higher. As a result, station operators should put most of their efforts on solving the queues while monitoring the less crowded location. They should guide passengers to take another route by the extra route by signs or make the extra route visible so that passengers’ need to avoid crowding is satisfied and congestion in front of bottleneck is relieved.

Train operators such as NS Reizigers can also make use of the results in their train operation. The values of crowding indicate the importance of crowding at stations to passengers. With the values, train operators can have a rough idea about how much they can sacrifice for improving total experience of train travelling. For example, a train can be delayed for half a minute to avoid an arrival of two busy trains at the same time at platforms. Adjustment to the operation can also be done by changing the stopping locations of trains to avoid congestion at platforms. Metro/bus/tram operators can also contribute to a less crowded station by adjusting their timetable better connected to the train timetable. As a result, passengers will spend less transfer time and therefore fewer passengers over time at station.
As for other stakeholders at station, local municipality is not directly interested in crowding at stations, while passengers cannot improve the crowding at Dutch stations.
7 Conclusions, discussions and recommendations

The chapter presents the conclusions of this thesis. It also discusses the possible future study and validity of this research.

7.1 Conclusions

The first main research question of this thesis was formulated as follows:

“Which aspects are important when evaluating the crowd management measures through cost-benefit analysis?”

To answer this main research question, three sub-research questions are followed. They are answered one by one in Chapter 2, 3 and 4.

(1) Which evaluation aspects can be considered during an evaluation from a multiple stakeholders’ perspective?

Five stakeholder functions are identified: rail infrastructure operator, station operator, passengers, train operator, metro, tram & bus operators, Local municipalities, and the government. Common interests appear among the most stakeholders. A Safe, secure and fast transfer connection at railway station are required by all stakeholders except local municipalities since they are not directly related to the railway station. However, conflicts in interests also exist. Operators would also consider their own operation efficiency and revenues while local municipalities concerns the interests for its region around station. Real crowd management case indicates that those conflicts can be dealt by finding common interests or a balanced point.

As the problem owner, the government would consider each interest as an evaluation aspect because it aims at balancing the different interests and getting all stakeholders agreed on certain transfer interventions. Important stakeholder functions at a railway station regarding to transfer process are rail infrastructure operator, station operator, and passengers. The aspects related to them are therefore deemed important.

(2) What is the importance of transfer aspects according to literature?

Safety, security, travel time, and reliability are all important to passengers. As for rail infrastructure and station operators, only the safety and security are the most important according to literature. The importance of an aspect is determined based on the importance of its related stakeholders and its importance to those stakeholders. After that, an evaluation checklist is developed. It includes 11 important evaluation aspects and their importance. Such checklist is the preliminary step for building a decision support framework for the government. It is also useful for NPC in the analysis of the transfer problem and ex-ante evaluation of the solution.

(3) What is the feasibility of transfer aspects to be measured in money according to literature?

The feasibility of aspects in cost-benefit analysis is determined by two criteria: a suitable indicator and a way to translate the indicator unit into money. Only safety and way-finding
do not have objective indicators in literature. As for another criterion, time, reliability, safety aspects have values to translate their units into money in literature. However, it is found that although comfort, walking distance, way-finding and security have either an objective indicator or a proxy to reflect the performance, it is still unknown how they can be measured by monetary terms.

In general, 4 evaluation aspects are not able to be quantified by monetary terms yet. They are safety under normal condition, way-finding, security, and comfort. The value of comfort in terms of crowding at stations is selected for monetizing study because it already has a suitable indicator for CBA. It is also an important unknown because the approach to determine the value of crowding can also be viewed as an example to measure other qualitative aspects in cost-benefit analysis.

The second main research question of this thesis was formulated as follows:

“How to evaluate crowding in front of station vertical infrastructure in cost-benefit analysis?”

To answer this main research question, three sub-research questions are followed. They are answered one by one in Chapter 5, 6 and 7.

(4) Which methodology should be used to determine the value of crowding in front of station vertical infrastructure?

A stated preference experiment is chosen to perform. This is because it is possible to control attribute levels in stated preference experiment. Stated preference experiment can also avoid the mix of attribute influence by excluding unnecessary attributes in a hypothetical alternative.

Three characteristics of crowding (location, density and queue length) are reflected in the survey design. Crowding location is chosen as the area in front of vertical infrastructure because it is the most congested area in Dutch railway stations. Density and queue length together describe the crowding condition of that area. 4 crowding levels are distinguished based on whether passengers can overtake another or they need stand still: 0.5p/m², 1p/m², 1.5p/m² with 2.5meter queue, 1.5p/m² with 5meter queue. Respondents are asked to make hypothetical route choices. Because walking time is an important aspect when people make choices on route levels, it is adopted as another attribute in the survey. Monetary values of crowding are determined by transforming the trade-off between walking time and crowding via the value of walking time. Pilot is conducted to know the priori of the attribute levels. The designed survey is sent out through internet and 214 people in total completed the survey. The quality of dataset is improved by excluding inconsistent choices.

(7) How to interpret the resulted values of crowding?

A basic multinomial logic model with generic parameters is estimated. “Very crowded” condition (1.5p/m² with 5meter queue) is valued as 1.09 euro per person. “Crowded” condition (1.5p/m² with 2.5meter queue) is valued as 0.45 euro per person. “Medium crowded” condition (1p/m² of a 2.5meter length area) is valued as 0.1 euro per person. The base level “not crowded” (0.5p/m² of a 2.5meter length area) is valued as 0 euro per person. The results of generic MNL model show that the value of crowding increases sharply when it is crowded. The presence of queue plays an important role in intensifying crowding perceptions.
The generic parameters in the basic model are segmented by social-demographic characteristics to see their influences on the value of crowding. It is found that only trip motives and frequency have impacts on the generalized walking time of crowding disutility. People with non-working motives would be willing to spend more time than those with working motives. However, since the value of time for non-working people is lower. The final values of crowding are similar among two groups. As for trip frequency, frequent traveller’s value of crowding is significantly lower than that of infrequent travellers.

(8) How can the values of crowding be applied in transfer evaluation and practice?

The value of crowding determined in the generic model can be directly applied into cost-benefit analysis. It can also be applied in other evaluation methods such as multi-criteria analysis. For NPC, the fact that passengers’ perceptions of crowding suggest a larger study region in pedestrian simulation should be adopted. For station operators, actions should be taken to guide passengers to avoid crowding by suggesting alternative route.

7.2 Discussions regarding validity

This section discusses several issues regarding the validity of the results:

7.2.1 Walking effort

In the stated preference experiment, it is assumed that people behave similarly as they do in real situation. Although the designs of attributes and choice situation aim at creating a real situation for respondents, it is still hard to let them perceive the attributes, such as walking time, the same as the real situation. Because walking is not experienced by the respondents, it is possible that they consider the disutility of extra walking time less than that of real situation. Therefore, respondents would be more willing to spend time to avoid crowding and this could lead to a higher value of crowding.

7.2.2 Impacts of crowding utility form

Dummy variables are used to represent 4 crowding conditions in this research. This is because it is believed that perceptions are not linear over the whole range of crowding conditions. In other words, an increase in density when the area is already crowded might cause higher disutility than a same increase in free-flow condition. To verify the unrepresentativeness of the pure linear relation, a linear function of density with single parameter for crowding variable is tested. The result is negative with lower explanatory power of the model compared to the one with dummy variables.

However, the major disadvantage of current approach is that it is unclear where exactly lies the threshold of the crowding perceptions. The values of crowding on 4 discrete levels are known while the values between two levels are unknown. Only assumptions can be made for the perception-density relations between two levels.

In order to know the full picture of crowding perceptions, more advanced functions, such as exponential function, should be tested. It is also possible to divide the whole range of crowding conditions into several segments and assume linear relations within each segment. The slope within each segment can be estimated to reflect the values of crowding within this segment of crowding condition. However, these approaches require more data and effort which is limited in this research.
7.2.3 Sample bias
As discussed in section 4.4.3, the sample is not fully representative for the NS population of social-demographic characteristics. However, from the analysis, it is found that monetary values of crowding only differ by trip frequency. Gender and age do not have a significant influence while the difference generalized walking time of crowding disutility by trip motive is offset by the difference in value of walking time. Therefore, only the unrepresentativeness in trip frequency creates a bias to the final monetary values of crowding.

In the sample, the percentage of infrequent traveller is overrepresented. Since the infrequent travellers tend to have a higher monetary value of crowding from the analysis in section 5.7, the general values of crowding are overestimated.

7.2.4 Transform perceptions of crowding via VOT
In this research, the monetary value of crowding is transform via value of walking time. This is because crowding at station usually occurs on route choice level where no travel cost is involved. Therefore, a trade-off is selected between crowding conditions and walking time which is an important and direct attribute in route choice.

However, the error in estimations of the parameters might be amplified in this transformation. The population for estimating the overall value of time is different from the population of estimating the generalized time of crowding disutility. Moreover, because cost is not explicitly addressed in the choice situation, the final monetary values of crowding might not be the same when a trade-off is made between costs and crowding conditions.

7.2.5 Crowding or queuing
What’s more, the goal of this stated preference experiment is to determine the value of crowding. Therefore, other attributes in the route choice are not described in the survey for the simplicity. This could lead to different understanding of the choice situation and thus different choice behaviour.

It is stated in the experiment that extra waiting time caused by crowding is not considered because this study only wants to explore the disutility caused by crowding. However, some respondents would naturally recall of extra waiting time when they see the pictures of severe crowding in front of stairs. As a result, the disutility of extra waiting time is added to the disutility of crowding which leads to a higher value of crowding.

7.3 Recommendations for future research
From the feasibility of evaluation aspects in cost-benefit analysis, it is found that pedestrian safety cannot be quantified for ex-ante evaluation yet. However, safety is almost the most important aspect for all stakeholders. Excluding safety aspect would lead to the inaccuracy of the evaluation results. Therefore, future research into exploring the relation between density and safety is suggested because density level is believed to have strong impacts on safety.

Another way to include qualitative aspects such as safety in an evaluation framework is to combine cost-benefit analysis and multi-criteria analysis. The multi-criteria analysis can easily measure the qualitative aspects while it is also possible to incorporate quantified criteria of aspects from cost-benefit analysis. Incorporating CBA into MCA can improve the accuracy of MCA while it deals with the difficulties in CBA. The application of values of
crowding in multi-criteria analysis in section 6.2 is an example of such incorporation. However, it should be noticed the aspects should not be double evaluated by two methods.

The estimated model in this research has a low explanatory power. Because pedestrian behaviour at railway stations differs a lot among individuals, it is recommended to recruit more people for the experiment. Moreover, to improve the quality of results, response data should be filtered based on more criteria, such as a check of whether respondent understand the meaning of the choice situation.

The results of passenger crowding perceptions are purely based on stated preference data. In the future, revealed preference experiment can be performed to validate the results. Considered the route choice at railway stations depends on several attributes besides time and crowding, more experiments at different locations are required.
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Verhoeff, L. (2015, June). Quantifying pedestrian safety. (T. Li, Interviewer)


## Appendix A: Experiment design for choice experiment

### Table 35 Choice experiment design

<table>
<thead>
<tr>
<th>Choice set number</th>
<th>Choice 1</th>
<th>Choice 2</th>
<th>Extra walking time (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Crowding condition</td>
<td>Crowding condition</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Very crowded</td>
<td>Crowded</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>Very crowded</td>
<td>Medium crowded</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>Crowded</td>
<td>Medium crowded</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Medium crowded</td>
<td>Not crowded</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Crowded</td>
<td>Not crowded</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>Crowded</td>
<td>Medium crowded</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>Very crowded</td>
<td>Not crowded</td>
<td>3</td>
</tr>
<tr>
<td>8</td>
<td>Crowded</td>
<td>Not crowded</td>
<td>2</td>
</tr>
</tbody>
</table>
Appendix B: Survey content

Station Crowding Survey

*Required

Welcome!

I'm a master student from TU Delft. For my master thesis, I am investigating people’s perception of crowding at train stations. So I need your help.

It will take about 6 minutes to finish the survey. Please switch to the wider side if you are using a phone.

What is your most frequent trip purpose of train travelling *
- Work and commuting
- Business or job appointment
- Study
- Visit a family or friend
- Vacation or outing
- Shopping
- Other: ____________________________

How often do you travel by train? *
- 4 days per week and more
- 1-3 days per week
- 1-3 days per month
- <1 day per month

NEXT
Station Crowding Survey

Introduction

Imagine when you arrive at platform by train on your common trip purpose and there are two routes to leave the station as shown in the graph below. Two routes differ in crowdedness and total walking time to exit. Waiting time has already been included in total walking time. Choice situations will be presented to you on the following pages.
Station Crowding Survey

1st Situation

Assume you know beforehand total walking time to exit and crowding conditions of two routes like the table below, which route would you choose normally?
(For route 2, you do not have to walk through the crowding shown on route 1. Crowding condition on the stairs is assumed to be the same as the picture shows)

<table>
<thead>
<tr>
<th>Two routes and their characteristics</th>
<th>Route 1</th>
<th>Route 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total extra walking time</td>
<td>--</td>
<td>+2mins</td>
</tr>
<tr>
<td>Crowding condition in front of stair</td>
<td><img src="image1.png" alt="Crowding Condition" /></td>
<td><img src="image2.png" alt="Crowding Condition" /></td>
</tr>
</tbody>
</table>

Which route would you take?

- [ ] Route 1
- [ ] Route 2

BACK  NEXT  27% complete
Station Crowding Survey

2nd Situation

Assume you know beforehand total walking time to the exit and crowding conditions of two routes like the table below, which route would you choose normally? (For route 2, you do not have to walk through the crowding shown on route 1. Crowding condition on the stairs is assumed to be the same as the picture shows)

Two routes and their characteristics

<table>
<thead>
<tr>
<th></th>
<th>Route 1</th>
<th>Route 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total extra walking time</td>
<td>--</td>
<td>+3mins</td>
</tr>
<tr>
<td>Crowding condition in front of stair</td>
<td>![Image]</td>
<td>![Image]</td>
</tr>
</tbody>
</table>

* Required

Which route would you take?

- [ ] Route 1
- [ ] Route 2

BACK  NEXT  36% complete
Station Crowding Survey

*Required

3rd Situation

Assume you know beforehand total walking time to the exit and crowding conditions of two routes like the table below, which route would you choose normally? (For route 2, you do not have to walk through the crowding shown on route 1. Crowding condition on the stairs is assumed to be the same as the picture shows)

Two routes and their characteristics

<table>
<thead>
<tr>
<th></th>
<th>Route 1</th>
<th>Route 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total extra walking time</td>
<td>--</td>
<td>+1 mins</td>
</tr>
<tr>
<td>Crowding condition in front of stair</td>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
</tr>
</tbody>
</table>

* Which route would you take?  
  - Route 1  
  - Route 2

BACK  NEXT

45% complete
Station Crowding Survey

*Required

4th Situation

Assume you know beforehand total walking time to the exit and crowding conditions of two routes like the table below, which route would you choose normally?
(For route 2, you do not have to walk through the crowding shown on route 1. Crowding condition on the stairs is assumed to be the same as the picture shows)

**Two routes and their characteristics**

<table>
<thead>
<tr>
<th></th>
<th>Route 1</th>
<th>Route 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extra walking time</td>
<td>--</td>
<td>+1mins</td>
</tr>
<tr>
<td>Crowding condition in front of stair</td>
<td><img src="image1" alt="Crowd" /></td>
<td><img src="image2" alt="Crowd" /></td>
</tr>
</tbody>
</table>

* 

Which route would you take?

- [ ] Route 1
- [ ] Route 2

54% complete
Station Crowding Survey

5th Situation

Assume you know beforehand total walking time to the exit and crowding conditions of two routes like the table below, which route would you choose normally? (For route 2, you do not have to walk through the crowding shown on route 1. Crowding condition on the stairs is assumed to be the same as the picture shows)

Two routes and their characteristics

<table>
<thead>
<tr>
<th>Extra walking time</th>
<th>Route 1</th>
<th>Route 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>--</td>
<td>+3mins</td>
</tr>
</tbody>
</table>

*Crowding condition in front of stair*

Which route would you take?

Route 1

Route 2

BACK NEXT

63% complete
Station Crowding Survey

*Required

6th Situation

Assume you know beforehand total walking time to the exit and crowding conditions of two routes like the table below, which route would you choose normally? (For route 2, you do not have to walk through the crowding shown on route 1. Crowding condition on the stairs is assumed to be the same as the picture shows)

Two routes and their characteristics

<table>
<thead>
<tr>
<th></th>
<th>Route 1</th>
<th>Route 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crowding condition in front of stair</td>
<td><img src="image1.jpg" alt="Image of Route 1 crowding" /></td>
<td><img src="image2.jpg" alt="Image of Route 2 crowding" /></td>
</tr>
<tr>
<td>Total extra walking time</td>
<td>--</td>
<td>+2mins</td>
</tr>
</tbody>
</table>

* Which route would you take?

- [ ] Route 1
- [ ] Route 2

72% complete
Station Crowding Survey

*Required

7th Situation

Assume you know beforehand total walking time to the exit and crowding conditions of two routes like the table below, which route would you choose normally? (For route 2, you do not have to walk through the crowding shown on route 1. Crowding condition on the stairs is assumed to be the same as the picture shows)

**Two routes and their characteristics**

<table>
<thead>
<tr>
<th>Total extra walking time</th>
<th>Route 1</th>
<th>Route 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crowding condition in front of stair</td>
<td>[Image]</td>
<td>[Image]</td>
</tr>
</tbody>
</table>

+3mins

* Which route would you take?

[ ] Route 1

[ ] Route 2

BACK  NEXT  81% complete
Station Crowding Survey

8th Situation

Assume you know beforehand total walking time to the exit and crowding conditions of two routes like the table below, which route would you choose normally? (For route 2, you do not have to walk through the crowding shown on route 1. Crowding condition on the stairs is assumed to be the same as the picture shows)

<table>
<thead>
<tr>
<th>Two routes and their characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Route 1</strong></td>
</tr>
<tr>
<td>Total extra walking time</td>
</tr>
<tr>
<td>Crowding condition in front of stair</td>
</tr>
</tbody>
</table>

*Which route would you take?*

- [ ] Route 1
- [ ] Route 2

BACK NEXT

90% complete
Station Crowding Survey

*Required

Personal information

In the end, I would like to know some personal information regarding your train travelling. Your answers will always be kept confidential!

What is your age range? *

- <18 years
- 18-24 years
- 25-34 years
- 35-44 years
- 45-54 years
- 55-64 years
- >64 years

What is your gender? *

- Male
- Female

Do you have any comments on this survey?

Your answer

BACK  SUBMIT  100%: You made it.
Appendix C Estimation results for generic model

Model: Multinomial Logit
Number of estimated parameters: 5
Number of observations: 1688
Number of individuals: 1688
Null log-likelihood: -1170.032
Cte log-likelihood: -1129.595
Init log-likelihood: -1170.032
Final log-likelihood: -1053.389
Likelihood ratio test: 233.287
Rho-square: 0.100
Adjusted rho-square: 0.095
Final gradient norm: +6.665e-004
Diagnostic: Convergence reached...
Iterations: 6
Run time: 00:00
Variance-covariance: from analytical hessian
Sample file: newfinaldata.dat

Utility parameters

<table>
<thead>
<tr>
<th>Name</th>
<th>Value</th>
<th>Std err</th>
<th>t-test</th>
<th>p-value</th>
<th>Robust Std err</th>
<th>Robust t-test</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABC</td>
<td>-0.511</td>
<td>0.160</td>
<td>-3.20</td>
<td>0.00</td>
<td>0.159</td>
<td>-3.21</td>
<td>0.00</td>
</tr>
<tr>
<td>B 0</td>
<td>-3.36</td>
<td>0.409</td>
<td>-8.20</td>
<td>0.00</td>
<td>0.412</td>
<td>-8.14</td>
<td>0.00</td>
</tr>
<tr>
<td>B 1</td>
<td>1.35</td>
<td>0.249</td>
<td>5.43</td>
<td>0.00</td>
<td>0.249</td>
<td>-5.42</td>
<td>0.00</td>
</tr>
<tr>
<td>B 2</td>
<td>-0.293</td>
<td>0.126</td>
<td>-2.33</td>
<td>0.02</td>
<td>0.125</td>
<td>-2.35</td>
<td>0.02</td>
</tr>
<tr>
<td>B 3</td>
<td>0.00</td>
<td>Fixed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B WT</td>
<td>-0.785</td>
<td>0.130</td>
<td>-6.06</td>
<td>0.00</td>
<td>0.132</td>
<td>-5.84</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Utility functions

<table>
<thead>
<tr>
<th>Id</th>
<th>Name</th>
<th>Availability</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A1 Crowded</td>
<td>one</td>
<td>B 0 * a + B 1 * b + B 2 * c</td>
</tr>
<tr>
<td>2</td>
<td>A2 Uncrowded</td>
<td>one</td>
<td>B 1 * d + B 2 * e + B 3 * f + B WT * WT + ABC * one</td>
</tr>
</tbody>
</table>

Figure 21 Estimation results of basic MNL model with generic parameters
Appendix D Estimation results for specific model

Trip motive

Model: Multinomial Logit

Number of estimated parameters: 7
Number of observations: 1688
Number of individuals: 1688
Null log-likelihood: -1170.032
Cte log-likelihood: -1129.595
Init log-likelihood: -1170.032
Final log-likelihood: -1040.692
Likelihood ratio test: 258.681
Rho-square: 0.111
Adjusted rho-square: 0.105
Final gradient norm: +1.536e-003
Diagnostic: Convergence reached...
Iterations: 7
Run time: 00:00
Variance-covariance: from analytical hessian
Sample file: newfinaldata.dat

Utility parameters

<table>
<thead>
<tr>
<th>Name</th>
<th>Value</th>
<th>Std err</th>
<th>t-test</th>
<th>p-value</th>
<th>Robust Std err</th>
<th>Robust t-test</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASC</td>
<td>-0.513</td>
<td>0.160</td>
<td>-3.20</td>
<td>0.00</td>
<td>0.159</td>
<td>-3.23</td>
<td>0.00</td>
</tr>
<tr>
<td>B_01</td>
<td>-2.92</td>
<td>0.338</td>
<td>-8.62</td>
<td>0.00</td>
<td>0.340</td>
<td>-8.57</td>
<td>0.00</td>
</tr>
<tr>
<td>B_02</td>
<td>-3.83</td>
<td>0.389</td>
<td>-9.86</td>
<td>0.00</td>
<td>0.396</td>
<td>-9.67</td>
<td>0.00</td>
</tr>
<tr>
<td>B_11</td>
<td>-0.977</td>
<td>0.195</td>
<td>-5.02</td>
<td>0.00</td>
<td>0.191</td>
<td>-5.13</td>
<td>0.00</td>
</tr>
<tr>
<td>B_12</td>
<td>-1.70</td>
<td>0.244</td>
<td>-6.98</td>
<td>0.00</td>
<td>0.246</td>
<td>-6.93</td>
<td>0.00</td>
</tr>
<tr>
<td>B_21</td>
<td>0.00</td>
<td>fixed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B_22</td>
<td>-0.535</td>
<td>0.151</td>
<td>-3.54</td>
<td>0.00</td>
<td>0.154</td>
<td>-3.47</td>
<td>0.00</td>
</tr>
<tr>
<td>B_3</td>
<td>0.00</td>
<td>fixed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B_WT</td>
<td>-0.797</td>
<td>0.121</td>
<td>-6.58</td>
<td>0.00</td>
<td>0.126</td>
<td>-6.35</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Utility functions

<table>
<thead>
<tr>
<th>Id</th>
<th>Name</th>
<th>Availability</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A1_Crowded</td>
<td>one</td>
<td>B_01 + a01 + B_02 + a02 + B_11 + b01 + B_12 + b02 + B_21 + c01 + B_22 + e02</td>
</tr>
<tr>
<td>2</td>
<td>A2_Uncrowded</td>
<td>one</td>
<td>B_11 + d01 + B_12 + d02 + B_21 + e01 + B_22 + e02 + B_3 + f + B_WT + WT + ASC * cse</td>
</tr>
</tbody>
</table>

Figure 22 Estimation results of basic MNL model with trip motive specific parameters
Trip frequency

Model: Multinomial Logit

Number of estimated parameters: 7
Number of observations: 1688
Number of individuals: 1688
Null log-likelihood: -1170.032
Cte log-likelihood: -1129.595
Init log-likelihood: -1170.032
Final log-likelihood: -1035.509
Likelihood ratio test: 269.048
Rho-square: 0.115
Adjusted rho-square: 0.109
Final gradient norm: +3.692e-003
Diagnostic: Convergence reached...
Iterations: 6
Run time: 00:01
Variance-covariance: from analytical hessian
Sample file: newfinaldata.dat

Utility parameters

<table>
<thead>
<tr>
<th>Name</th>
<th>Value</th>
<th>Std err</th>
<th>t-test</th>
<th>p-value</th>
<th>Robust Std err</th>
<th>Robust t-test</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABC</td>
<td>-0.507</td>
<td>0.161</td>
<td>-3.16</td>
<td>0.00</td>
<td>0.160</td>
<td>-3.18</td>
<td>0.00</td>
</tr>
<tr>
<td>B_01</td>
<td>2.69</td>
<td>0.357</td>
<td>7.55</td>
<td>0.00</td>
<td>0.358</td>
<td>-7.51</td>
<td>0.00</td>
</tr>
<tr>
<td>B_02</td>
<td>-3.76</td>
<td>0.395</td>
<td>-9.51</td>
<td>0.00</td>
<td>0.399</td>
<td>-9.42</td>
<td>0.00</td>
</tr>
<tr>
<td>B_11</td>
<td>-0.764</td>
<td>0.210</td>
<td>-3.64</td>
<td>0.00</td>
<td>0.206</td>
<td>-3.70</td>
<td>0.00</td>
</tr>
<tr>
<td>B_12</td>
<td>-1.65</td>
<td>0.245</td>
<td>-6.74</td>
<td>0.00</td>
<td>0.245</td>
<td>-6.74</td>
<td>0.00</td>
</tr>
<tr>
<td>B_21</td>
<td>0.00</td>
<td>fixed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B_22</td>
<td>-0.418</td>
<td>0.141</td>
<td>-2.96</td>
<td>0.00</td>
<td>0.142</td>
<td>-2.93</td>
<td>0.00</td>
</tr>
<tr>
<td>B_3</td>
<td>0.00</td>
<td>fixed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B WT</td>
<td>-0.758</td>
<td>0.124</td>
<td>-6.42</td>
<td>0.00</td>
<td>0.127</td>
<td>-6.27</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Utility functions

<table>
<thead>
<tr>
<th>Id</th>
<th>Name</th>
<th>Availability</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A1_Crowded</td>
<td>one</td>
<td>B_01 * a01 + B_02 * a02 + B_11 * b01 + B_12 * b02 + B_21 * c01 + B_22 * c02</td>
</tr>
<tr>
<td>2</td>
<td>A2_Uncrowded</td>
<td>one</td>
<td>B_11 * d01 + B_12 * d02 + B_21 * e01 + B_22 * e02 + B_3 * f + B WT * WT + ABC * one</td>
</tr>
</tbody>
</table>

Figure 23: Estimation results of basic MNL model with trip frequency specific parameters
Age

Model: Multinomial Logit

Number of estimated parameters: 8
Number of observations: 1688
Number of individuals: 1688
Null log-likelihood: -1170.032
Cte log-likelihood: -1129.595
Init log-likelihood: -1170.032
Final log-likelihood: -1053.723
Likelihood ratio test: 232.618
Rho-square: 0.099
Adjusted rho-square: 0.093
Final gradient norm: +1.003e-003
Diagnostic: Convergence reached...
Iterations: 7
Run time: 00:00
Variance-covariance: from analytical hessian
Sample file: newfinaldata.dat

Utility parameters

<table>
<thead>
<tr>
<th>Name</th>
<th>Value</th>
<th>Std err</th>
<th>t-test</th>
<th>p-value</th>
<th>Robust Std err</th>
<th>Robust t-test</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASC</td>
<td>-0.493</td>
<td>0.161</td>
<td>-3.07</td>
<td>0.00</td>
<td>0.161</td>
<td>-3.06</td>
<td>0.00</td>
</tr>
<tr>
<td>B_01</td>
<td>-2.86</td>
<td>0.318</td>
<td>-9.01</td>
<td>0.00</td>
<td>0.319</td>
<td>-8.97</td>
<td>0.00</td>
</tr>
<tr>
<td>B_02</td>
<td>-2.60</td>
<td>0.291</td>
<td>-8.93</td>
<td>0.00</td>
<td>0.294</td>
<td>-8.84</td>
<td>0.00</td>
</tr>
<tr>
<td>B_03</td>
<td>-2.86</td>
<td>0.448</td>
<td>-6.38</td>
<td>0.00</td>
<td>0.468</td>
<td>-6.10</td>
<td>0.00</td>
</tr>
<tr>
<td>B_11</td>
<td>-0.997</td>
<td>0.196</td>
<td>-5.08</td>
<td>0.00</td>
<td>0.197</td>
<td>-5.06</td>
<td>0.00</td>
</tr>
<tr>
<td>B_12</td>
<td>-0.840</td>
<td>0.168</td>
<td>-5.00</td>
<td>0.00</td>
<td>0.168</td>
<td>-5.01</td>
<td>0.00</td>
</tr>
<tr>
<td>B_13</td>
<td>-1.34</td>
<td>0.316</td>
<td>-4.24</td>
<td>0.00</td>
<td>0.321</td>
<td>-4.18</td>
<td>0.00</td>
</tr>
<tr>
<td>B_3</td>
<td>0.00</td>
<td>fixed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B_WT</td>
<td>-0.633</td>
<td>0.111</td>
<td>-5.72</td>
<td>0.00</td>
<td>0.113</td>
<td>-5.63</td>
<td>0.00</td>
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</tbody>
</table>

Utility functions

<table>
<thead>
<tr>
<th>Id</th>
<th>Name</th>
<th>Availability</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A1_Crowded</td>
<td>one</td>
<td>B_01 * a01 + B_02 * a02 + B_03 * a03 + B_11 * b01 + B_12 * b02 + B_13 * b03 + B_2 * c</td>
</tr>
<tr>
<td>2</td>
<td>A2_Uncrowded</td>
<td>one</td>
<td>B_11 * d01 + B_12 * d02 + B_13 * d03 + B_2 * e + B_3 * f + B_WT * WT + ASC * c</td>
</tr>
</tbody>
</table>

Figure 24 Estimation results of basic MNL model with age specific parameters
Gender

Model: Multinomial Logit

Number of estimated parameters: 7
Number of observations: 1688
Number of individuals: 1688
Null log-likelihood: -1170.032
Cte log-likelihood: -1129.595
Init log-likelihood: -1170.032
Final log-likelihood: -1049.797
Likelihood ratio test: 240.471
Rho-square: 0.103
Adjusted rho-square: 0.097
Final gradient norm: +4.322e-003
Diagnostic: Convergence reached...
Iterations: 6
Run time: 00:00
Variance-covariance: from analytical hessian
Sample file: newfinaldata.dat

Utility parameters

<table>
<thead>
<tr>
<th>Name</th>
<th>Value</th>
<th>Std err</th>
<th>t-test</th>
<th>p-value</th>
<th>Robust Std err</th>
<th>Robust t-test</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASC</td>
<td>-0.507</td>
<td>0.160</td>
<td>-3.16</td>
<td>0.00</td>
<td>0.160</td>
<td>-3.17</td>
<td>0.00</td>
</tr>
<tr>
<td>B_01</td>
<td>-2.86</td>
<td>0.320</td>
<td>-8.94</td>
<td>0.00</td>
<td>0.322</td>
<td>-8.89</td>
<td>0.00</td>
</tr>
<tr>
<td>B_02</td>
<td>-3.48</td>
<td>0.378</td>
<td>-9.21</td>
<td>0.00</td>
<td>0.380</td>
<td>-9.15</td>
<td>0.00</td>
</tr>
<tr>
<td>B_11</td>
<td>-1.01</td>
<td>0.183</td>
<td>5.51</td>
<td>0.00</td>
<td>0.181</td>
<td>5.55</td>
<td>0.00</td>
</tr>
<tr>
<td>B_12</td>
<td>-1.45</td>
<td>0.244</td>
<td>-5.95</td>
<td>0.00</td>
<td>0.244</td>
<td>-5.94</td>
<td>0.00</td>
</tr>
<tr>
<td>B_21</td>
<td>0.00</td>
<td>fixed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B_22</td>
<td>-0.437</td>
<td>0.167</td>
<td>-2.62</td>
<td>0.01</td>
<td>0.167</td>
<td>-2.61</td>
<td>0.01</td>
</tr>
<tr>
<td>B_3</td>
<td>0.00</td>
<td>fixed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B_WT</td>
<td>-0.727</td>
<td>0.117</td>
<td>-6.21</td>
<td>0.00</td>
<td>0.120</td>
<td>-6.05</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Utility functions

<table>
<thead>
<tr>
<th>Id</th>
<th>Name</th>
<th>Availability</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A1_Crowded</td>
<td>one</td>
<td>[B_{01} \cdot a_{01} + B_{02} \cdot a_{02} + B_{11} \cdot b_{01} + B_{12} \cdot b_{02} + B_{21} \cdot c_{01} + B_{22} \cdot c_{02} ]</td>
</tr>
<tr>
<td>2</td>
<td>A1_Uncrowded</td>
<td>one</td>
<td>[B_{11} \cdot d_{01} + B_{12} \cdot d_{02} + B_{21} \cdot e_{01} + B_{22} \cdot e_{02} + B_{3} \cdot f + B_{WT} \cdot WT + ASC \cdot one ]</td>
</tr>
</tbody>
</table>

Figure 25 Estimation results of basic MNL model with gender specific parameters