# INFLUENCING THE WAITING LOCATION OF RAILWAY PASSENGERS ON THE RAILWAY PLATFORM SUBCONSCIOUSLY

*An improvement in railway platform safety and passenger flows*

*M.J.M. Oerlemans – Master Thesis*
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# Preface

Creating better environments using technologies is something I strongly believe in. Due to this thought, this research was born. This master thesis is focused on the behaviour that waiting railway passengers have on the railway platform, and how this behaviour can be influenced by using smart technologies.

During the graduation process a lot of people made efforts to help me. Firstly, I would like to thank my first supervisor Jan Dijkstra. His guidance during the graduation process was invaluable for the process. Sharing his experience in researching has helped me improve this master thesis a lot. Secondly, I would like to thank Eelco and Wieger, who gave me an internship at RoyalHaskoningDHV. During this internship, they gave me a lot of input, with a lot of enthusiasm for the research.
Furthermore, I would also like to thank my best friend Simon, my girlfriend Sarah and my buddy Onno. Their critiques and tips have helped me to write this thesis on the way it is now. Last but not least I would like to thank everyone who has helped me during the finishing of this master thesis; you all have helped me incredibly.

*Maarten Oerlemans*

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## MANAGEMENT SUMMARY *ENGLISH*

The Dutch Railways (NS) transports about one million railway passengers a day to their destination. These passengers get on and off trains through railway station buildings. When designing railway station buildings, the flow of passengers through the building is very important. The research for this Master thesis is to look at integrating additional stimuli on a part of the railway platform to stimulate a better distribution of passengers along it.
On the railway platform, there is a peak in the number of passengers just after a train arrives. In normal circumstances, this larger number of railway passengers does not cause problems, but there are still areas on the railway platform, which can get overcrowded. The entrance of the railway platform is one of these places that can get overcrowded.
Another reason why a better distribution is desirable is due to the time the train has to stand still on the railway platform. When railway passengers distribute better over the railway platform, the time that is used to get them in and out of the train could be shortened. This results in a train that could carry on earlier than the current situation.
To understand the factors that have influence on the problem of over crowded areas and the poor distribution of railway passengers, research questions are developed. The sub questions are the following:

- *What types of railway stations are there in the Netherlands, and what is the impact on the waiting behaviour of passengers on railway platforms?*
- *Who are the stakeholders involved in the operation of a railway platform?*
- *How do railway passengers currently choose their waiting location on the railway platform?*
- *What are the methods to influence railway passengers behaviour on a railway platform?*

These sub questions are there to answer the main question:

- *In what way is it possible to distribute waiting passengers more evenly on railway-platforms using adaptive technologies to change the comfort of the railway platform environment?*

During the literature study, sub questions were answered. Railway passengers who are leaving the railway station by train have the tendency to wait near the entrance point of the railway platform. This has to do with the comfort railway passenger's experience. On average, a railway passenger choses for ease and comfort. The comfort levels on a railway platform are similar on the whole platform. The entrance of the railway platform is easier to reach than the far side of the railway platform. Therefore, railway passengers wait near the entrance of the railway platform.
By making a difference in the comfort on railway platforms, railway passengers should be influenced to spread out further over the platform. There are many ways of changing these levels of comfort. During this research *adding warm coloured lights to the railway platform ceiling* is chosen. The research is performed by developing a 3D model of the railway station of Leeuwarden. With this 3D model, four virtual reality environments are created. These environments consist of the following models; quiet dark, quiet light, busy dark and busy

light. A total of 263 respondents, who also answered a questionnaire, have watched this VR model. This number of respondents is considered to be a reasonable number.

With the help of the questionnaire, the effect of crowdedness and additional light was measured. From the results, a few conclusions can be drawn. Firstly, the effect of crowdedness has a significant effect on how railway passengers choose their waiting location on the railway platform. Secondly, the railway passengers are more tended to move to another waiting spot when warm coloured additional light is introduced on the railway platform. However, this tendency does not show a significant effect.

The research offers opportunities to integrate adaptive technologies in railway station buildings. In addition to the mentioned effects of crowdedness and warm coloured additional light, other factors should also be researched on their effect. For example different light intensities and different colours could be tested. Besides these light related factors, other environmental stimuli can also be researched. For example music and temperature related factors could have influence on the waiting location choice of the railway passengers. It is also recommended to research the effects of the stimuli on both must travellers and lust travellers. Both traveller types have different preferences on the railway platform. Therefore, a separation between these groups can give more insight to which group the tested factor has the most effect.

## MANAGEMENT SUMMARY *DUTCH*

De Nederlandse Spoorwegen (NS) vervoeren dagelijks ongeveer één miljoen treinreizigers naar hun bestemming. Deze reizigers stappen in, en verlaten de trein door gebruik te maken van treinstations. Tijdens het ontwerpen van deze treinstations dient er rekening te worden gehouden met de reizigersstromen die hierbij ontstaan. In dit afstudeeronderzoek wordt er gekeken naar de mogelijkheid om extra stimulansen op een deel van het perron te integreren, zodanig dat reizigers zich beter zullen verspreiden over het perron.
Net na het arriveren van de trein, is er een piek in het aantal reizigers op het perron. Onder normale omstandigheden levert dit geen problemen op. Er zijn echter nog wel locaties op het perron waar problemen zich kunnen voordoen met betrekking tot drukte, als het aantal reizigers toeneemt. Een van die locaties is het entreepunt van het perron.
Naast de problemen die ontstaan door drukte is er ook nog een andere reden om reizigers beter te verspreiden over het perron. Het gaat dan om de tijd die een trein stil moet staan op het perron. Als reizigers zich beter verspreiden over een perron gaat het in en uitstappen sneller; de trein kan dan eerder vertrekken dan dat nu het geval is.
Om meer inzicht te krijgen in de factoren die invloed hebben op de slechte verspreiding van reizigers en de daar uit resulterende drukte, zijn er onderzoeksvragen opgesteld. De deelvragen luiden als volgt:

- Welke type treinstations zijn er in Nederland, en wat is de invloed van deze types op het wachtgedrag van de treinreiziger op het perron?
- Wie zijn de belanghebbenden bij het operationaliseren van een treinstation in Nederland?
- Hoe kiezen treinreizigers momenteel hun wachtlocatie op het perron?
- Welke methodes zijn er om het gedrag van treinreizigers te beïnvloeden op een perron?

Deze deelvragen zijn er om de hoofdonderzoeksvraag te beantwoorden:

- Op welke manier kunnen wachtende treinreizigers beter verdeeld worden over het perron, waarbij gebruik gemaakt wordt van adaptieve technologieën die het comfort in een omgeving kunnen beïnvloeden?

Tijdens de literatuurstudie worden de deelvragen beantwoord. Treinreizigers die het station verlaten met de trein, hebben de neiging te wachten rondom entreepunten van het perron. Dit heeft te maken met comfort wat de treinreiziger ervaart op een perron. Over het algemeen zoekt een passagier naar comfort en reisgemak. Op het perron zijn de comfortniveaus normaal gesproken overal ongeveer gelijk. Het entreepunt van het perron is gemakkelijker te bereiken dan andere gelegen gedeeltes. Hierdoor zullen passagiers voor het gemak kiezen, en dus rondom deze entreepunten blijven wachten.
Door het comfort op het perron aan te passen, zouden treinreizigers beïnvloed kunnen worden zodat ze zich beter gaan verspreiden. Er zijn meerdere opties om het gedrag van de treinreiziger te beïnvloeden. Voor dit onderzoek is ervoor gekozen om naar de factor *het toevoegen van warmkleurige verlichting in de perronkap* te kijken. Het onderzoek wordt uitgevoerd door een 3D model te creëren van station Leeuwarden. In dit 3D model zijn vier virtuele werelden gecreëerd. Deze virtuele modellen zijn: rustig donker, rustig verlicht, druk

donker, en druk verlicht. In totaal hebben 263 respondenten het VR model bekeken, en daarnaast ook een vragenlijst ingevuld. Dit aantal respondenten wordt als voldoende beschouwd.

Met behulp van de vragenlijst worden de effecten van drukte en extra verlichting gemeten. Uit de resultaten konden enkele conclusies worden getrokken. Ten eerste heeft drukte een significant effect op hoe de treinreiziger zijn wachtlocatie op een perron kiest. Ten tweede, treinreizigers zijn meer geneigd zich te verspreiden over het perron als er extra, warmkleurig licht geïntroduceerd wordt. Dit effect is echter niet significant, maar laat wel een tendens zien.

Het onderzoek geeft een aantal mogelijkheden om adaptieve technieken te integreren in treinstations. Als toevoeging op het genoemde effect van *drukte* en *warm gekleurd extra licht*, kunnen andere factoren ook nog worden onderzocht. Er kan bijvoorbeeld worden gekeken naar andere intensiteiten en kleuren voor de verlichting. Naast het veranderen van verlichting kan er ook nog worden gekeken naar andere factoren die van invloed kunnen zijn op het comfort, zoals muziek en temperatuur. Deze factoren kunnen ook invloed hebben op de keuze van een wachtlocatie. Ook wordt aanbevolen om te onderzoeken hoeveel effect deze factoren hebben op de twee verschillende reizigersgroepen: must en lust reizigers. Beide groepen hebben andere voorkeuren betreffende het wachten. Een onderscheid in deze groepen kan meer inzicht geven in welke factor meer invloed heeft op welk type reiziger.

# 1 INTRODUCTION

This chapter presents the subject of the thesis. Firstly, the research context is described in order to gain an understanding of the defined problem definition. Subsequently the main research question will be formulated and research sub-questions will be established in order to answer the main question. Finally, the research structure will be explained followed by the description of the expected results.

## 1.1 RESEARCH CONTEXT

Compared to other countries in the European Union, the Dutch railway network is one of the most intensively used railway networks (CBS, Hoe druk is het nu werkelijk op het Nederlandse spoor?, 2009). The number of travellers is increasing and the younger generation of 18-25 years old are travelling more by public transport than they do by car (CBS, 2015; NS, 2015). The Dutch Railways therefore must continually invest to ensure enough capacity to provide passengers with a safe and comfortable transfer in railway station buildings.

Every day there are over one million railway passengers in the Netherlands (NS, 2015). These passengers travel from 400 currently existing railway stations in the Netherlands (ProRail, 2013). Before passengers board the train, there is a moment of waiting, which takes an average of 5 minutes (Bosina, Britschgi, Meeder, & Weidmann, 2015; Ton, 2014). Most of the time waiting is spent on the railway platform (Ton, 2014). During this time, railway passengers barely spread out over the railway platform (Bosina, Britschgi, Meeder, & Weidmann, 2015). On average, the passengers experience their waiting time to be 1.21 longer than the actual waiting time (Fan, Gurthrie, & Levision, 2016). Passengers tend to wait at entrance points of railway platforms. This could either be an elevation point (stair, elevator and/or escalator) or an entrance point at the street level. The lack of distribution of waiting railway passengers on the railway platform usually is not a problem, but it becomes one when the size of the crowd increases. This problem can be seen at some of the larger railway stations in the Netherlands.

## 1.2 PROBLEM DEFINITION

Two specific aspects can be distinguished when crowding arises at the entrance of a railway platform. These aspects are discussed as problem areas from this point.

The first problem concerns the clogging of the railway platform at its entrance by the railway passengers (Bosina, Britschgi, Meeder, & Weidmann, 2015). When passengers are in the process of waiting, this clogging does not often happen. It is more likely that the entrance of a railway platform gets clogged moments after the arrival of a train. When a train arrives, the arriving passengers leave the train before departing passengers board the train. This results into a peak in railway platform population. The entrance points of railway platforms are more likely to be congested, which can cause hazardous situations (Davidich, Geiss, Mayer, Pfaffinger, & Royer, 2013).

The second problem concerns the distribution of passengers on a railway platform in relation to train occupancy. Passengers board the train through the door that is closest to their waiting location (Wiggenraad, 2001). When waiting passengers are not evenly distributed over the railway platform, this can cause an uneven boarding process of the train, resulting in:

- An unevenly occupied train.
- A delayed boarding process since doors closer to places that are heavily populated with waiting passengers, will take more time for the train to be ready for departure (Wiggenraad, 2001).

If the boarding times can be shortened, trains can be used more efficiently. If the distribution of passengers is more even, the number of complaints on the availability of seats may be less.

Van Hagen (2011) has done research in the field of passenger waiting experiences (Van Hagen, 2011). He discussed that the waiting experience is heavily dependent on the comfort levels on railway platforms; the distribution of passengers is only briefly mentioned. It is assumed that local differentiation of comfort levels on railway platforms can be used to get a more even distribution of passengers on railway platforms.

This graduation thesis will focus on creating a more even distribution of passengers on the railway platform. Therefore, the main research question is formulated as follows:

*"In what way is it possible to distribute waiting passengers more evenly on railway platforms by using adaptive technologies to change the comfort of the railway platform environment?"*

## 1.3 Research Questions

In order to answer the main research question, four sub-questions are formulated:

1. What types of railway stations are there in the Netherlands, and what is their impact on the waiting behaviour of passengers on railway platforms?
2. Who are the stakeholders involved in the operation of a railway platform?
3. How do railway passengers currently choose their waiting location on the railway platform?
4. What are the methods to influence railway passengers behaviour on a railway platform?

## 1.4 Research Design

The backbone of the research is the research process. The research process is supported by input. The output of the research process is presented in the chapters of this thesis. Input, research process and output are shown as separate columns in the research design (Figure 1). The research process is structured and based on the starting point of this research, namely the research proposal. Based on the research proposal and additional literature, the research is further defined and research questions are provided. Subsequently, a literature study will be conducted on railway stations as well as the waiting behaviour on railway platforms. The first part of the literature study concerns the differences in railway station types and the different stakeholders. The second part of the literature study focuses on the waiting behaviour of passengers, and in what ways passenger behaviour can be influenced. Then, based on the research definition and the subsequent literature study, a research model is created. A questionnaire associated with the research model will provide data to answer the research question. The collected data will be analysed and interpreted. Finally, conclusions will be drawn and recommendations will be made.

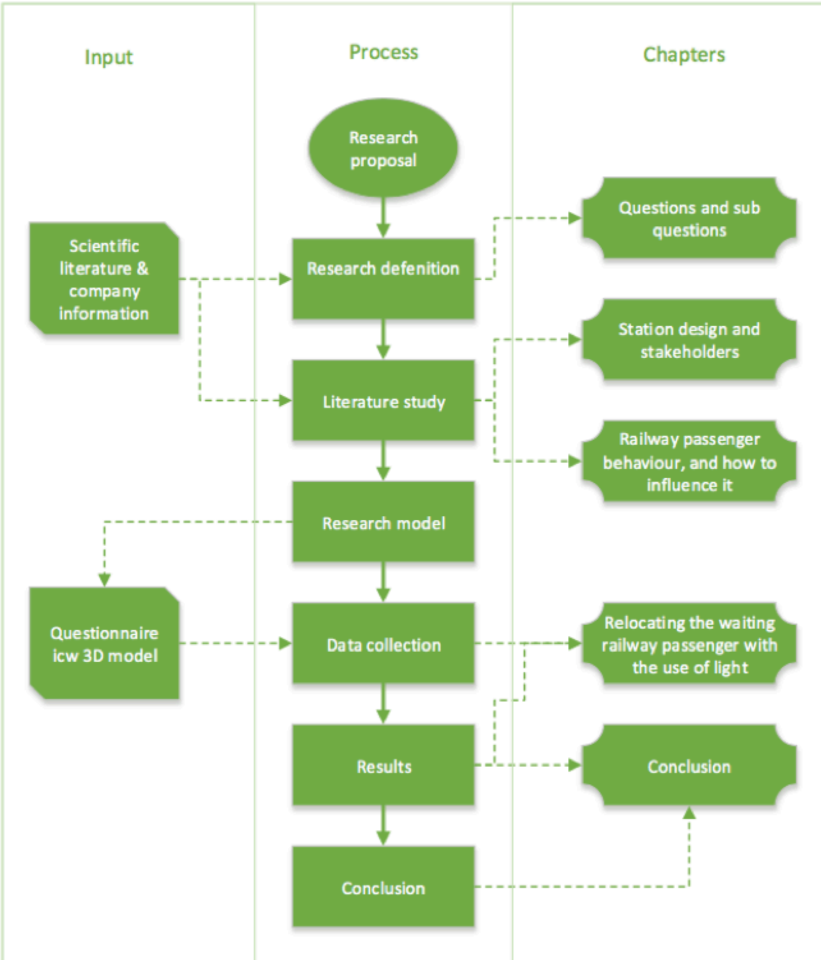



*Figure 1 – Research design*

### 1.5 Expected Results

Based on the literature, it is expected that comfort is an important factor for the waiting experience at a waiting location on a railway platform. If a higher level of comfort is clearly visible for passengers, it is more likely that the distribution of waiting passengers on the railway platform will be more uniform. The passengers, who travel by train more often, will probably be less influenced. They have more knowledge about the waiting locations, and they have habitual preferences in their waiting behaviour.
It is not clear what the effect of the comfort factor is. The goal of this research is to determine whether there are any effects. The possibility exists that passengers' behaviour is difficult to influence and therefore, the influence of relevant factors might not be significant.

If the outcome of the research shows an effect on the choice of a waiting location on a railway platform, this effect can be integrated in systems that predict railway passengers behaviour on railway stations. ProRail has shown interest in these methods for the distribution of passengers (Pasman, 2016). It is also possible to integrate the outcome of this research into existing pedestrian behaviour simulation models.

# 2 Railway stations: Design and stakeholders

In this chapter, a literature review will be conducted focusing on railway stations and the stakeholders that are involved. Firstly, railway stations and the distinguished domains as well as the categorization of railway stations in the Netherlands will be discussed. Subsequently, the corporate stakeholder will be presented. Finally, the non-corporate stakeholder will be presented.

## 2.1 Railway stations

Railway station buildings have multiple functions, which makes the design of that building a very complex task. A railway station functions as a connection between different transport modes. The main function of a railway station is to facilitate the movement of railway passengers to and from the train. Besides getting in and out of the train, there are other functions such as a commercial function. Between the different transport modes, walking is the primary way to get from one transport mode to another (Bosina, Britschgi, Meeder, & Weidmann, 2015). The ministry of transport (1961) described the traffic between destinations as follows: "*Between destinations there is traffic. Traffic is therefore a function of activities*" (Ministry of Transport, 1961).

### 2.1.1 Domains

To gain a clear understanding of the different functions of a railway stations, the functions should be separated into domains. In this approach, there is the *surrounding domain*, the *walking zone*, the *entrance domain*, the *traveller domain* and the *stay domain* (Bureau Spoorbouwmeester, 2012). In Figure 2 a graphical overview of the connection between the different domains is shown.

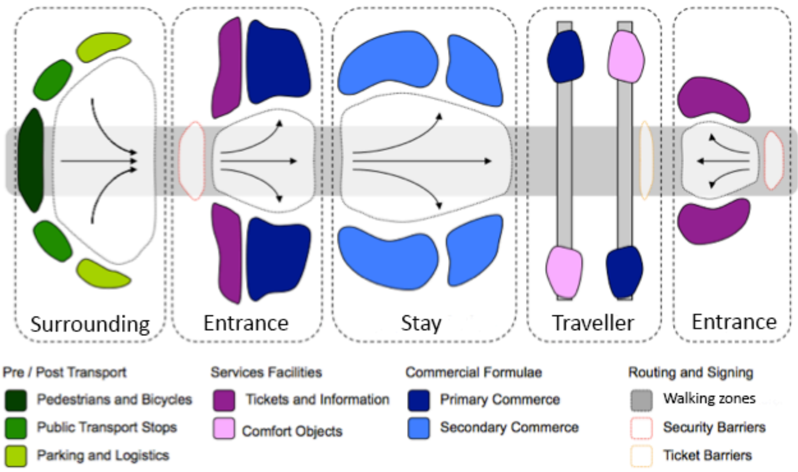



*Figure 2 – Domains and fields - Based on (van de Ree, 2011)*

These domains will be briefly explained, and after that they will be used to define the types of railway station (in *section 2.1.2*).

- *Surrounding domain* - is the definition of the areas outside of the railway station. In the municipality where the railway station is established signs should point out the location of the railway station entrance. In the surrounding areas there often is a forecourt site, which is dedicated to pedestrians. Before entering this forecourt the different transport methods are separated. By introducing parking spaces and bike storages, almost everyone is a pedestrian after storing their vehicle (Brouwer, 2010). This is needed for the *entrance domain*.

- *Entrance domains* - are the more public areas of the railway station buildings. Often the railway station buildings are iconic buildings for the city (Spoorbeeld, 2015). The entrance area has to deal with passengers that come to depart by train. The goal of the entrance area is to welcome passengers, and to give them relevant information. The information is focussed on their travel, either by train or other ways of transport. Also within the entrance area there is enough room for recreation, with or without consuming.

- *Stay domains* – are domains that are dedicated to waiting. Most passengers will see their waiting time as lost (Hagen, 2011). The stay domain tries to give a use to this time. In the stay domain passengers have access to stores and other activities to pass time.

- *Traveller domains* - are domains that are only important for the people who use the building as a transfer hub. The railway platforms are areas dedicated to travellers. When someone does not travel by train, they have no need to visit the platform. The railway platforms are the areas that can influence the traveller's experience (Hagen, 2011). With the introduction of the controlled access (by introducing gates), the platforms are no longer accessible for regular visitors who do not travel by train. Next to the entrance and stay domain, the traveller domain is mostly about safety and speed, and focuses on the loading and unloading of passengers from the train. Some of the platforms have stores (Kiosks) on them. These stores are service related. The platforms can be classified in different zones. Figure 3 shows a schematic view of how the theoretical optimal platform works. The waiting and walking zone are marked separately, but in reality they overlap each other. The traveller domain is therefore a complex domain to manage, because many different levels of service are applicable to the domain.

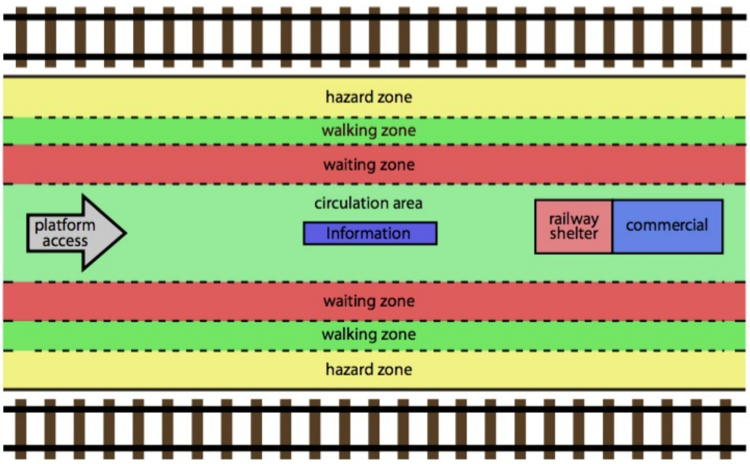



*Figure 3 – Platform classification (ProRail, 2005)*

- *Walking zones* - are the connective areas that can be found between the different domains. It often passes one domain to other domains, but has a separate place between these domains. Sometimes the railway station also has a connective function within the surrounding area. For example Eindhoven central station has a very obvious connective function. The north and south side of the station are connected through a hallway. The railway station additionally serves to connect both sides. Not every user of the railway station will use the train (ProRail, 2005).

### 2.1.2 Types of railway stations

Not every railway station has to deal with the same number of passengers. Nor is the expectation of railway passengers the same for every railway station. To gain an understanding of the different railway stations, van Hagen & Exel (2012) categorized railway stations in six different types (Table 1) (van Hagen & Exel, 2012). The railway station type also has an influence on the design of the railway station. Different types of railway stations will have different priorities and needs (ProRail, 2005).

*Table 1 – Railway station types*

| Type | Description | Train type servicing station: | Passengers / day |
|---|---|---|---|
| **Type 1** | Very big station, in big city | HST/IC, Intercity and Sprinter | > 50.000 |
| **Type 2** | Big station in middle big city | Intercity and Sprinter | 10.000 – 50.000 |
| **Type 3** | Pre-city station with junction function | Intercity and Sprinter | 5.000 – 25.000 |
| **Type 4** | Station near village or city | Sprinter | 2.500 – 10.000 |
| **Type 5** | Pre-city station without junction function | Sprinter | 2.500 – 5.000 |
| **Type 6** | Station in rural area | Sprinter | < 2.500 |

The categorization of the railway station types is as follows:

- Type 1 - a very big railway station railway station. For example Utrecht and Amsterdam's central railway stations. Inside railway stations of type 1, there generally is a clear distinction between the different domains. All the distinguished domains are applicable to this railway station type. The number of services offered inside the first type of railway station is very high. With more than 50,000 passengers a day, the railway station is busy. The railway station has direct connections with the other big railway stations. Multiple types of trains stop on the platforms of these stations, even international trains.
  Because these railway stations are built at the centre of major cities, a frequent issue is the lack of space. Due to the lack of space, these railway stations are relatively difficult to reach with other transportation modes. Walking is the preferred way of reaching a type 1 railway station.

- Type 2 - a big railway station in a medium-sized city. The type 2 railway station houses most of the domains, but the stay domain is not always present within the building. InterCity trains stop at these railway stations. These railway stations have to handle large groups of passengers who transfer from one train to another.

- Type 3 - a railway station that mostly located in the suburbs. The main advantage of this railway station type is that; they discharge the nearby railway stations of type 1. The railway station of Amsterdam Zuid is an example of a type 3 railway station. The type 3 railway stations have an InterCity train stop. It is easier for passengers to reach their final destination when travelling through a type 3 station. At least this is the case when the passenger does not have to be in the city centre. This railway station type lacks stay domains, but has the advantage of offering different transport modes, passengers can chose their way of transport pre-travel. There is more room for parking and bike storage. The travel domain is the most important domain for this type of railway station. Commercial activities on the railway platform are uncommon.

- Type 4 - a smaller railway station where Sprinter trains stop. A type 4 railway station can have a junction function. You can easily reach it, using every type of transport (train, car, bike and by foot).

- Type 5 - a smaller railway station located in the suburbs. It is built for regional connections and is mainly used during rush hours. These railway stations mainly consists of two domains: it has a traveller domain and walking zones. The entrance domain is often small.

- Type 6 - a small railway station with a low number of passengers. This type of railway station provides service for the area around it. A peak in the number of passengers can be seen during rush hour.

### 2.2 Corporate stakeholders

Within a railway station building several stakeholders are involved. They are classified as corporate stakeholders and passengers. In this section a description will be given for the stakeholders who have collective interest in the railway station building. A distinction between five different corporate stakeholders is made. They will be discussed successively.

Firstly, the most obvious stakeholder is *NS-Stations (NS-S)* (Dutch Railways – Stations). NS-S manages the railway stations but is a separate company next to the NSR (NS Reizigers: Dutch Railways - Traveller) (NS GROEP, 2016; NS, 2015). NS-S and NSR together are referred to as ‘the NS’ (Dutch Railways). The NS-S is managing nearly all stations, even the railway stations where NS-trains do not stop. Two main divisions can be found within the NS-S, namely *real estate and development* and *retail and services* (NS - Stations, 2016). The real estate and development division focuses on the development and maintenance of the railway stations. This concerns the entrance domains, the stay domains and the walking zones.
The focus of the retail and services division, as the name suggests lies on the stores and the services around theme. These services also includes the cleaning of the railway stations. This cleaning is done in all the different domains, except the surrounding domain (which is maintained by the municipality). Retail is most likely to take place in the stay and entrance domain, but some of the stores are located on the platforms, which extends the scope of the retail to the traveller domain.

Secondly, there is *ProRail*. ProRail is in charge of the railway infrastructure in the Netherlands. They are also responsible for the railway platforms and the connections between the platforms to the main railway station building. These railway platforms are an important part of the railway station building; ProRail has to make sure these platforms are safe and available for use (ProRail, 2016).

The third corporate stakeholder is *NSR* (NS-Reiziger: Dutch Railways - Traveller). NSR is the company that most Dutch associate with the NS (Dutch Railways). The NSR is responsible for

the trains and their train timetables. The train staff is employed by NSR. Other carriers, such as bus transport companies also participate in railway stations. For example Arriva, who provides transportation by bus and train. The NSR is the prime public transporter on the Dutch railways. During this research when a reference is made to a public transporter, this refers to NSR.
The NSR also has a say in the operation of the railway station buildings. The *OVCP-Project* (Public transport chip gates) is carried out by the NSR. The placement of the OVCP can have influence on the arrangement of the different domains. The OVCP-Project dependents on the different carriers that offer their services within the railway station.

The fourth stakeholder of railway station buildings is the *municipality*. The municipality has to adapt the land-use plans for the building to be built and operated. They also have to make sure all permits for the buildings are checked. Besides the land-use plan, the municipality has a lot of influence on the surrounding domain. Through this, the municipality has an influence on the accessibility of the railway station.

There is one more stakeholder, who is considered important for this research, at railway stations, namely *Bureau Spoorbouwmeester* (Master Agency of buildings in the railway sector), who coordinates the whole building process at the railway stations. This stakeholder is an independent agency that monitors if the vision of all stations is met; i.e. the different interests, which are applicable to the railway station building will be checked.

## 2.3 Passengers

In the context of railway stations, the literature distinguishes railway passengers into two categories: *lust* travellers and *must* travellers (Wiggenraad, 2001; Hagen M. v., 2010; Galetzka & de Vries, 2012; Vos, 2013). Each year there are approximately 1 million must travellers, and 8 million lust travellers. The must travellers have a share of about 50% in the total number of trips made (Kramer, 2009). The NS uses another system to distinguish different traveller types. They will be briefly described in section 2.3.3.

### 2.3.1 Must travellers

Must travellers are characterized by their daily routine and knowledge about their trip. They have a very predicable routine from which they do not want to deviate. Mostly, they travel during rush hour (Galetzka & de Vries, 2012). In the Netherlands about 12% of the daily commuters use the train for their transportation (CBS, 2015), and can be classified as must travellers.
Must travellers have a focus on speed and efficiency of their travel (Roelofs, 2010; Barta & Ahtola, 1991; Boes, 2007). They want a clear and predictable environment in which they can orientate themselves easily. More stimuli than necessary in the railway station environment are undesirable for a must traveller (Van Hagen, 2011).

### 2.3.2 Lust travellers

Inside a railway station, lust travellers are generally more insecure than must travellers, due to the fact that they are less experienced travellers (Galetzka & de Vries, 2012). The lust traveller is usually unfamiliar with the railway station and the dynamics that are associated with it. The feeling of familiarity with a building will result into different behaviour than when people are not familiar with the structure of a building (Dijkstra, de Vries, & Jessurun, 2014).

If a passenger is not familiar with a railway station, route-seeking behaviour will arise. To avoid route-seeking behaviour, the railway station design should be clear enough to ensure that visitors of the railway station are able to move as fluidly as possible through the building. In general, to users of a building, visual information is very important for indoor orientation (Helbing, Buzna, Johansson, & Werner, 2005). A passenger that is unfamiliar with the situation will focus on information that is applicable to his needs (Kielar & Borrmann, 2016).

The feeling of unfamiliarity with a railway station can also lead to a *herding* effect. Herding can occur when an unfamiliar passenger is looking for other passengers to track the appropriate behaviour (Helbing, Buzna, Johansson, & Werner, 2005; Galetzka & de Vries, 2012). Herding behaviour can lead to congestions on railway platforms. Unfamiliar passengers will make a safe bet on their waiting location, and will join other passengers on their waiting location.

#### 2.3.3 Terminology NS

The NS categorizes its passengers into six groups (van Hagen & Exel, 2012). In this section, these groups will be briefly illustrated:

- Convenience seeker (*Dutch: Gemakszoeker*): This group of passengers uses the train as an easy way of transportation. They do not prepare their trip in advance. Passengers of this type do not check times before going to the railway station. They will gain their travel information by asking others.
- Life enricher (*Dutch: Levensverrijker*): A type of passenger that wants to be independent. This type of traveller generally has a high level of education. The live enricher uses the train to travel in a corporate manner. These trips take place during rush hours.
- Individualist (*Dutch: Individualist*): This type of passenger finds importance in his status. Two thirds of this group only travels for recreational purposes. They have a preference for first class travels.
- Functional planner (*Dutch: Functionele planner*): A passenger type who uses the train for business purposes. The functional planner knows the train travel system, and needs little preparation before a trip.
- Certainty seeker (*Dutch: Zekerheidszoeker*): This type of traveller only uses the train for recreational travels. The certainty seeker plans the travel very carefully before departure. They check with others whether they have the right information or not.
- Sociability seeker (*Dutch: Gezelligheidszoeker*): The group recreational travellers mainly consist out of sociability seekers. They are usually unfamiliar with train travels. They plan their trip carefully.

Within this categorisation of different traveller types, the travel frequency is also an important factor. The sociability seeker, certainty seeker and individualist can also be categorized as lust travellers. The functional planner, life enricher and convenience seeker can be categorized as must travellers. Not all passengers fit within these categorisations, but in general, it gives a good indication about the different types of passengers with whom the NS has to deal with daily.

### 2.4 Conclusion

A railway station building has multiple stakeholders. When looking at the railway platform, the most important stakeholders are ProRail, NS Stations and the railway passenger. ProRail and NS-S have to agree on the design, which will have consequences for the passenger.
The stakeholders are the same for any type of railway station. The number of passengers and the number of arriving and departing trains is the main difference between railway station types. Furthermore, some types of railway station do not have domains that other railway station types do have. With larger numbers of passengers, the amount of services offered increases. Different types of passengers will have different preferences when it comes to services. For example, the addition of stores in the stay domain is favourable for sociability seekers. Extra information, and NS-service points are favourable for the certainty seekers.

# 3 Waiting behaviour of railway passengers in relation to the location on the railway platform

**Abstract** – Railway passengers have the tendency to wait near the entrance points of the railway platform. It is the intent to organize a railway platform so that passengers are distributed more evenly, resulting in faster loading and unloading of passengers from the train. The effect of changing the waiting environment will also positively contribute to the safety aspect. The waiting behaviour of the passengers on a railway platform is dependent on both the type of traveller (must or lust) and the general behaviour of the passenger. For the must traveller, the most important behavioural factor is their habitual behaviour. A must traveller has developed a pattern in his trips; it thus is very difficult to get the must traveller out of this pattern. The average lust traveller is an insecure traveller, who does not spread out on the railway platform very easily. Both must and lust travellers have in common that they are looking for an optimal comfort level while waiting. The railway passenger looks for an optimum in comfort for his trip. On average the comfort levels are comparable on the whole platform. Therefore, the railway passenger tends to wait near the entrance point of the railway platform, because walking further will not result in more comfort. If the entrance point of the railway platform is too crowded, the passengers have the tendency to spread out further away from the entrance point. This is because the passengers feel uncomfortable when they are crammed together.
Increasing local comfort levels on the railway platform can stimulate the spreading of passengers. Introducing *environmental stimuli* can influence the comfort levels. These can be music, light and colour. Music is very dependent of the taste of the railway passenger, but can be introduced to improve comfort on certain places of the railway platform. A combination of light and colour seems to be the most viable option to change the waiting behaviour of the railway passenger. Because light and colour are less dependent on personal taste and can be observed from the entire railway platform as long as there are sightlines.

***Keywords***: *Environmental stimuli, Railway passenger behaviour, Comfort zone, Comfort level, Railway platform*

## 3.1 Introduction

A railway station building has as main function to optimise the movement of passengers between different transport solutions. Within the railway station, the behaviour of the railway passenger is very important. This behaviour should be taken into account when designing a railway station. This chapter will start with the explanation of the behaviour railway passengers currently show, more specifically the waiting behaviour of passengers. Subsequently, the focus will be on finding ways to influence the waiting behaviour of the railway passenger. The behaviour of the passengers will be explained using three categories, namely *must* travellers, *lust* travellers, and *general passengers*. These categories will be discussed successively within this section, where the behaviour of general passengers is illustrated, common behavioural issues will be explained.

Subsequently a few environmental stimuli are researched that could influence the choice of the railway passenger on their waiting location. The environmental stimuli *music, light* and *colour* will be discussed as well as some other influences. Finally from the acquired information the most promising option will be selected. This option will be researched in chapter 4.

## 3.2 Railway passenger behaviour

In chapter 2 it is already mentioned that railway passengers can be distinguished in *must* travellers and *lust* travellers. The main difference between the two traveller types is the frequency of travel. Must travellers travel at least once a week, lust travellers travel less frequently (Galetzka & de Vries, 2012). Assumed is that the difference of travel frequency result in a difference in knowledge of how railway station buildings function.

### 3.2.1 Must travellers behaviour

Passengers who travel with a high frequency are more likely to develop patterns in their behaviour. This behaviour is called *habitual behaviour*. The habitual behaviour has pros and cons considering travel efficiency, when looking how must travellers move through a railway station building. Habitual behaviour is defined as subconscious behaviour (Galetzka & de Vries, 2012; Dijksterhuis, Smith, van Baaren, & Wigboldus, 2005).

Besides this subconscious habitual behaviour, some must travellers show conscious habitual behaviour. They decide where to wait, due to their knowledge gained by regularity in their trips. For example they know where their train will stop at their destination railway station. They will choose their boarding location with their destination in mind, in order to travel more efficient (Thiellier, 2015).

Due to the habitual behaviour, the must traveller is a passenger that moves fast through the railway station. With the knowledge that the must traveller has gathered over time, a preference for routes and waiting locations is developed. The advantage of this behaviour is that the must traveller minimizes the travel time through the building. The disadvantage of this habitual behaviour is that the must traveller is quite stubborn. Motivating must travellers to change their behaviour is therefore challenging (Galetzka & de Vries, 2012).

### 3.2.2 Lust travellers behaviour

Passengers that do not travel very often are called lust travellers. Lust travellers are generally more insecure inside the railway stations (Galetzka & de Vries, 2012). The lust traveller is often unfamiliar with environment around him. This results in different way-finding behaviour than the must traveller has. Due to the unfamiliarity of the situation, the lust traveller is searching for information about the building structure. This information could be presented as signage in the building (Arthur & Passini, 1992). Besides the signage, the behaviour of other passengers can serve as an example for the lust traveller. Lust travellers choose certitude and are less inclined to spread out over the railway platform. They choose their waiting locations so that they are more certain to board the train. These locations are usually found around entrance points (Bosina, Britschgi, Meeder, & Weidmann, 2015).

### 3.2.3 General passenger behaviour

Both passenger types have their own preferences inside railway station buildings, but some of the behavioural aspects are similar for both groups. Both the lust and must passengers like to have the certainty that they can board the train. Therefore they are poorly distributed on the railway platform. Must travellers have gained extra knowledge from regular trips and they are therefore are more likely to spread out along the railway platform (Galetzka & de Vries, 2012).

What are important factors for all passengers when choosing a waiting location? Van Hagen (2010) has developed a pyramid of quality dimensions, which implies an order of importance (Figure 4) (Van Hagen, 2011). This pyramid illustrates a generalised image of preferences of NS passengers.

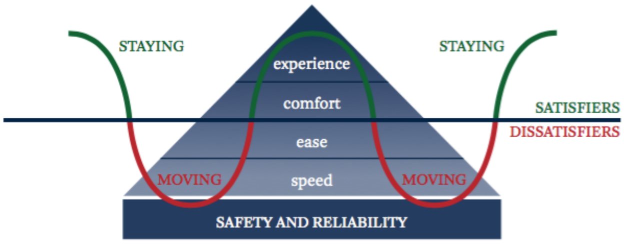



*Figure 4 – Pyramid of quality dimensions*

The most important factor for the NS passenger is safety and the reliability of the trip. Without safety and reliability, potential passengers will not become railway passengers. On top of that, the speed and ease of the travel are very important. Since these factors are dependent of the NSR, they are not relevant for this research. Comfort and waiting experience are the important factors for the waiting passenger. When the stay in a railway station building gives a positive feeling, the railway passenger has a more satisfied feeling.

To make sure the passengers board the train with a positive feeling; the experience and comfort should be optimised to the full extent (van Hagen, 2008). But how can this waiting experience be improved? When talking about crowds of passengers there is an optimum in the feeling of comfort and safety. Fruin (1971) has linked a level of service to the feeling of the passengers, which is influenced by the amount of passengers around (Fruin, 1971). ProRail uses these levels of services (LOS) when railway platforms are being designed (ProRail, 2005). When areas become crowded, most people will feel uncomfortable. Table 2 shows these levels of services and the corresponding (generalised) feelings are displayed. The LOS are based on slightly moving crowds.

*Table 2 – Level of Service (Fruin, 1971) (ProRail, 2005)*

| Level of service (LOS) | General feeling | Intensity (passengers per square meter) |
|---|---|---|
| A | Restful | < - 0.3 |
| B | Normal business | 0.3 – 0.4 |
| C | Reasonably busy | 0.4 – 0.7 |
| D | Crowded | 0.81 – 1.1 |
| E | Very crowded | 1.1 – 2 |
| F | Unacceptable crowded. | 2 - > |

ProRail uses LOS – C as the maximum level that crowds will have to experience (ProRail, 2005). Even if exceptional situations occur, the number of passengers per square meter should never get to the LOS – F (Unacceptable). The level of services will experience a peak just after a train arrives. Arriving passengers have the urgency to leave the railway station as soon as possible (Davidich, Geiss, Mayer, Pfaffinger, & Royer, 2013). Departing passengers have to wait until the arriving passengers are out of the train. When the arriving passengers are out of the train, the railway platform has a peak load of the number of passengers.

Besides the LOS, there are other factors that play a role in the route and location choice of passengers. Alfonzo (2005) has created a list of factors of importance (Alfonzo, 2005). These factors are:

1. *Feasibility* (Is the passenger capable of walking there)
2. *Accessibility* (Can the passenger walk there)
3. *Safety* (How is the perception of safety)
4. *Comfort* (Is it comfortable for the passenger to walk there)
5. *Pleasantness* (Is the surrounding interesting)

These factors are steps that will play an unconscious role in the mind of the passenger. The first 3 steps are the basic needs of the passengers on railway platforms. Steps 4 and 5 are both satisfiers. Passengers need a suitable platform, but a comfortable platform is just desirable. If the passenger can choose between a suitable platform with or without comfort, then the passenger will be more likely to choose the comfortable platform. If the comfortable platform is not present the rating, based on customer experience, of the platform is lower (NS-S, 2007).

In both the *pyramid of quality dimensions* (Figure 4, p.25) and the above mentioned *list of important factors* for passengers, the notion of comfort is mentioned. But what is meant by comfort? In this research, comfort relates to the comfort zone.
As shown in Figure 5 there is an optimum level between boredom and anxiety in comfort perception at the waiting location. Overstimulation will lead to anxiety. In the contrary, understimulation will lead to boredom (Van Hagen, 2011). Between the overstimulation and understimulation there is the comfort zone. "*The comfort zone is a situation or position in which a person feels secure, comfortable, or in control"* (Reverso-Softissimo, 2016).

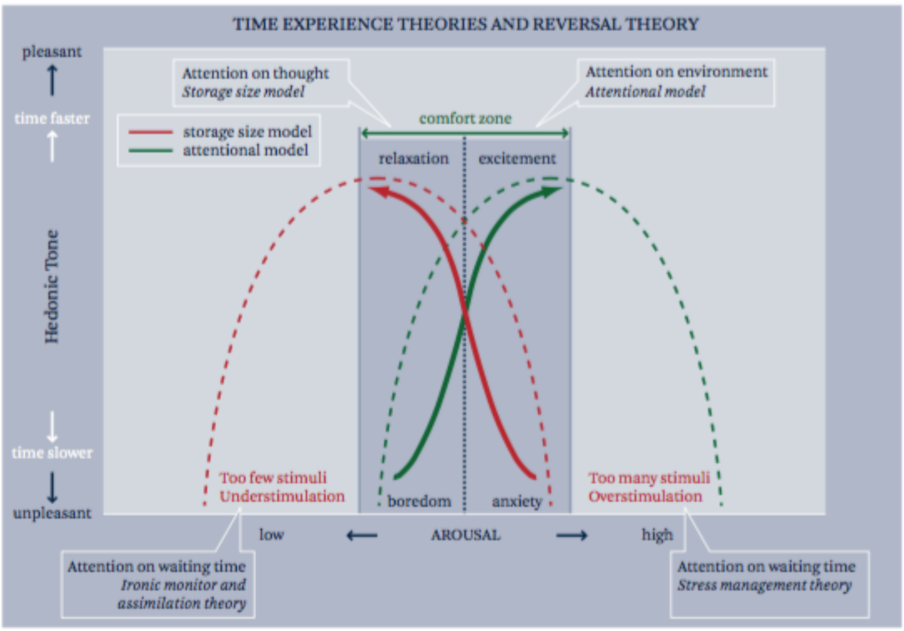



*Figure 5 – Comfort zone (Van Hagen, 2011)*

In addition to the comfort zone, there is also the Stimulus-Organism-Response (SOR) model (Figure 6). This SOR is based on the influence on approach and avoidance behaviour through emotions, because of environmental stimuli (Mehrabian & Russell, 1974).

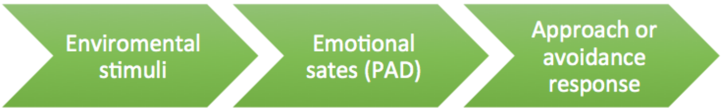



*Figure 6 – Stimulus Organism Response model*

Approach behaviour means that passengers would like to approach the area, and then want to stay in the area. They feel connected to the spot and would like to return there. With avoidance behaviour the opposite applies. This behaviour is based on emotions. These emotions can be explained by the terms *pleasure*, *arousal* and *dominance* (PAD). Pleasure is the degree of comfort that is available in the environment. Arousal is the degree of stimulation encountered in a situation. Dominance relates to the sense of control, a passenger feels in a certain area. For the approach behaviour, the three PAD emotions should be positive. If one of the emotions is negative, the avoidance behaviour is more likely.

### 3.2.4 Crowd behaviour

Crowd behaviour differs from the behaviour of single individuals (Duives, Daamen, & Hoogendoorn, 2013; Wijermans, Jorna, Jager, & van Vliet, 2007). In the context of this research, a crowd is characterised by single passengers all with the same goal, for example boarding the train. This goal is not the final goal, but the sequence of activities the passengers have to fulfil to reach their final destination (Ministry of Transport, 1961).

When the waiting crowd starts moving from or towards the train, multiple crowd behaviour effects are visible (Duives, Daamen, & Hoogendoorn, 2013). Two effects are identified; the *Zipper effect* (Hoogendoorn & Daamen, 2005) and the *Faster-is-Slower effect* (Helbing & Johansson, 2010). The zipper effect is an effect that is typical for people who let other people get in their pathway if there is enough space in front of them. When getting in or getting out of a train, it is important to have this space available for a quick flow of passengers. The faster-is-slower effect is about clogging up around bottlenecks because the rear part of the crowd keeps moving forward, although the crowd in front cannot move faster (Figure 7). Instead of moving faster, the whole crowd will slow down. This effect may occur around the boarding area of the train. The faster-is-slower effect is an undesirable effect that can lead to dangerous situations, because of the clogging up of areas in railway stations.

*Figure 7 – Faster-is-Slower (Getty, 2016)*

### 3.2.5 Waiting location on the railway platform

Within this subsection multiple behavioural aspects of railway passengers will be explained. How do these different aspects influence the choice for a waiting location of a passenger? Bosina et al. (2015) have examined how passengers currently choose their waiting location (Bosina, Britschgi, Meeder, & Weidmann, 2015). In Figure 8, the findings from their observational studies are shown. The conclusion of this field study is that passengers tend to wait near the entrance or elevation point of the railway platform. Figure 8 demonstrates this clearly.

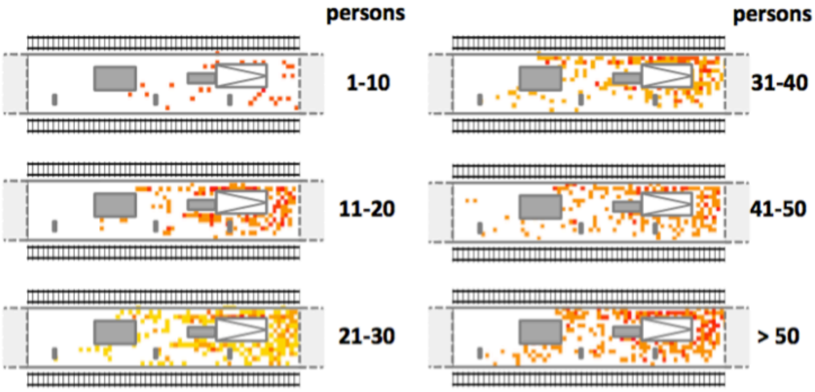



*Figure 8 – Waiting location (Bosina, Britschgi, Meeder, & Weidmann, 2015)*

The behaviour that is presented by Bosina et al. (2015) can be explained. Firstly, poor distribution on platforms can be (partly) explained by comfort. Because the comfort zone is between boredom and anxiety, the chosen location should have a good mix of these two aspects. Entrance points are the first feasible and accessible locations on the platform where a passenger arrives. If the passenger feels safe and no other options around the passenger seem to have more comfort, the passenger is more likely to stay in that area (Alfonzo, 2005). The passenger does not feel safe if the number of other passengers on the platform is too high (LOS > C –Table 2 p.25). If there is a good mix of pleasure, arousal and dominance, the passengers are distributed around the entrance point. However if other waiting location seems to be more comfortable and pleasant, these locations will be chosen. As described by Bosina et al. (2015), waiting locations with some shelter from the crowd are preferred (Bosina, Britschgi, Meeder, & Weidmann, 2015).

Must travellers are more likely to move to locations further on the platform, he does no need extra stimuli, which explains the movement away from the crowd around the entrance point. The life enricher and functional planner are very likely to move away to get a relatively quiet spot, while the certainty seeker is more likely to stay with the crowd (Boes, 2007).
Another factor that could influence the must traveller for his waiting location is the chance of getting a seat in the train. The must traveller is likely to have more knowledge about possible seats than the lust traveller. The lust travellers are less experienced travellers, and are less aware of pleasant waiting spots and the potential of free seats.

The conclusion is that railway passengers spread out poorly on the railway platform, because they seek the easiest and most obvious waiting location during their travel. When experience in the railway platform is introduced, the railway passenger is more likely to move to the least crowded locations on the railway platform. Otherwise, the passenger chooses the most pleasant and most comfortable location nearby.

## 3.3 Influencing the choice of the waiting location on the railway platform

In the Netherlands, railway passengers have the tendency to wait close to the entrance point of the railway platform. As mentioned before, this can result into dangerous situations. In this section, the influences to motivate the railway passenger to distribute more evenly over the platform will be studied.

The influences are based on the *optimal arousal theory* by Hebb (1955) (Hebb, 1955). This theory states that when there is too little arousal, the environment leads to boredom, and too much arousal leads to stress. Passengers tend to find a waiting spot where they find optimal arousal (Hagen, 2011). The five-minute wait should not lead to stress, neither should it lead to boredom. The arousal can be introduced in different ways. These different ways will be described below.

The environment should stimulate railway passengers to distribute themselves more. But what are the environmental stimuli? The literature describes a number of methods on how the environment can be changed to reach a close to optimal arousal level on railway platforms (Boes, 2007; Hagen M. v., 2010; Barta & Ahtola, 1991; Overduin, 2012). Not all environmental stimuli will be perceived (Lin, 2004). *Music* and *light & colour* will be discussed, because they have the greatest impact on the perception of quality of services (Baker, Grewal, & Parasuraman, 1994). Besides that, some recommendations of possible environmental stimuli that can be examined will be given.

### 3.3.1 Music

Music can have a positive influence on the railway passenger (Boes, 2007). It is an extra stimulus that can have a positive effect when the waiting passenger is bored. There are many different genres available that appeal to different audiences. When looking at the railway passenger, the lust traveller prefers music as a stimulus. Must travellers prefer background music (not too much extra stimuli). Boes (2007) describes the integration of music in railway station buildings as a complex task, because there are too many differences in music preferences (Boes, 2007). These different preferences could also be an opportunity to distribute people more evenly over a platform. When different types of music are spread over the platform, it could lead passengers to choose their waiting spot based on the type of music that is played on a certain location.

### 3.3.2 Light & Colour

Light is one of the most commonly used methods of getting attention. It is a very important visual stimulus (McIntyre, 2014). There are many examples where light is used to signal people. For example, in traffic, lights are commonly used. Traffic lights and brake lights are signals that can be thought of. The colour of the light is a very important aspect in signalling. The lights that are used as examples are direct lights (where one directly looks into the light).

Indirect lightning is commonly used to direct people in certain ways inside commercial buildings (Bellizzi, Crowley, & Hasty, 1983; Van Hagen, 2011). One can think of spotlights and different lighting patterns throughout retail buildings. With visual stimuli people are triggered to move to certain predefined locations.

Light intensity also has influence on the behaviour of people. When the intensity of light is too low (37 Lux), people can feel unsafe (Johansson, Rosén, & Küller, 2011). With higher intensity of the light (74 Lux), the dominance of the passenger increases (Hagen, 2011). The dominance rises because lighting enhances visibility, and that enhances the overview of the platform (Vos, 2013; Hof, 2008; Machleit, Eroglu, & Powell Mantel, 2009). The higher intensity of light also has an effect on the experienced waiting time. With higher light intensities the experienced waiting time increases (Hagen M. , 2008).

The colour of the light is also a factor that has an impact on the behaviour of people. Colours can attract or repel passengers (Hidayetoglu, Yildirim, & Akalin, 2012; Van Hagen, 2011). Warmer colours (< 4000K) attract people, while lighter colours (> 5000K) repel people. The colours between 4000K and 5000K are experienced as daylight, and have little effect on the behaviour of people. Colour is also easily memorised, which makes it a good attribute for way finding.

Lights have the advantage that they can easily be switched to the desired state. Because the control of lights is easily achievable, lights can be transformed into an adaptive system for influencing people. The disadvantage of lights is that, for railway platforms, the effects of the light are dependent on the light condition outside. After sunset, the effect will be more noticeable than after sunrise.

### 3.3.3 Other influences

Besides music and light & colour, there are more ways to influence the railway passenger in their choice of a waiting spot. In this section some methods will be suggested that could have a possible effect.

*Thermal influences* – By changing the temperature on certain spots, the level of comfort (LOC) that is obtained may rise. Hanging heaters, or other heating devices can change the thermal-LOC. On hot days this is undesirable, then flowing air can be introduced. Flowing air could be a good stimulus for warmer days, but on colder days it could also have an effect. The effect will then be a negative effect, which pushes waiting passengers away. On colder days, the negative effect of flowing air can also be superseded with extra shelter, leading to an increase in the thermal-LOC.

*Odour* – With the introduction of different scents, the passengers should be motivated to move to different places. The introduction of different scents presents the same issue as music. Scents are based on personal preferences (Hagen, 2011). This means that differentiating scents could separate passengers.

## 3.4 Conclusion

Must and lust travellers have different ways of choosing their waiting location, but there also is some overlap between their behaviours. The must traveller characterizes himself by its stubborn behaviour, whereas the lust traveller changes his behaviour more easily. For both groups, safety and reliability are very important during their travel. Besides that, the must traveller looks more for the practicality of the transportation mode. For the must traveller, time and quietness are very important. The lust traveller is looking for comfort and reassurance.

When looking at the waiting behaviour of railway passengers, the following trend can be observed. Most of the passengers have the tendency to wait near the entrance point of the railway platform. This can result in dangerous situations. The challenge is to find a solution for this problem, so that both lust travellers and must travellers will be triggered to spread out more on the platform. As mentioned before, the must traveller has, on average, a stubborn behaviour. It is very difficult to change his behaviour (Galetzka & de Vries, 2012). Railway passengers should not be exposed to a crowdedness of LOS C or higher (Table 2, p.25), because this could lead to a feeling of insecurity. The crowdedness plays a major factor in the comfort that railway passenger will experience. As discussed in section 3.2.5, passengers start to spread when the favourite waiting locations become too crowded.

To change the waiting behaviour of both the lust and must traveller, influences that could change the behaviour of both are studied. To create a more even distribution on the railway platform, the comfort will have to be optimised in the spaces where people should start waiting. The triggers that are looked for are environmental stimuli. Nowadays, they are used in a general way, changing the whole platform. Music, light and colour are used to optimise the comfort on the entire railway platform. Passengers feel safer with a higher light intensity. They are attracted to warm coloured lights. For music, the preferences depend on the preferred choice of music the individual passenger has.

Music, light and colour are ways that are confirmed by literature to be able to change the behaviour of people. Therefore, they are the most viable option when trying to distribute railway passengers on the platform. For the spreading of passengers, passengers should be able to notice their optimal comfort zone. Lights and colour are thought to be the most effective option, because lights can easily be seen throughout the entire platform. Therefore the research carried out in chapter 4 will be focussed on additional lights in the railway platform ceiling. The musical stimulus will not be examined because the range of music dependents on the source that is used to spread the music.

# 4 Relocating the waiting railway passenger by using the influence of light

**Abstract** – On railway platforms, railway passengers tend to wait near the entrance point. To influence this waiting behaviour so that passengers more evenly spread across the railway platform, some possible methods are proposed as they are derived from the literature. During the literature research, studies were conducted on the effect of additional lighting, which is attached to the ceiling of the platform. The research will focus on three factors, being; *additional lights, crowdedness* and the *location of waiting*. These factors will be examined using a Virtual Reality (VR) model in combination with a questionnaire. A total of 263 respondents were interviewed. Results show that crowdedness has a big influence on the behaviour of railway passengers. Railway passengers are spreading out further on the platform when the crowdedness increases. Railway passengers, who experienced a busy situation, indicate that they feel uncomfortable on their current waiting spot, and that they want to leave because of the crowdedness. Railway passengers show the tendency to leave their current waiting spot when additional lighting is integrated in a part of the platform ceiling. This trend is mentioned, but the effect is not significant, which is probably due to the lack of respondents.

***Keywords***: *Railway platform, Waiting location, Railway passenger behaviour, Crowdedness, Light stimulus*

## 4.1 Introduction

The Dutch railway network is the most intensively used train network in Europe (CBS, Hoe druk is het nu werkelijk op het Nederlandse spoor?, 2009). On the Dutch railway network, the Dutch Railways (NS-R) and other railway transport companies transport passengers from one railway station to another. Some of these railway stations (*Type 1, 2* and *3* (Table 1*, p.17*)) have to deal with large numbers of passengers every day. The 1.2 million railway passengers that travel every day have to get in and out of the train on railway platforms (NS, 2015). On these railway platforms, passengers tend to wait near the entrance point of the platform. This can lead to overcrowded areas around these entrance points (Bosina, Britschgi, Meeder, & Weidmann, 2015). Railway passengers almost find comfort levels to be as important as safety levels. This research will focus on this aspect of comfort to spread passengers more evenly on the railway platform in order to overcome safety issues with overcrowded railway platforms. ProRail has shown interest in this research, which has never been done before (Pasman, 2016). The research should give more insight in the effect of environmental stimuli on the behaviour of the waiting passengers. This chapter examines whether the passenger can be motivated to distribute more evenly on the railway platform. The influences in relation to this motivation have been examined in chapter 3 and labelled as factors. The effect of the light factor and crowdedness on the railway platform will be researched. Lights are often used to influence the way passengers choose their location (Bellizzi, Crowley, & Hasty, 1983). Whereas crowdedness also helps to spread railway passengers on a railway platform (Bosina, Britschgi, Meeder, & Weidmann, 2015).
This chapter is organized as follows. Firstly, the research methodology is discussed to show the methods used in the research process, including model variables, model presentation,

how to gather information and how to present the research model to respondents. After which, the process of data collection, analysis of the data, and the interpretation of results of the analysis are described. Finally, to conclude, there is a discussion about the results.

## 4.2 METHODOLOGY

As mentioned in the introduction, a research methodology describes the research process and is shown in (Figure 9).

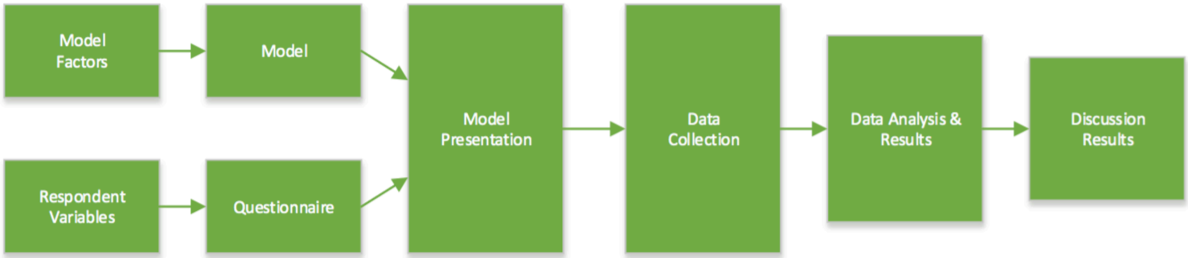



*Figure 9 - Research methodology*

Firstly, the light factor and crowdedness factor are incorporated as model factors in a VR-based model. Also, respondent variables are set. A questionnaire will be supplied to gather information about these respondent variables. The questionnaire and the VR-based model are introduced in the model presentation. The model presentation will be shown to respondents who answered both general questions as well as questions about the VR-based model. Then the responses on the model presentation provide the data collection. After that the essential part of data analysis and interpreting the results of this data analysis will be conducted. At the end, the results will be discussed.

## 4.3 FACTORS AND MODEL PRESENTATION

In this section, the chosen factors and their integration into the models will be discussed. The factors are chosen after an intensive literature study, which is done in chapters 2 and 3. In the literature study, the attraction of light and the feeling of comfort when one is in a crowd, is described. Firstly, these factors will be explained. Subsequently the impact of these factors on the creation of the model will be presented.

### 4.3.1 FACTORS

The research will focus on three different factors, being; *additional light*, *crowdedness* and *waiting location*. These factors are chosen after extensive literature study, which is mentioned before. The main reason why these factors are selected are described hereafter:

***Additional light*:**

For changing the waiting location choice of the passengers, the passengers need to be triggered to move to another place. Additional light can serve as a stimulus for the waiting railway passengers (Bellizzi, Crowley, & Hasty, 1983). To make sure the additional light can be seen by every passenger, it will be placed in the ceiling of the roof of the railway platform. When this is done, the additional lights have a higher chance to be seen, because the roof can be seen from almost any place on the platform. As van Hagen (2011) suggests, warm coloured light with a higher than average intensity attracts people (Hagen, 2011). For this research, the choice was made to use warm coloured lights (3500K). The additional light is added to the existing lights. This results in a higher light intensity.

***Crowdedness*:**
The number of people around a waiting passenger is a factor that could influence the choice for a waiting location. Within the research it is necessary to keep sightlines in the models (section 4.3.2). Fruin (1971) linked the intensity of crowdedness for groups with levels of services (LOS)(See Table 2, p.25). For crowded there is chosen for LOS of type C, which is described as reasonable busy. The railway platform is divided in boxes of 10 meters by 7.5 meters. With 30 people in this box the LOS is:

$$LOS = \frac{30p}{75m^2} = 0.4\ \mathrm{p}/m^2 \quad \text{(Eq.1)}$$

where:

*p = people*

The outcome of Eq.1 shows 0.4 passengers per square meter, which refers to a reasonably busy railway platform resulting in a LOS of type C. For the less crowded model the choice is made to use LOS of type A ($\leq 0.3$ p/m$^2$). The number of people will be kept very low on the platform ($<0.1$ p/m$^2$). It is assumed that railway passengers will experience this as quiet.

***Waiting location*:**
The goal of the research is to influence the choice of the waiting location. Therefore, this is an important factor. The research will be seen as successfully if the passenger board one carriage further than when none extra stimuli are integrated (26.4 meter (ProRail, 2016)).

By combining factors, hypotheses can be drawn up for the research. The first hypothesis is a combination of crowdedness and the waiting location. When the platform becomes more crowded, people will have the tendency to move away from the entrance point. Crowdedness is a *push* factor (pushes railway passengers away from their current waiting spot). Therefore the hypothesis is:

*(H0: The passenger will not move when the crowdedness increases)*
*(H1: The passenger will move further away from the current waiting spot when the crowdedness increases)*

The integration of additional lights, introduces a *pull* factor (pulls railway passengers away from their current waiting spot). The lights should be tested within a situation where the additional lights are on, and where the additional lights are off. The hypothesis is stated as follows:

*(H0: The passenger will not move further when additional light is introduced)*
*(H1: The passenger will move toward the light when additional light is introduced)*

#### 4.3.2 Model presentation

The surrounding of where the questionnaire is if filled in has an influence on the results (Rhodes, 2002; Meet4Research, 2012). During this research efforts were made to ensure repeatability, this is why the choice was made to use virtual reality as a research method. The advantage of using virtual reality is the standardisation of a situation. With virtual reality techniques, the situation shown can be exactly the same for each respondent. This can be very helpful to rule out additional factors that might influence the results. Four different models will be made. Two factors in two different states will be investigated, resulting in $2^2$ models. Busy vs. Quiet and Additional light vs. No additional light will be considered. With the use of VR it is less likely that other factors influence the results, because only the considered factors change between the models.

The VR model will be developed using Autodesk Revit 2016. Within Revit 2016, there is a renderer called stereoscopic rendering by which a three-dimensional view can be created. The rendering can be viewed within web-browsers, and in stereoscopic glasses (also known as Virtual Reality goggles). During this research, the stereoscopic rendering is used.

To get a good virtual reality experience, the model has to be as realistic as possible (Doucet, Gulli, & Martinez-Trujillo, 2016). As basis for the models, Leeuwarden railway station is chosen. This railway station is a terminus railway station. The railway platforms are all connected through a square (Figure 10, Yellow – the stay domain). The passengers departing from this railway station have the tendency to wait near the end of the railway, where the stay domain and the travel domain blend. The waiting behaviour on this point can lead to congestions when trains arrive (Thiellier, 2015). Therefore, Leeuwarden's station is an appropriate railway station for this research.

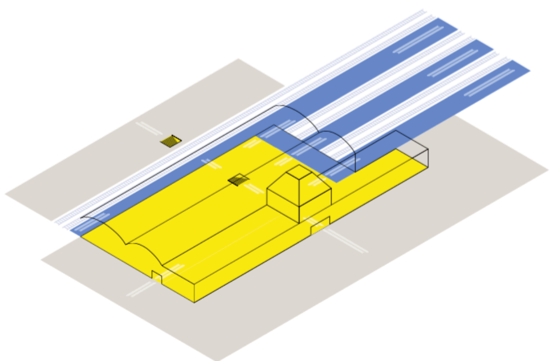


*Figure 10 – Leeuwarden station schematic (Bureau Spoorbouwmeester, 2012)*

For the development of the models, a 3D scan was made of the railway station building of Leeuwarden. The 3D scan was made using a point cloud. The point cloud is then imported in Autodesk Revit. After that, the models are created using the following successive steps:

1. Masses are created.
    - The rough structure of the building is created using the point cloud. The point cloud helps modelling through guiding when placing the walls and floors in the model.

2. Objects are modelled and placed.
    - The point cloud is not precise enough to integrate detailed objects in the model. From pictures and masses (created with the point cloud), objects like the columns are made. The train tracks are standard objects, imported from a library.
3. Materials are added to the components and objects.
    - Before the materials are added, the model is a grey mass. With pictures as comparison, the model is updated with materials that show as much similarity as possible.
4. Small objects, like information signs, bins etc. are added.
    - To give the model a more realistic feeling, small objects are added to the 3D environment. With the addition of billboard, information signs, bins and much more, the environment is made more realistic.
5. The additional lighting is added.
    - Revit files for the light sources are downloaded from Philips (Philips, 2016). These lights are integrated into the Revit model. For the two models where the warm light effect is integrated, warm coloured (3500K) Philips Pro Air spots are chosen as additional light to the normal situation.
6. Passengers and boxes are added.
    - Crowdedness is an important part of the research. By adding passengers, the model becomes crowded. There are two different types of passengers added; walking and standing passengers. A mix of these passengers gives a realistic feeling. There is chosen for *grey mass passengers.* The grey mass would not distract from the additional lighting effect or other details. If colourful clothes were added to the model, they could influence the final results.
    - On the railway platform, boxes are created by adding black lines on the railway platform. These boxes have a length of 10 meters, and have the width of the platform. Inside the boxes, the passengers are divided. In the *quiet* models they are spread out evenly. Within the *busy* models, the passengers are spread out so that LOS level C is reached at, what the respondent sees as, *the current waiting spot*.
7. Differentiation of factors is made between the models.
    - Four different models are rendered. The four different models for the different factors are made and made ready for uploading so that the models can be viewed on the Internet. After the rendering, the models get a new background (clouded dark air) added with Adobe Photoshop.
        - A static picture of the four different models is added in appendix 1.

## 4.4 RESPONDENT VARIABLES AND QUESTIONNAIRES

For the collection of data, respondents should answer research questions. The questions that have been are based on the variables to be are needed for this research. Therefore, the structure is as follows: Firstly the respondent variables will be explained. After which, the questions for the questionnaire will be presented.

### 4.4.1 RESPONDENT VARIABLES

For measuring the impact of the different variables on the behaviour of the railway passengers, respondent variables are needed. With these variables drafted, the questionnaire can be made.

Firstly, some general information is desired for the research. If the behaviour is different between certain groups, this could lead to interesting results. Therefore, *age* and *gender* are chosen as differentiating factors. Also the frequency of travel can have effects on the distribution of passengers (Wiggenraad, 2001). Subsequently, the factor *working in the railway sector* is added, because people working in the railway sector can have different perceptions on the boarding process.

Subsequently, the variables about the models can be tested. These variables will be based on the emotional states that are described in the Stimulus organism response model (Figure 6, p.27). These emotional states are *pleasure*, *arousal* and *dominance* (PAD). Pleasure and dominance can be measured with a simple question. The arousal is measured using multiple questions about the tendency to leave the location.

### 4.4.2 QUESTIONNAIRE

For the discovery of differences between the models, questions should be asked. This could be done with the help of an interview or with a questionnaire. The choice has been made for a questionnaire because an interview would limit the amount of respondents too much. To make sure the respondents would not get bored during the questionnaire, the time the questionnaire takes is minimized. Table 3 shows the first part of the questionnaire, and the reasoning behind the questions is given.

*Table 3 – Questionnaire questions and reasons*

| Question | Reason |
|---|---|
| *1. What is your age?* | To identify the differences in waiting behaviour correlated to the age. |
| *2. What is your gender?* | To identify the differences between man and woman for the waiting behaviour. |
| *3. Do you work in the railway sector?* | There is a chance that people working in the railway sector behave different on railway platforms. |
| *4. How often do you travel by train?* | The frequency of travel can separate lust and must travellers. |
| *5. Assumption: I am at ease here* | To identify if the waiting passengers feels *pleasure*. (Considering the entire railway station) |
| *6. Do you have the feeling you could easily walk to another spot?* | To identify if the waiting passenger feels *dominance.* |
| *7. Assumption: I think that my current spot (within the model) is a pleasant waiting spot* | To identify the *pleasure* the passenger feels on the current spot. |
| *8. Assumption: I think that my current spot is crowded* | To check if the feeling of crowdedness has influence on the waiting location (Arousal) |
| *9. Assumption: I would rather wait somewhere else than my current spot* | To check the tendency of leaving the current waiting spot (Arousal) |
| *10. Are you tempted to move to another waiting spot?* | To check if people will make the move to another waiting spot (Arousal) |

Question 10 influences on the progress of the questionnaire. If question 10 is answered with a yes response, the questions of Table 4 will be asked. When question 10 is answered with a no response, the question from Table 5 is asked. The respondent does not know this, for the reason that he/she will not choose the answer from question 10 for a specific reason.

*Table 4 – Questionnaire yes response*

| Question | Reason |
|---|---|
| *11. (Yes) Which other waiting location attracts you the most?* | There has to be chosen from 5 answers. (Location 2, current location cannot be chosen). This should specify if people are attracted to the light. |
| *12. What is the main reason you choose for the other waiting location?* | To qualify why people choose for that specific waiting spot |
| *13. What is the main reason to leave your current waiting spot?* | To qualify why people wanted to leave the current waiting spot |

*Table 5 – Questionnaire no response*

| Question | Reason |
|---|---|
| *11. (No) What is the main reason you would like to stay on the current waiting spot?* | To better understand why people want to stay at the current spot. This information can be used for future research |

All the questions with the exception of 1, 11 (No), 12 and 13, are multiple-choice questions. Question 1 (Age) can only be filled in with a number between 10 and 120. Question 11 (No), 12 and 13 are qualitative questions. These questions are aimed at gaining a better understanding of the current behaviour, and what drives passengers to their optimal waiting location. The remaining questions are all quantifiable.
Questions 5,7,8 and 9, are questions that are based on an assumption. To test these assumptions, a 7-point Likert scale is used. The scale goes from totally disagree to totally agree in seven gradations. The mid (*numbered 0 in the data)* of the Likert scale is the neutral point. The 7-point Likert scale is often used in behavioural research, and is considered stronger than a 5-point scale (Nunnally, 1994). There are more options to choose from, but not too many choices that bring respondents into doubt.

A context must be created in order to ask the questions. The following context is chosen:

*You are going to visit your family in Utrecht. Your train is delayed and will depart in about 5 minutes from platform 3.*

The context is briefly presented, so that respondents do not need to read large amounts of text when filling in the questionnaire

### 4.5 Presentation to respondents

Before collecting results through the questionnaire, it has to be presented to the respondents. For this presentation, a website has been created. The website (http://school.myfocus.nl) starts with a home page that introduces the research (Appendix 2). When a choice has been made for a language, and the *start* button is activated, one of the four models is randomly selected. The respondent does not know that he gets a randomly selected model. The randomizer has been tested, and has given a clear 24%, 26%, 25%, 25%) distribution (N=500).

When the start button is activated, a page with a (randomly chosen) model is displayed. The model can be viewed on the left side of the page. On the right side of the page the questionnaire is displayed. This is done to make sure that respondents can keep looking at the model when filling in the questionnaire (Appendix 3).

Usually within stereoscopic renderings there is an option to change the field of view. During this research, the field of view is fixed according to the standard human field of view in order to ensure that all respondents view the model the same way.

## 4.6 The collection of data

This section provides an overview of how the data is collected.

### 4.6.1 Number of respondents

For the research at least 384 respondents are needed. This is based on a calculation that is normally used for market research to select the best product (Research Company, 2014). In this research, it must be determined which option is the best, and by how much this 'option' differs from the others. The formula used to calculate the number of respondents is:

$$n = p * Q * (\frac{z}{e})^2 \quad \text{(Eq. 2)}$$

where:

- *n* = minimal number of respondents
- *p&q* = if the research is biased, this will correct (not in this case)
  - *The research is assumed not biased with p=0.5 & q=0.5*
- *z* = number of reliability (1.96), at a 95% confidence interval
- *e* = expected error, which has influence on the accuracy. An accuracy of 5% is chosen, therefore *e* = 5 (Research Company, 2014)

That results in:

$$n = 0.5 * 0.5 * \left(\frac{1.96}{5}\right)^2 = 384 \quad \text{(Eq. 3)}$$

### 4.6.2 Data collection

The data from the questionnaire is collected through Google forms. Google forms is a web-based data-collecting tool where questionnaires can be created and where their completion can be managed. The data that is collected through Google forms is saved in a Google-sheet file, which can be exported as an Excel file. Within the Excel file insight is given into the answers. The multiple-choice questions are stored as numbers of the answer. Answers of the open questions are stored in their original format. Google forms gives the option to restrict respondents in the answer they can give. For example, the question related to age can only be answered with numbers between 10 and 120.
The Excel file can be opened in SPSS. Within SPSS, the answers can be rated. The 7-Point Likert scale answers are described as ordinal data, the other multiple-choice questions are interpreted as nominal data.

## 4.7 Data and analysis

For the experiment the effect of additional lights in the roof of the platform will be studied. To research the effect of the extra lighting, a reference analysis should be made. The amount of passengers already present on the platform could influence the decision of moving to another waiting spot. This should be taken into account during the research. Therefore, four situations are researched. Two types of crowdedness (busy or quiet), and two types of lights (normal or extra lights) are researched. The ($2^2 = 4$) four different models that are needed for the research are described in Table 6. The numbers used in front of the model name are the numbers that represent the model in the data.

*Table 6 – Model description*

| Light effect / Crowdedness | None | Available |
|---|---|---|
| Quiet | *1 – Quiet Dark* | *2 – Quiet Light* |
| Crowded | *3 – Busy Dark* | *4 – Busy Light* |

### 4.7.1 Data Description

The data that are gathered using the questionnaire are shown in this section. First general information that can be extracted from the data will be discussed. After which the *pleasure*, *arousal* and *dominance* (PAD) data that is collected during the questionnaire will be analysed. Subsequently, research will be conducted regarding the changes in waiting locations. Finally the qualitative results will be interpreted.

#### 4.7.1.1 General statistics

In total, 263 respondents took part in this research. This does not meet the required 384 respondents needed (Section 4.6.1). On average the respondents are 26.1 years (*SD* = 9.46) old, which is lower than the average 43 years the Dutch population has (CBS, Bevolking; Kerncijfers, 2015). From the respondents, 41 (16%) are working in the railway sector and 222 (84%) are not. It can be seen in Figure 11 that the mode were not selected evenly, but the distribution of male and female respondents between the models is corresponding to the total sample size. From the group of 263 respondents, 114 (43%) are females, and 149 (57%) are male.

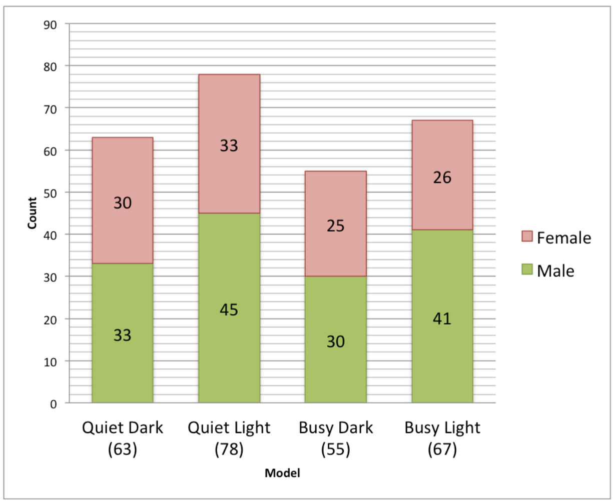



*Figure 11 – General respondent information on the models*

The distribution of the frequency of the travels is shown in Figure 12. Most of the respondents (39%) travel by train with a high frequency, which is more than once a week.

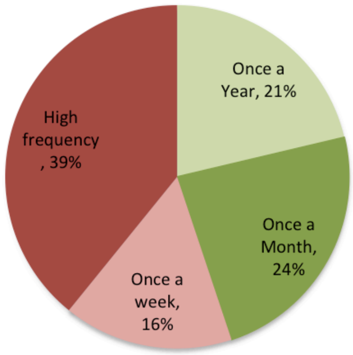



*Figure 12 - Frequency of travel*

The distribution of travel frequency corresponds with the distribution that the Dutch Railways (NS) use. As described in section 2.3 (*p.19*) the must travellers (high frequency & once a week) are responsible for about 50% of the travels. The obtained result of 55% of must travellers in this research is close to the number obtained from the Dutch Railways, indicating that the sample is representative for the target group. It can thus be assumed that the outcomes of the survey are representative for the entirety of Dutch Railway travellers.

#### 4.7.1.2 Crowdedness

The four models that were surveyed show a clear differentiation between the thought of crowdedness. With the question "I think that my current spot is crowded", the crowdedness was verified (Figure 13).

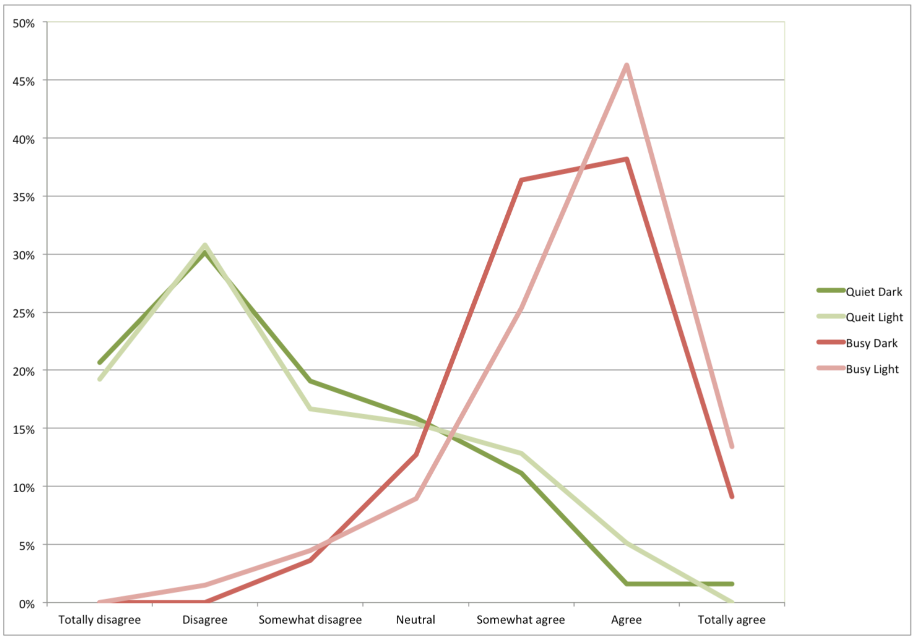



*Figure 13 - Crowdedness check*

In Figure 13, a clear distinction between the busy and quiet models can be seen. The difference in between the light and dark model show very little difference. Table 7 shows the mean values of the responses within the range of 'Totally disagree' (-3), 'Disagree' (-2), 'Somewhat disagree' (-1), Neutral (0), 'Somewhat agree' (1), 'Agree" (2) and "Totally agree (3). The standard deviation (*SD*) shows the quantification of the spread around the mean value. The table shows the responses for the four different models and the aggregation models for their light effect and crowdedness.

*Table 7 – Crowdedness: Mean values (range [-3,3] and SD*

| Model name | Mean values | SD |
|---|---|---|
| Quiet, Dark | -1.22 | 1.45 |
| Quiet, Light | -1.13 | 1.49 |
| Busy, Dark | 1.36 | 0.95 |
| Busy, Light | 1.50 | 1.08 |
| Quiet (Dark & Light) | -1.17 | 1.47 |
| Busy (Dark & Light) | 1.44 | 1.02 |
| Dark (Quiet & Busy) | -0.02 | 1.79 |
| Light (Quiet & Busy) | 0.09 | 1.89 |

When both the busy models and the quiet models are combined, a significant difference between busy and quiet can be seen (Table 8). Therefore, it can be assumed that the model is accurate with regards to crowdedness and quietness.

*Table 8 – Crowdedness: T-test*

| Comparison | | Levene's Test for Equality of Variances (equal variances assumed) | | | T-Test for Equality of Means | |
|---|---|---|---|---|---|---|
| vs. | | F | Sig. | Assumed | t | Sig. |
| Quiet, Dark | Quiet, Light | 0.159 | .690 | No | -.378 | .706 |
| Quiet, Dark | Busy, Dark | 10.949 | .001 | Yes | -11.261 | .000[1)] |
| Quiet, Dark | Busy, Light | 7.395 | .007 | Yes | -12.212 | .000[1)] |
| Quiet, Light | Busy, Dark | 15.108 | .000 | Yes | -10.934 | .000[1)] |
| Quiet, Light | Busy, Light | 10.953 | .001 | Yes | -12.028 | .000[1)] |
| Busy, Dark | Busy, Light | 0.458 | .500 | No | -.783 | .435 |
| Quiet (Dark & Light) | Busy (Dark & Light) | 21.178 | .000 | Yes | -16.501 | .000[1)] |
| Dark (Quiet & Busy) | Light (Quiet & Busy) | 0.685 | .409 | No | -.472 | .638 |

[1)]Significant at 0.05 level

#### 4.7.1.3 Pleasure arousal dominance (PAD)

Besides this general information, questions were also asked regarding the feeling that respondents got when seeing the 3D model. The analysis of the answers relating to the feeling of ease on the waiting spot is presented in Figure 14. The data is presented in percentages, to ensure that the response rate of each model does not lead to misinterpretation of the data.


*Figure 14 - Ease*

The graphical representation in Figure 14 shows a difference between the four models. The mean values and standard deviations of the models are shown in Table 9. The results of the T-Test for equality of means are shown in Table 10.

*Table 9 – Ease: Mean values (range [-3,3]) and SD*

| Model name | Mean values | SD |
|---|---|---|
| Quiet, Dark | 1.27 | 1.30 |
| Quiet, Light | 1.40 | 1.10 |
| Busy, Dark | 0.36 | 1.43 |
| Busy, Light | 0.51 | 1.43 |
| Quiet (Dark & Light) | 1.34 | 1.19 |
| Busy (Dark & Light) | 0.43 | 1.43 |
| Dark (Quiet & Busy) | 0.85 | 1.43 |
| Light (Quiet & Busy) | 0.99 | 1.33 |

The mean values of the "ease measurement" shows the following tendency: The *dark* models score lower than the *light* models, but not significantly lower. The *busy* models score lower in feeling of ease than the *quiet* models. This difference in feeling of ease is significant (see Table 10).

*Table 10 - I am at ease: T-test*

| Comparison | | Levene's Test for Equality of Variances (equal variances assumed) | | | T-Test for Equality of Means | |
|---|---|---|---|---|---|---|
| vs. | | F | Sig. | Assumed | t | Sig. |
| Quiet, Dark | Quiet, Light | 1.421 | .235 | No | -.621 | .536 |
| Quiet, Dark | Busy, Dark | 2.129 | .147 | Yes | 3.606 | .000[1)] |
| Quiet, Dark | Busy, Light | 1.332 | .251 | Yes | 3.178 | .002[1)] |
| Quiet, Light | Busy, Dark | 8.503 | .004 | No | 4.503 | .000[1)] |
| Quiet, Light | Busy, Light | 6.489 | .015 | Yes | 4.237 | .000[1] |
| Busy, Dark | Busy, Light | .102 | .750 | No | -.553 | .582 |
| Quiet (Dark & Light) | Busy (Dark & Light) | 8.283 | .004 | Yes | 5.569 | . 000[1] |
| Dark (Quiet & Busy) | Light (Quiet & Busy) | 2.049 | .153 | No | -.807 | .421 |

[1)]Significant at 0.05 level

Table 10 shows a significant difference between the *crowded* and *quiet* models comparisons. Respondents who have seen a *quiet* model, experience to be more at ease than respondents who had a *busy* model. The crowdedness of the platform has a significant effect on the feeling of ease at the platform. For the factor *light* the data shows less of an effect on the pleasure felt at the railway platform. When the models with additional lights (*light*) are combined and the models without the additional lights (*dark*), no significant impact can be determined. With the independent sample t-test the influence of the crowdedness on the pleasure (PAD) that is experienced by the waiting railway passenger can be determined.

The pleasure experienced on the current waiting spot, which is displayed in Figure 15, shows a similar effect. The pleasure experienced on the current waiting spot is assessed by a question regarding waiting spot, and not the whole building, which is done in the *"I am at ease"* question.


*Figure 15 – Pleasure current waiting spot*

It is shown in Figure 15 that, on average the respondents who have seen the *busy* models give a lower score of pleasure than the respondents that have seen the *quiet* models. When looking at the means (Table 11), a significant difference between the *quiet* and *busy* models can also be identified. The *dark* and *light* models do not show any significant difference between them. In Table 12 these differences are displayed.

*Table 11 – Pleasure current waiting spot: Mean values (range [-3,3]) and SD*

| Model name | Mean values | SD |
|---|---|---|
| Quiet, Dark | 0.57 | 1.60 |
| Quiet, Light | 0.60 | 1.44 |
| Busy, Dark | -1.60 | 1.57 |
| Busy, Light | -1.46 | 1.36 |
| Quiet (Dark & Light) | 0.59 | 1.51 |
| Busy (Dark & Light) | -1.53 | 1.46 |
| Dark (Quiet & Busy) | 0.12 | 1.65 |
| Light (Quiet & Busy) | 0.08 | 1.51 |

The mean values show that the assumption based on Figure 15 (*The busy models have a significant lower pleasure rating than the quiet models*) can be confirmed. On average the *busy* models score 2.12 points lower than the *quiet* models. Between the *dark* and *light* models the differences only are of 0.04 points. As shown in Table 12, the difference between the *dark* and *light* models is not significant for this factor, whereas the difference between *busy* and *quiet* models is significant.

*Table 12 – Pleasure current waiting spot: T-test*

| Comparison | | Levene's Test for Equality of Variances (equal variances assumed) | | | T-Test for Equality of Means | |
|---|---|---|---|---|---|---|
| vs. | | F | Sig. | Assumed | t | Sig. |
| Quiet, Dark | Quiet, Light | 1.410 | .237 | No | -.120 | .905 |
| Quiet, Dark | Busy, Dark | 0.032 | .859 | No | 3.319 | .001[1)] |
| Quiet, Dark | Busy, Light | 3.278 | .073 | No | 4.256 | .000[1)] |
| Quiet, Light | Busy, Dark | .934 | .336 | No | 3.747 | .000[1)] |
| Quiet, Light | Busy, Light | .507 | .477 | No | 4.883 | .000[1)] |
| Busy, Dark | Busy, Light | 2.521 | .115 | No | .510 | .611 |
| Quiet (Dark & Light) | Busy (Dark & Light) | .304 | .582 | No | 5.806 | .000[1)] |
| Dark (Quiet & Busy) | Light (Quiet & Busy) | 1.131 | .289 | No | .217 | .829 |

[1)] Significant at 0.05 level

Besides the pleasure, the arousal and dominance are also measured. While the arousal is described in the tendency to move (Section 4.7.1.4, p.48), the dominance is measured using the question "*Do you have the feeling you could easily walk to another spot?*". Figure 16 gives the assumption that the dominance of the passenger is mainly influenced by the crowdedness of the model.

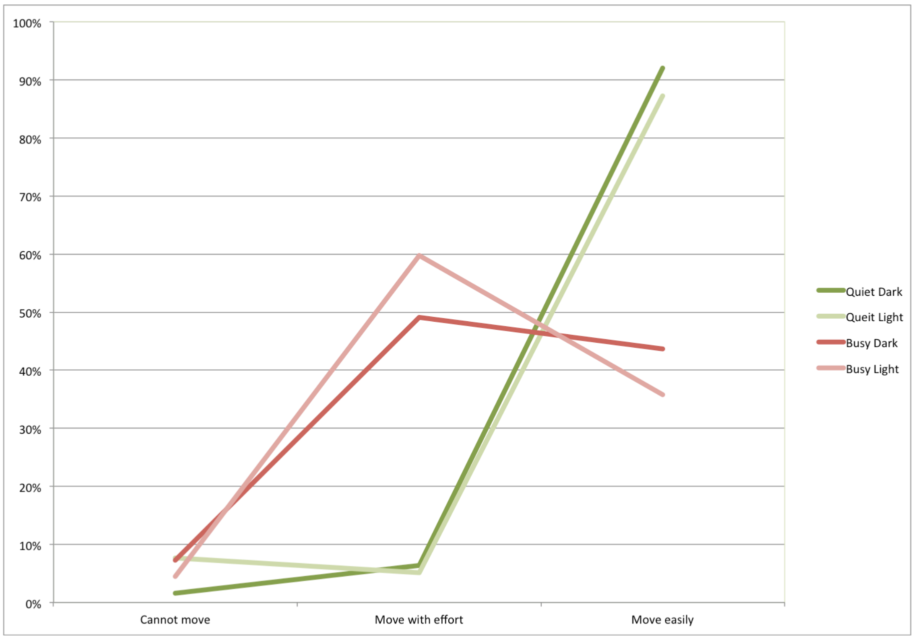



*Figure 16 – Dominance (Question 6)*

Both of the *busy* models and both the *quiet* models have corresponding shapes. The mean values of the models are also very close to each other as be seen in Table 13.

*Table 13 – Dominance - Mean values (range [1,3]) and SD*

| Model name | Mean values | SD |
|---|---|---|
| Quiet, Dark | 2.91 | 0.35 |
| Quiet, Light | 2.80 | 0.57 |
| Busy, Dark | 2.36 | 0.62 |
| Busy, Light | 2.31 | 0.56 |
| Quiet (Dark & Light) | 2.84 | 0.48 |
| Busy (Dark & Light) | 2.34 | 0.58 |
| Dark (Quiet & Busy) | 2.65 | 0.56 |
| Light (Quiet & Busy) | 2.57 | 0.61 |

The mean values between the *quiet* and *busy* models do differ (18% difference), whereas the *dark* and *light* models do not differ by much (3% difference). As displayed in Table 14, the models where the *quiet* model is compared to a *busy* model are significantly different. The other models do not show any significance difference between them.

*Table 14 – Dominance, independence sample T-test*

| Comparison | | Levene's Test for Equality of Variances (equal variances assumed) | | | T-Test for Equality of Means | |
|---|---|---|---|---|---|---|
| vs. | | F | Sig. | Assumed | t | Sig. |
| Quiet, Dark | Quiet, Light | 7.958 | .005 | Yes | 1.348 | .180 |
| Quiet, Dark | Busy, Dark | 53.153 | .000 | Yes | 5.952 | .000[1)] |
| Quiet, Dark | Busy, Light | 42.925 | .000 | Yes | 7.224 | .000[1)] |
| Quiet, Light | Busy, Dark | 8.927 | .003 | Yes | 4.158 | .000[1)] |
| Quiet, Light | Busy, Light | 4.899 | .028 | Yes | 5.145 | .000[1)] |
| Busy, Dark | Busy, Light | 1.834 | .178 | No | .466 | .642 |
| Quiet (Dark & Light) | Busy (Dark & Light) | 34.305 | .000 | Yes | 7.725 | .000[1)] |
| Dark (Quiet & Busy) | Light (Quiet & Busy) | 3.019 | .083 | No | 1.109 | .269 |

[1)] Significant at 0.05 level

The conclusion that can be drawn from this is that the dominance (related to movement) of the railway passenger is dependent of the amount of people around him.

#### 4.7.1.4 Changing waiting location

This section is an important part of this research. Within this section the different influence of the factors on the behaviour of the passengers should be identified. That would mean the integration of additional lights is a success. The question "I would rather wait somewhere else" checks how much intention there is for the respondent to move. The results of the responses are displayed in Figure 17.


*Figure 17 – I would rather wait somewhere else*

The four lines of the models are relatively parallel in Figure 17. When taking a closer look at the graph, the figure displays that quiet models core lower than the busy models. The mean values in Table 15 confirm this.

*Table 15 –I would rather wait somewhere else Mean values (range [-3,3]) and SD*

| Model name | Mean values | SD |
|---|---|---|
| Quiet, Dark | -0.08 | 1.96 |
| Quiet, Light | 0.31 | 1.78 |
| Busy, Dark | 0.98 | 1.39 |
| Busy, Light | 0.98 | 1.46 |
| Quiet (Dark & Light) | 0.14 | 1.87 |
| Busy (Dark & Light) | 0.98 | 1.43 |
| Dark (Quiet & Busy) | 0.41 | 1.79 |
| Light (Quiet & Busy) | 0.62 | 1.67 |

The *quiet* (*dark & light*) models score lower by 0.84 points compared to the *busy* models. This is a significant difference (Table 16). Between the *dark* (*quiet & busy*) and *light* (*quiet & busy*) models a difference begins to emerge. There is a difference of 0.21 points between the light *(quiet & busy)* and dark *(quiet & busy)* models. Respondents who have seen the *light* models tend to leave the area more frequently than respondents who have seen a *dark* model. This effect is not significant (66% certainty), but a tendency shows ($p$ = 0.342). It is possible that a larger sample size would result in a significant effect for this factor.

*Table 16 – I would rather wait somewhere else: T-test*

| Comparison | | Levene's Test for Equality of Variances (equal variances assumed) | | | T-Test for Equality of Means | |
|---|---|---|---|---|---|---|
| | vs. | F | Sig. | Assumed | t | Sig. |
| Quiet, Dark | Quiet, Light | 1.539 | .217 | No | -1.213 | .227 |
| Quiet, Dark | Busy, Dark | 15.968 | .000 | Yes | -3.341 | .001[1)] |
| Quiet, Dark | Busy, Light | 15.223 | .000 | Yes | -3.522 | .001[1)] |
| Quiet, Light | Busy, Dark | 9.298 | .003 | Yes | -2.344 | .021[1)] |
| Quiet, Light | Busy, Light | 8.825 | .003 | Yes | -2.476 | .014[1)] |
| Busy, Dark | Busy, Light | 0.009 | .924 | No | -.013 | .990 |
| Quiet (Dark & Light) | Busy (Dark & Light) | 23.897 | .000 | Yes | -4.172 | .000[1)] |
| Dark (Quiet & Busy) | Light (Quiet & Busy) | 1.859 | .174 | No | -.952 | .342 |

[1)]Significant at 0.05 level

When analysing the mean values of the separate (not combined) models, it can be seen that the tendency to *wait somewhere else* only shows when analysing the *quiet* models. This difference is not significant, but shows a higher certainty than the combined effect. It is possible that, when people have free space to move, they are more likely to move to the light area.
The results can be summarized as follows: Whether passengers feel the need to move somewhere else is heavily influenced by crowdedness. Additional lights aimed at the railway platform roof also show an effect on the behaviour of the passengers. Although this effect is not proven to be significant, the trend can be identified.

The actual movement of the railway passengers is determined through the question "Are you tempted to move to another waiting spot". This can only be answered with a *yes* (*1*) or a *no* (*2*). 150 (57%) respondents indicate that they would like to move to another waiting spot, whereas 113 (43%) respondents do not want to move. As can be seen in Figure 18, the tendency to move increases when light and crowdedness are added (seen from top to bottom).

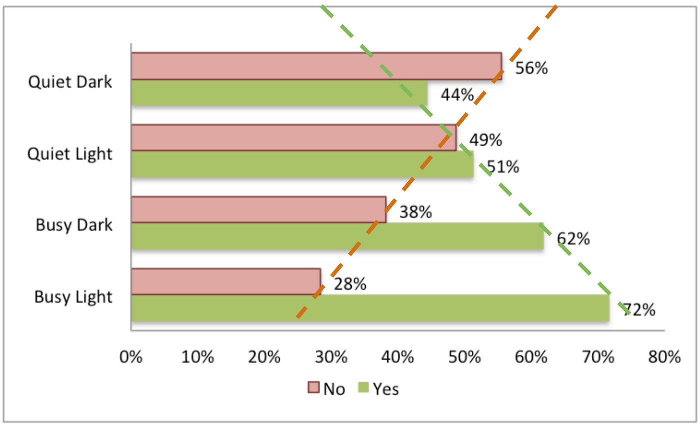



*Figure 18 – Are you tempted to move to another waiting spot*

In this situation the data differs significantly when testing the *quiet* (*quiet & busy*) and *dark* (*quiet & busy*) models (Table 17 & Table 18) against each other. The *busy* models have the highest score for leaving the waiting spot. The lights also have influence on this, but this is not significant.

*Table 17 - Are you tempted to move to another waiting spot: Mean values (range [1,2]) and SD*

| Model name | Means values | SD |
|---|---|---|
| Quiet, Dark | 1.56 | 0.50 |
| Quiet, Light | 1.49 | 0.50 |
| Busy, Dark | 1.38 | 0.49 |
| Busy, Light | 1.28 | 0.45 |
| Quiet (Dark & Light) | 1.52 | 0.50 |
| Busy (Dark & Light) | 1.33 | 0.47 |
| Dark (Quiet & Busy) | 1.48 | 0.50 |
| Light (Quiet & Busy) | 1.39 | 0.49 |

There is also a trend visible between the presence of additional lights and the percentage of respondents that want to leave their current waiting spot. This trend is visible in Figure 18 and Table 17.

*Table 18 – Are you tempted to move to another waiting spot: T-test*

| Comparison | | Levene's Test for Equality of Variances (equal variances assumed) | | | T-Test for Equality of Means | |
|---|---|---|---|---|---|---|
| | vs. | F | Sig. | Assumed | t | Sig. |
| Quiet, Dark | Quiet, Light | .808 | .370 | No | .804 | .423 |
| Quiet, Dark | Busy, Dark | 1.758 | .187 | No | 1.901 | .060 |
| Quiet, Dark | Busy, Light | 11.604 | .001 | Yes | 3.247 | .001[1)] |
| Quiet, Light | Busy, Dark | 4.363 | .039 | Yes | 1.202 | .232 |
| Quiet, Light | Busy, Light | 17.522 | .000 | Yes | 2.560 | .012[1)] |
| Busy, Dark | Busy, Light | 4.782 | .031 | Yes | 1.147 | .254 |
| Quiet (Dark & Light) | Busy (Dark & Light) | 18.164 | .000 | Yes | 3.148 | .002[1)] |
| Dark (Quiet & Busy) | Light (Quiet & Busy) | 4.763 | .030 | Yes | 1.327 | .186 |

[1)]Significant at 0.05 level

Table 18 displays that only the relation between *busy* and *quiet* models is significant. The null hypothesis (*H0: The passengers will not move when the crowdedness increases*) that is given in section 4.3, can be rejected.
The other comparisons between models show no significant effect. Although the effects between the dark and light models seemed promising, the null hypothesis (*H0: The passengers will not move further when additional light is introduced*) cannot be rejected. This is probably due to the sample size, but with an increasing number of respondents there is the possibility that the null hypothesis can be rejected.

To gain more insight in what influences the need to move, some extra tests are conducted. One of those tests is to see if gender has influence on the temptation to move.

*Table 19 - Gender and movement: Mean values (range [1,2] and SD*

| Gender | Mean values | SD |
|---|---|---|
| Male | 1.38 | 0.49 |
| Female | 1.49 | 0.50 |

The gender of the railway passengers does not seem to have a significant influence on the choice of (Independent sample t-test, equal variance assumed) (Table 19 & Table 20).

*Table 20 –Gender and movement: T-test*

| Comparison | | | Levene's Test for Equality of Variances (equal variances assumed) | | | T-Test for Equality of Means | |
|---|---|---|---|---|---|---|---|
| | vs. | | F | Sig. | Assumed | t | Sig. |
| Male | | Female | 6.504 | .011 | Yes | -1.768 | .078 |

When looking at the likeliness to move to another waiting spot, males and female do not react significantly different to the difference in crowd nor the addition of light (Figure 19). Using a Chi-square test these factors are compared to each other. This test, $X^2$ (1, $N$ = 263) = 3.1138 shows a significant effect ($p$ = 0.078) at 0.1 (90% confidence). It seems that *males* have a stronger urge to change their position than *females*. The difference is mostly in the *busy dark* & *quiet light* model, where men are more likely to move.

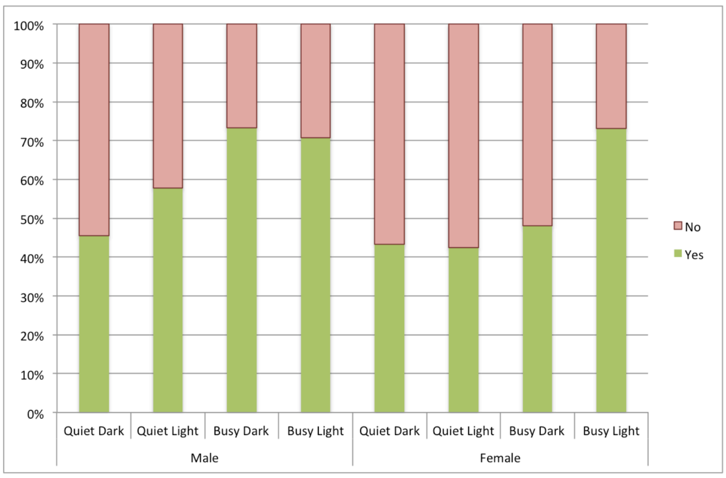



*Figure 19 – Gender and movement by model*

People working in the railway sector are thought to have more knowledge about the problems that can occur on a railway platform, and that they will be more likely to spread out over the platform (Table 21).

*Table 21 –Working in PT: Mean values (range [1,2]) and SD*

| PT - Prof | Mean values | SD |
|---|---|---|
| Yes | 1.34 | 0.48 |
| No | 1.45 | 0.50 |

Combining the professional knowledge and the tendency to move, a trend can be seen for people working in the sector of public transportation. They are more likely to move to another waiting spot than passengers who do not work in the railway sector. However, the effect is not significant (Table 22).

*Table 22 – Public transport Professional: T-test*

| Comparison | | Levene's Test for Equality of Variances (equal variances assumed) | | | T-Test for Equality of Means | |
|---|---|---|---|---|---|---|
| vs. | | F | Sig. | Assumed | t | Sig. |
| Professional | Non professional | 11.369 | .001 | Yes | -1.241 | .216 |

As described by Galetzka & de Vries (2012) the frequency of travel can also have influence on the waiting location that a passenger chooses (Galetzka & de Vries, 2012).

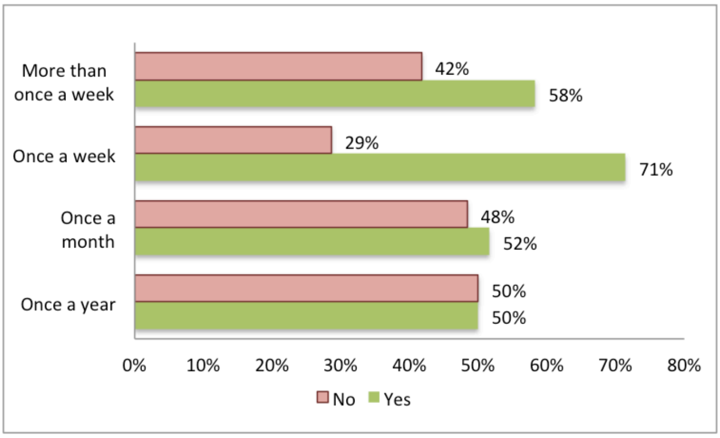



*Figure 20 – Travel frequency and movement*

Must travellers, who travel once a week or more, are more likely to relocate themselves than the lust traveller, who travels once a month or less (Figure 20, Table 23 and Table 24).

*Table 23 –Travel frequency and movement - Mean values (range [1,2]) and SD*

| Frequency | Mean values | SD |
|---|---|---|
| Often | 1.41 | 0.50 |
| Once a week | 1.29 | 0.46 |
| Once a month | 1.48 | 0.50 |
| Once a year | 1.50 | 0.50 |
| Frequent (combined) | 1.38 | 0.49 |
| Infrequent (combined) | 1.49 | 0.50 |

As shown in Table 24, there is a difference when frequent travellers (often & once a week) (must travellers) and infrequent travellers (once a month & once a year) are compared with each other.

*Table 24 –Travel frequency and movement: T-test*

| Comparison | | Levene's Test for Equality of Variances (equal variances assumed) | | | T-Test for Equality of Means | |
|---|---|---|---|---|---|---|
| | vs. | F | Sig. | Assumed | t | Sig. |
| Often | Once a week | 11.566 | .001 | Yes | 1.484 | .140 |
| Often | Once a month | 1.550 | .215 | No | -.825 | .411 |
| Often | Once a year | 1.548 | .215 | No | -.991 | .324 |
| Once a week | Once a month | 13.390 | .000 | Yes | -2.042 | .044[1)] |
| Once a week | Once a year | 12.343 | .001 | Yes | -2.165 | .033[1)] |
| Once a month | Once a year | 0.057 | .811 | No | .174 | .863 |
| Freq (Combined) | Infreq (combined) | 7.143 | .008 | Yes | 1.833 | .069 |

[1)] Significant at 0.05 level

However, the effect cannot be proven to significant. When a certainty level of 90% (instead of 95%) is used, the effect is significant. The following effect can be seen; the more frequent a traveller travels, the more he tends to move away from the "current" location. When comparing these results to the literature study (section 3.2, *p.24*), this effect was expected. Must travellers (frequent travellers) are more likely to spread out over the railway platform than lust travellers (infrequent travellers).

With a Chi-Square test it is tested if the frequency of travel has an effect on the likeliness to move, when focusing on the different types of models. No significant correlation between these three factors is found. During the analysing no significant correlation has been found in any of the models, $X^2$ (3, $N$ = 263) = 5.488, $p$ = 0.14.

The frequency of travel, in any of the models, does not seem to have an effect of how likely the passenger is to move to another waiting location.
Only the quiet dark model shows a close to significant difference between the different frequencies of travel. This can be explained by the lack of respondents. Figure 21 shows an outlier in the *quiet dark* model for the frequency of once a week, which goes against the expected outcomes.

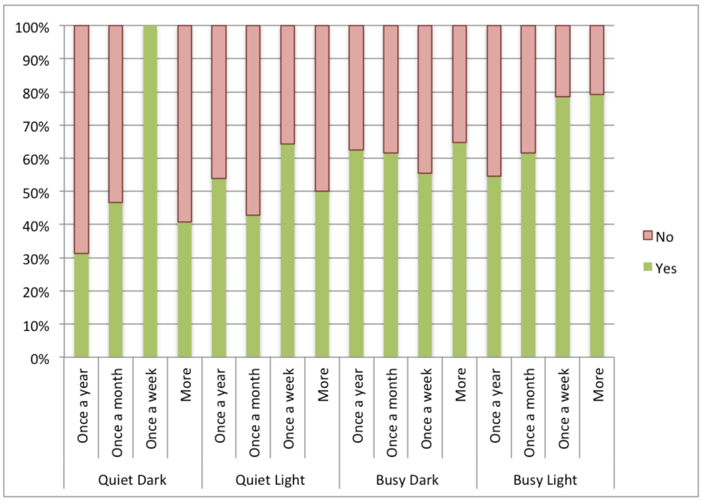



*Figure 21 – Model type, travel frequency & tendency to move*

The results for every model type are displayed in Table 25. Within the different models, no significant difference between *likeliness to move* and *travel frequency* can be found. The results show a trend, where must travellers are more likely to move than lust travellers. Additional research with more respondents is needed to verify this trend.

*Table 25 – Chi-Square results per model*

| Model | Results |
|---|---|
| *Quiet dark* | $X^2$ (3, $N$ = 63) = 7.558, $p$ = 0.06 |
| *Quiet light* | $X^2$ (3, $N$ = 78) = 1.598, $p$ = 0.66 |
| *Busy dark* | $X^2$ (3, $N$ = 55) = 0.213, $p$ = 0.98 |
| *Busy light* | $X^2$ (3, $N$ = 67) = 3.406, $p$ = 0.33 |

#### 4.7.1.5 Moving to another waiting location

The 150 respondents who indicated they want to move to another waiting location have been asked which other waiting location had their preference. The remaining 113 respondents were not asked this question. Sometimes they contribute to the results and are then integrated in the analysis, which is indicated with the text “Stayers included”.
In the 3D-model the waiting locations were presented as boxes (10 meter*platform width) with numbers in them. A schematic representation of the top view is shown in Figure 22.

| | | | | | |
|---|---|---|---|---|---|
| 1 | ***2*** | 3 | 4 | 5 | 6 |

*Figure 22 – Schematic representation numbered railway platform: View 1*

The respondent have view the 3D model from waiting location *2.* This is at the entrance point. Locations *3 to 6* are located on the platform. Location *6* is far away from location *2*, and location *1* is behind the respondent and represents a waiting location that has a negative effect on the distribution, keeping in mind that the distribution of the railway passengers is the goal of the research. During the analysis of the results the numbers used are not ideal. The data is recoded and is presented in two different forms.

Figure 23 presents a schematic overview of the first way of recoding the data. The amount of boxes that the respondent is willing to walk is used as measurement.

| 1 | *0* | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|

*Figure 23 - Schematic representation numbered railway platform: View 2*

With this approach the amount of meters that the respondent is willing to walk can be identified. This method gives less insight in the effect of the different factors that are tested. Therefore the recoding that is presented in Figure 24, will also be used.

On average the relocating respondents indicated that they are willing to move 2.4 boxes (24 meters - Table 27). The average distance walked by all respondents is 1.4 box (14 meters) (Stayers included).

*Table 26 –Movement count (including Stayers): T-test*

| **Comparison** | | **Levene's Test for Equality of Variances (equal variances assumed)** | | | **T-Test for Equality of Means** | |
|---|---|---|---|---|---|---|
| vs. | | F | Sig. | Assumed | t | Sig. |
| Quiet, Dark | Quiet, Light | .048 | .827 | No | -.417 | .678 |
| Quiet, Dark | Busy, Dark | .008 | .931 | No | -1.307 | .194 |
| Quiet, Dark | Busy, Light | .046 | .831 | No | -2.708 | .008[1)] |
| Quiet, Light | Busy, Dark | .085 | .770 | No | -.986 | .326 |
| Quiet, Light | Busy, Light | .001 | .980 | No | -2.458 | .015[1)] |
| Busy, Dark | Busy, Light | .077 | .782 | No | -1.251 | .214 |
| Quiet (Dark & Light) | Busy (Dark & Light) | .081 | .776 | No | -2.690 | .008[1)] |
| Dark (Quiet & Busy) | Light (Quiet & Busy) | .018 | .894 | No | -1.147 | .252 |

[1)] Significant at 0.05 level

A significant difference can be found between quiet and busy models. Between the dark and light models a tendency to move can be observed. This is only the case when the stayers are included during the t-test for equality of means.

*Table 27 – Movement count - Mean values (range [1,4]) and SD*

| **Model name** | **Without Stayers** | | **With Stayers** | |
|---|---|---|---|---|
| | **Mean values** | **SD** | **Mean values** | **SD** |
| Quiet, Dark | 2.46 | 0.96 | 1.10 | 1.39 |
| Quiet, Light | 2.33 | 0.97 | 1.19 | 1.36 |
| Busy, Dark | 2.32 | 1.12 | 1.44 | 1.44 |
| Busy, Light | 2.46 | 1.03 | 1.76 | 1.41 |
| Quiet (Dark & Light) | 2.38 | 0.96 | 1.15 | 1.37 |
| Busy (Dark & Light) | 2.40 | 1.06 | 1.62 | 1.42 |
| Dark (Quiet & Busy) | 2.39 | 1.04 | 1.25 | 1.42 |
| Light (Quiet & Busy) | 2.40 | 1.00 | 1.46 | 1.41 |

To identify what the result of additional lights and crowdedness are, the relocation of the passengers is recoded as presented in Figure 24.

| -1 | *0* | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|

*Figure 24 - Schematic representation numbered railway platform: View 3*

When the data are recoded in this manner, the data gives insight in the effect on the distribution of the railway passengers. The data cannot be used to determine the average distance the respondents are willing to walk to their waiting location.

Table 28 and Table 29 display the results of the respondents, considering the effect of movement.

*Table 28 –Effect of movement (including Stayers): T-test*

| **Comparison** | | **Levene's Test for Equality of Variances (equal variances assumed)** | | | **T-Test for Equality of Means** | |
|---|---|---|---|---|---|---|
| vs. | | F | Sig. | Assumed | t | Sig. |
| Quiet, Dark | Quiet, Light | .004 | .953 | No | -.325 | .746 |
| Quiet, Dark | Busy, Dark | .175 | .676 | No | -1.111 | .269 |
| Quiet, Dark | Busy, Light | .195 | .659 | No | -2.363 | .020[1)] |
| Quiet, Light | Busy, Dark | .248 | .619 | No | -.863 | .390 |
| Quiet, Light | Busy, Light | .278 | .599 | No | -2.170 | .032[1)] |
| Busy, Dark | Busy, Light | .000 | .989 | No | -1.118 | .266 |
| Quiet (Dark & Light) | Busy (Dark & Light) | .829 | .364 | No | -2.453 | .019[1)] |
| Dark (Quiet & Busy) | Light (Quiet & Busy) | .183 | .669 | No | -1.005 | .316 |

[1)] Significant at 0.05 level

With the inclusion of the stayers, the difference between the quiet and busy model are significant. Between the quiet and dark models a trend is visible, but the effect is not significant.

*Table 29 – Effect of movement Mean values (range [-1,4]) and SD*

| **Model name** | **Without Stayers** | | **With Stayers** | |
|---|---|---|---|---|
| | **Means values** | **SD** | **Mean values** | **SD** |
| Quiet, Dark | 2.39 | 1.13 | 1.06 | 1.41 |
| Quiet, Light | 2.23 | 1.19 | 1.14 | 1.40 |
| Busy, Dark | 2.21 | 1.34 | 1.36 | 1.51 |
| Busy, Light | 2.33 | 1.29 | 1.67 | 1.52 |
| Quiet (Dark & Light) | 2.29 | 1.16 | 1.11 | 1.40 |
| Busy (Dark & Light) | 2.28 | 1.31 | 1.53 | 1.52 |
| Dark (Quiet & Busy) | 2.29 | 1.25 | 1.20 | 1.46 |
| Light (Quiet & Busy) | 2.28 | 1.24 | 1.39 | 1.47 |

Without stayers, the average distance walked there is of 22.5 meters. This is enough to board the next door of the train. Although the 22.5 meters do not look like much of a result, it would be enough to prevent the clogging problem on the railway platform.

To identify whether the travel frequency of the railway passenger has influence on the choice of the waiting location, a distinction between *must* and *lust* travellers is made. Table 30 shows the mean values for the movement for both the traveller types.

*Table 30 – Effect of movement per traveller type Mean values (range [-1,6]) and SD*

| Traveller type | Mean values | SD |
|---|---|---|
| Lust traveller | 1.06 | 1.36 |
| Must traveller | 1.50 | 1.53 |

A significant difference can be found between the numbers of meters that both traveller types want to walk to a location further (Table 31).

*Table 31 – Effect of movement per traveller type: T-test*

| Comparison | | Levene's Test for Equality of Variances (equal variances assumed) | | | T-Test for Equality of Means | |
|---|---|---|---|---|---|---|
| vs. | | F | Sig. | Assumed | t | Sig. |
| Must traveller | Lust traveller | 4.222 | .041 | Yes | -2.461 | .014[1)] |

[1)] Significant at 0.05 level

Therefore, it can be concluded that must travellers want to continue the platform walk more than lust travellers. This corresponds with the literature, where is described that must travellers will walk further because they are more secure of themselves when travelling (section 3.2.1, p.24).

#### 4.7.1.6 Qualitative results

Within this subsection the results of the three 'open answer' questions are discussed. Examination of these questions has resulted in a classification into five categories. Each question has a different classification. For each model Table 32 shows the number of times an answer is given in a category for stayers who were asked why they wanted to stay at their current waiting spot.

*Table 32 – Stayers, why they stay on their spot*

| | Quiet, Dark | Quiet, Light | Busy, Dark | Busy, Light |
|---|---|---|---|---|
| *Luggage* | 1 | 1 | 0 | 0 |
| *Comfort* | 10 | 13 | 9 | 7 |
| *Crowd and spaces* | 6 | 11 | 3 | 3 |
| *Distribution – Platform – Train* | 5 | 3 | 6 | 4 |
| *Information and overview* | 9 | 9 | 2 | 4 |

As shown in Table 32, comfort is the most mentioned reason to stay at the current waiting spot. As a generalization it can be assumed that comfort is described as the following statement: "*I think that my current waiting spot is pleasant. I do not have a any reason to move*". It is interesting to see that between the quiet and busy models a difference is visible when looking at the *crowd and spaces*. The stayers in a quiet model state that they have enough space and that it is not too crowded. Furthermore, the stayers who have experienced a quiet model stay on their current waiting spot because they are close to the information and have an overview of the platform. Information and overview are two factors that were not integrated in the research. For future research, these two factors might be considered.

On the other hand, the leavers leave their current waiting spot mainly because of crowd related issues (Table 33).

*Table 33 – Leavers, why they leave their spot*

| | Quiet, Dark | Quiet, Light | Busy, Dark | Busy, Light |
|---|---|---|---|---|
| *Comfort* | 1 | 7 | 1 | 3 |
| *Crowd* | 10 | 10 | 27 | 28 |
| *Information and overview* | 4 | 1 | 0 | 3 |
| *Distribution – Platform – Train* | 3 | 8 | 4 | 8 |
| *Walking path related* | 8 | 9 | 1 | 4 |

The respondents who experienced a busy model want to leave because of the crowdedness. The respondents, who have experienced a quiet model, expect a crowd at the current spot. They also care about the fact that they are in a walking path and that they do not want to block the entrance of the railway platform for other passengers.
Table 31 shows that people are willing to move to another spot, mainly because it looks less crowded there.

*Table 34 – Leavers, what attracts from the other waiting spot*

| | Quiet, Dark | Quiet, Light | Busy, Dark | Busy, Light |
|---|---|---|---|---|
| *Comfort* | 4 | 4 | 2 | 2 |
| *Crowd* | 9 | 17 | 25 | 33 |
| *Distribution – Platform – Train* | 14 | 9 | 5 | 8 |
| *Lights* | 0 | 4 | 1 | 0 |
| *Other* | 0 | 2 | 1 | 3 |

The other reason why they are attracted to the other spot is the distribution of passengers on the platform, related to free seats in the train. In the *quiet light* model, a few respondents were triggered by the additional lights in the ceiling of the platform.

## 4.8 Conclusion

The research is based on three different factors: the addition of light, crowdedness and the waiting location. The conclusions of this research will be based on these factors, which are collected through a questionnaire in combination with a 3D model.
In total 263 respondents participated in the research although the goal was 384 respondents. The mean value of the age of the respondents is lower than the mean value of the age of the Dutch population. The mean values of gender and frequency of travel are close to the mean values of the Dutch population.

The waiting pleasure and the dominance of the passenger are dependent on the crowdedness of the model. A strong separation between the *quiet* and *busy* models can be identified, but very little difference in waiting pleasure can be seen between *light* and *dark* models.

When focussing on the *change of the waiting location*, interesting results can be observed. The tendency to leave the waiting location is influenced by the crowdedness, but also by the presence of additional light. Adding light has not resulted into substantial differences in movement on the railway platform, but the results show a trend. The same is true for the results, when railway passengers were asked if they would rather wait somewhere else. Also, a difference of opinion appears with respect to the wait on their spot and the tendency to leave this spot. For the difference between the *quiet* and *busy* models this is significant ('*H0: The passenger will not move when the crowdedness increases*' can be rejected (Section 4.3.1 p.34)), but for the difference between *light* and *dark* models only a trend is observed. The reason these effects are not significant can be ascribed to the lack of respondents who contributed to the research. Therefore the hypothesis '*H0: The passenger will not move further when additional light is introduced'* cannot be rejected (Section 4.3.1, p.34).

When the respondents, who were willing to move, were asked question to which location they wanted to move to, they answer that on average they want to move by 13.6 meters. On average (stayers included), the passengers move 13 meters in the positive direction. When only the passengers who were willing to move are used in the calculation, the average amount of meters they were willing to walk is 22.9 meters. This is almost the length of one carriage. As van Wiggenraad (2001) stated, people choose the train door closest to them (Wiggenraad, 2001). When the train moves 13 meter further (half of the carriage), the next train door is closer, and therefore is more likely to be chosen. Between must and lust travellers a significant difference can be found when looking at this movement. On average, The *lust* travellers are willing to move 10 meters, whereas the *must* travellers are willing to move 15 meter.
None of the differences between *light* and *dark* or *busy* and *quiet* are more than 13 meters. Thus the effect is not enough to spread out passengers more over the platform. There are a few explanations why these passengers do not spread out any further than the average of 13 meters.
The first reason is that, the first questions of the questionnaire are about the railway platform and about the feeling the respondents have on the platform. These questions are subconscious questions. When the respondents are asked about the waiting location and why they are moving, they start thinking about their choice and are therefore conscious about the issues of the railway platform. They look at the model in a less feeling-based way and, moreover they will try to affirm their choice. This reasoning is also applicable to the qualitative questions. When respondents were asked to motivate their choice, many different answers were the result. Related answers to crowdedness are found very often, even in the *quiet* models. Whilst the "busy check (Figure 13, p.42)" clearly shows that the respondents experience the platform quiet, when a *quiet* model is seen.

A second reason why the respondents answer that they do not spread out more on a railway platform, is that in the 3D environment the visibility decreases when the other waiting spot is further away. This is the same in real life, but the feeling of distances is decreased in the VR-reality environment (Hoffman, 2007). In a VR model, 10 meters appears further away than the actual 10 meters, but this effect is not the same for everyone. Therefore, in the VR-model this could not be taken into account.

Generally, this research only shows results of partial significance. The crowdedness is a significant influencing factor on the waiting behaviour of the railway passenger. Additionally to the crowdedness is the effect of additional lighting, which is not proven to be significant, but clearly shows a trend. Further research (with more respondents) could prove that additional lighting is an important factor in the choice of a waiting location of a railway passenger.

# 5 Conclusions

This chapter discusses the conclusions of this graduation thesis. In the first section the conclusion about the research questions will be discussed. The conclusions are based on the literature study and the research results. The second section describes the relevance of the research results from different points of view. The final section includes a discussion and some recommendations.

## 5.1 Research questions

The objective of this graduation thesis is to study the potential of stimuli in distributing railway passengers on a railway platform. This can have an impact on the platform design. Therefore, the following research question is answered:

*In what way is it possible to distribute waiting passengers more evenly on railway platforms using adaptive technologies to change the comfort of the railway platform environment?*

There are several different ways to distribute passengers on the railway platform. In this study, the stimuli; *music*, *light and colour* are investigated. These stimuli are chosen because they are thought to be the three most effective stimuli. They are also appropriate to be applied in an adaptive system. If needed, music, light and colour can easily be switched on or off. With odour or thermal comfort this is not the case; they need more adjustment measures to ensure their effect.

In this research, the effect of light has been tested in combination with the influence of crowdedness on a railway platform. The research results show that crowdedness has more effect on the choice of the waiting location than additional lights. Furthermore, the research results show a trend for the effect of additional lights, although the effect is not significant in its application. Approaching a major group of respondents could meet this need.

In order to achieve the answers to the main question, the following sub-questions were answered.

*1. What types of railway stations are there in the Netherlands, and what is the impact on the waiting behaviour of passengers on railway platforms?*

Stations can be defined in many different ways, but for this research the classification methodology of the Dutch Railways (NS) is used. The railway stations of the Netherlands can be classified into six different types. A type 1 station is a very large train station in the centre of a big city, with at least 50,000 travellers a day. A type 6 station is a station located in a rural area with up to 2500 passengers a day. Between the different railway stations, there are differences in the arrival of the passengers. Where type 1 stations are hard to reach by car, type 6 stations have enough parking spaces for cars.

Another difference these stations have is the number of services that are offered. A type 1 station houses multiple services in the stay domain. Which are absent in the type 6 station. These differences between stations also have influence on the behaviour of the railway passenger traveling between these stations. When there are more domains in a station, the

train passenger will stay longer in the railway station building. The railway passenger goes to the platform (travel domain) on average five minutes before the arrival of the train.
The size of the railway station building has an influence on the overall passenger experience, but on the railway platforms the behaviour of the railway passengers is more or less the same, regardless of the type of station. The differences in domains that are available in the different types of railway stations, only has influence on the passenger experience.

*2. Who are the stakeholders involved in the operation of a railway platform?*

There are multiple stakeholders in the operation of a railway station building. ProRail and NS (both NSR and NS-S) have a high level of influence in how a railway station operates. The railway platforms are the responsibility of ProRail, but the trains that stop at these platforms are the responsibility of NSR. The building that connects the railway platform is owned by NS-S. In addition to these three main stakeholders, the municipality and Bureau Spoorbouwmeester also have a say in the operation of the railway station building. This makes changing a railway station building a complex matter.
Another important stakeholder of the railway station building is the end user, being the railway passenger. The railway passenger can be classified into two categories, namely the lust traveller and the must traveller. The frequency of travel can be identified as the main difference. Must travellers have a high travel frequency (more than once a week), which results in preferences on the railway platform during their travel. They are not likely to change their routine that is formed though their high travel frequency. Lust travellers travel less than once a week and are thought to have less knowledge about the train travelling process. They show more uncertainty about their location choice on the platform.

In conclusion, railway station buildings involve multiple different stakeholders. This makes the railway station building a complex building to control. When changes are needed inside a railway station building, these stakeholders are all affected.

*3. How do railway passengers currently choose their waiting location on the railway platform?*

For the choice of the waiting location for the railway passengers, differences but also some similarities can be observed between lust and must travellers. On average lust travellers are more insecure in their travel behaviour. Herding is the result of this insecurity, which leads to a lack of spreading of the lust traveller on the railway platform. The lust traveller is seeking for extra stimuli. The average must traveller has created a preference in his travel pattern. He or she knows the places on the railway platform where the chances of available seats in the train are higher. This results in an improved spreading of the must travellers on a railway platform. Additional stimuli, which influence the choice of the waiting spot, are undesirable.

Both groups of travellers have similar behaviour regarding the search for an optimal comfort level, called the comfort zone. For many railway passengers the whole railway platform seems to have the same comfort level. This results in waiting around the entrance point of the railway platform, because a further walk from their spot will not result in a higher level

of comfort. This research study also showed that the comfort level, and with that the choice of waiting location, is dependent on the crowdedness on the platform.
It can be concluded that passengers choose their waiting location based on the optimal level of comfort that they could achieve without too much effort. Most of the times, this is the entrance point of the railway platform. When the area around the entrance point becomes too crowded, the level of comfort lowers at that location, so the passengers start moving. Must travellers have the experience that they can get a higher level of comfort in their travel by spreading out over the railway platform. On average, they are willing to walk 5 meters further than a must traveller.

*4. What are the methods to influence railway passengers' behaviour on a railway platform?*
There are many ways of influencing the behaviour of passengers, but only a few are applicable for changing the waiting behaviour of railway passengers. The described stimuli are music, light and colour. Music has the disadvantage that it is sensory related, whereas light and colour are less sensory related. Research results show that light has influence on the passenger behaviour. The effect of light was visible, but shows no significant difference. The qualitative questions show that some respondents want to stay close to the information services, which is a recommendation for future research. This can be explained by the levels of comfort. The presence of information will give the railway passenger more certainty in their travel, which results in a more comfortable feeling.

## 5.2 Research Relevance
This section will describe the relevance of this research in the following areas of interest, namely scientific relevance, societal relevance, and beneficiary relevance.

### 5.2.1 Scientific relevance
On railway platforms dangerous situations can occur when crowd sizes suddenly increase. By influencing the railway passenger's choice for a waiting location these dangerous situations could be avoided. The societal relevance of this graduation thesis is related to resolve these dangerous situations. Another socially relevant aspect of this research is the improvement of the boarding time on railway platforms. When railway passengers are spread out more evenly across the railway platform, the boarding time can be shortened.

Companies like NS-S and ProRail have already shown interest in this kind of measurements to improve the distribution of passengers on railway platforms. As far as is known, this research has not yet been conducted elsewhere.

### 5.2.2 Societal relevance
At the Dutch Railways, a lot of research is done to improve the customer experience of the waiting railway passengers. This waiting experience is spread throughout of the whole railway platform. In research to influence customer behaviour, the focus is to affect buying behaviour. Although van Hagen (2011) has mentioned interest in this type of research, this graduation research is an introduction in the field of influencing of the choice of the waiting location. This research can be considered as a first step in this field of research. After this research study, other relevant factors on the waiting behaviour can be reviewed. It is also possible to test the relevant influencing factors in other environments than virtual reality

environments. For example, a real life experiment on a railway platform to test the effect of additional light, would be a valuable contribution to this research.

#### 5.2.3 Beneficiary relevance

This research study is developed in collaboration with RoyalHaskoningDHV. As the research results show, there is to achieve a potential profit in optimization of the distribution of railway passengers on the railway platform. The knowledge that is gained during this research can be used to advise the stakeholders of the Dutch railway stations with the distribution of passengers over the railway platform. Further research would be advisable for interested companies.

### 5.3 Discussion and recommendation

The research for this graduation thesis has been conducted in a quite conservative environment. Companies like ProRail and the Dutch Railways benefit from safety and reliability. Keeping safety and reliability in mind, this market holds on to their old operating system. That means that changing the environment of the railway platform is a difficult matter. Experiments on platforms, where the environment would be changed to influence the waiting location, were hardly possible. This had to do with costs related to safety measures that should be taken before the experiments could be performed.

Virtual reality offered a solution to overcome these costs, but presumably a lower number of respondents is inevitable. The advantage of virtual reality is that it is possible to ask more questions to the respondents. However, real behaviour of respondents could not be measured. Virtual reality is very suitable to be used in appropriate cases in research to identify potential results. In these cases, a research can be performed with low costs and relative ease.

The trend that this research had showed when researching the effect of additional light, gives a good introduction to how the behaviour could be influenced by introducing the light effect in an existing situation. To know how the effect would be in reality, a real life experiment is necessary. Although VR-results are close to reality, people may react differently when they take part it in a real life experiment.

In my opinion, this study is the first of its kind in influencing waiting behaviour of railway passengers through added stimuli on a railway platform. Due to the fact that the effect of additional lights is not substantial, the first recommendation is to collect additional respondents for future research. It is also a possibility to research other values concerning the light. For example, other colours of light than the current 3500K. Also other light intensities and crowd intensities are a potential factor for future research.
Another way to demonstrate the concept of extra lighting is an experiment on a railway platform itself with a structure similar to this research. To reach the crowdedness of LOS C, the experiment can be performed on the busier stations during rush hours. The crowdedness can be controlled using boxes of *10*platform-width*. After that, the number of passengers inside these boxes should be counted.

In both the VR experiment and the 'real environment' experiment, a research for other light intensities and levels of crowdedness can be conducted. Insights into the turning point for crowds levels and light intensities can be acquired to better distribute railway passengers on the railway platform. As a result, these factors can be optimally integrated into railway station designs.

Besides researching the effect of additional lights, it is also recommended to research the effect of different environmental stimuli; for example the effect of music. If more research is conducted regarding the different stimuli, an optimal environment can be created for the distribution of railway passengers.

It is also recommended to introduce more differentiation between must and lust travellers in the research for additional stimuli to examine the effect of these stimuli to the respective groups.

## REFERENCES

Alfonzo, M. (2005). To Walk or Not to Walk? The Hierachy of Walking Needs. *Enviromental Behavior , 6* (37), 808-836.

(2013). In S. Ali, K. Nishoino, D. Manocha, & M. Shah, *Modeling, Simulation and Visual Analysis of Crowds - A mulidiciplinary Perspective.* Florida: Springer.

Al-Kodmany, K. (2013). Crowd managment and urban design: New scientific approaches. *Urban Design International , 18*, 282-295.

Arthur, P., & Passini, R. (1992). Wayfinding: People, signs and Architecture. Ontario: McGraw-Hill Ryerson Ltd. .

Baker, J., Grewal, D., & Parasuraman, A. (1994). The influence of store enviroment on quality inferences and store image. *Journal of the Academy of Marketing Science , 4* (22), 328-339.

Barta, R., & Ahtola, O. (1991). Measuring the hedonic and utilitarian sources of consumers attitudes. *Marketing Letters , 2* (2), 159-170.

Bellizzi, J., Crowley, A., & Hasty, R. (1983). The effects of color in store design. *Journal of Retailing and Consumer Services , 1* (59), 21-45.

Boes, E. (2007). *Stations? Daar zit muziek in! Een onderzoek naar de effecten van muziektempo op stationsbeleving. .* UT, Faculteit gedragspsychologie. Enschede: Universiteit twente.

Bosina, E., Britschgi, S., Meeder, M., & Weidmann, U. (2015). Distribution of passengers on railway plaforms. *STRC 2015* (pp. 1-23). Zurich: STRC.

Brouwer, I. (2010). *Fixing the link.* TU Delft. Delft: TU Delft.

Bureau Spoorbouwmeester. (2012). *Het Stationsconcept.* ProRail & NS. Utrecht: Spporbeeld.

CBS. (2015, November 26). *Bevolking; Kerncijfers*. Retrieved August 24, 2016 from Centraal bureau voor de statistiek: http://statline.cbs.nl/statweb/publication/?vw=t&dm=slnl&pa=37296ned&d1=0-2,8-13,19-21,25-35,52-56,68&d2=0,10,20,30,40,50,60,64-65&hd=151214-1132&hdr=g1&stb=t

CBS. (2009). *Hoe druk is het nu werkelijk op het Nederlandse spoor?* Centraal Bureau voor de statistiek. Den Haag/Heerlen: Centraal Bureau voor de statistiek.

CBS. (2015). *Transport en mobilitiet 2015.* Centraal bureau voor de Statistiek. Den Haag: CBS.

Davidich, M., Geiss, F., Mayer, H. G., Pfaffinger, A., & Royer, C. (2013). Waiting zones for realistic modeling of pedestrian dynamics. A case study using two major German railway stations as examples. *Transportation Research Part C , 37*, 210-222.

Dijksterhuis, A., Smith, P., van Baaren, R., & Wigboldus, D. (2005). The unconscious consumer: Effects of enviroment on consumers behavior. *Journal of Consumer Psychology , 3* (15), 193-202.

Dijkstra, J., de Vries, B., & Jessurun, J. (2014). Wayfinding search strategies and matching familiarity in the build enviroment through virtual navigation. *Transportation Research Procedia , 2*, 141-148.

Doucet, G., Gulli, R., & Martinez-Trujillo, J. (2016). Cross-species 3D virtual reality toolbox for visual and cognitive experiments. *Journal of Neuroscience Methods* , 1-32.

Duives, D., Daamen, W., & Hoogendoorn, S. (2013). State-of-the-art crowd motion simulation models. *Transportation Research Part C , 37*, 193-209.

Fan, Gurthrie, & Levision. (2016). Waiting time perceptions at transit stops and stations: Effects of basic amenities, gender, and security, gender. *Transportation Research Part A , 88*, 251-264.

Finnis, K., & Walton, D. (2008). Field observations to determine the influence of population size, location and factors on pedestrian walking speeds. *Ergonomics , 51* (6), 827-842.

Fruin, J. (1971). Pedestrian Planning and Design.

Fujiyama, T. (2004). *Evaluation of Accessible Design of Public Transport Facilities.* London: UCL.

Fujiyama, T., & Tyler, N. (2004). *An explicit study on walking speeds of pedestrians on stairs.* University college London, Centre for Transport Studies. London: Accesibility Research group.

Galetzka, M., & de Vries, P. (2012). *Motieven, Omgeving, en Gedrag; Wat Beweegt de Mustreiziger? Transfercapiciteit op perrons, stijgpunten, traverseruimtes en halvoorzieningen.* Universiteit Twente. Enschede: UT.

Getty. *Clogging up around escalators.* Getty.

Hagen. (2011). *Waiting Experience at Train stations.* Delft: Eburon Academic Publishers.

Hagen, M. (2008). *The influence of Colour and light on the experience and satisfaction with a Dutch railway station.* Twente: Association for European Transport and contributors.

Hagen, M. v. (2010). De invloed van kleur en licht op de stationsbeleving. *Vervoersplanologisch Speurwerk* (pp. 1-15). Roermond: NS.

Harris, N. G., Graham, D. J., Anderson, R. J., & Li, H. (2013). *The impact of Urban Rail Boarding and Alighting factors.* London: The Railway consultancy.

Heikoop, H. (1996). *Tramhalters en reistijd.* Technische Universiteit Delft, Faculteit der Civiele Techniek. Delft: RET/TU Delft.

Helbing, D., & Johansson, A. (2010). Pedestrian, crowd and evacuation dynamics. *Encyclopedia of complexity and System Science* (16), 6476-6495.

Helbing, D., Buzna, L., Johansson, A., & Werner, T. (2005). Self-Organized Pedestrian Crowd Dynamics: Experiments, Simulations, and Design Solutions. *Transportation Science , 39* (1), 1-24.

Hidayetoglu, M. L., Yildirim, K., & Akalin, A. (2012). The effects of color and light on indoor wayfinding and the evaluation of the percieved enviroment. *Journal of Enviromental Psychology , 32*, 50-58.

Hof, v. '. (2008). *Circling Safely - Feeling (Un)Safe at Railway Station.* University of Twente. Enschede: University of Twente.

Hoffman, G. A. (2007). Vergence–accommodation conflicts hinder visual performance and cause visual fatigue. *Journal of Vision , 8*.

Hoogendoorn, & Daamen. (2005). Pedestrian behaviour at botlenecs. *Transportation Science* (39), 147-159.

Hurk, E. v. (2015). *Passengers, Information and Disruptions.* Erasmus Universiteit Rotterdam, Erasmus Research Institute of Managment. Rotterdam: ERIM.

Johansson, Rosén, & Küller. (2011). Individual factors influencing the assesment of outdoor lighting of an urban foortpath. *Lighting Research and Technology , 43*, 31-43.

Kielar, P. M., & Borrmann, A. (2016). Modeling Pedestrians interest in locations: A concept to improve simulations of pedestrian destination choice. *Simulation Modelling Practice and Theory , 61*, 47-62.

Kneidl, A., Hartmann, D., & Borrmann, A. (2013). A hybrid multi-scale approach for simulation of pedestrian dynamics. *Transportation Research Part C , 37*, 223-237.

Kramer. (2009). *Wachten wordt leuk.* Universiteit Twente. Enschede: Universiteit Twente.
Lee, Y.-C. (2005). *Pedestrian Walking and Choice Behavior on Stairways and Escalators in Public Transport Facilities.* Delft University of Technology , Department of Transport & Planning. Delft: DUT.
Lerman, Y., Rofe, Y., & Omer, I. (2014). Using Space Syntax to model pedestrian movement in urban transportation planning. *Geographical Analysis , 42*, 392-410.
Lin, I. (2004). Evealuating a servicescape: the effect of cognition and emotion. *Hopspitality Managment , 23*, 163-178.
Machleit, K., Eroglu, S., & Powell Mantel, S. (2009). Percieved retail crowding and shopping satisfaction: What modifies this relationship. *Journal of Customers Psychology , 9* (1), 29-42.
Martin, A. (2006). *Factors influencing pedestrian safety: a literature review.* London: TRL.
McIntyre, G. (2014). Applying visual attention theory to transportation safety research and design: Evaluation of alternative automobile rear lighting systems. *Accident Analysis & Prevention , 67*, 40-48.
Meet4Research. (2012). *Klantbeleving Den Haag HS.* ProRail, Den Haag.
Mehrabian, A., & Russell, J. (1974). An approach to environment Psycholog. *Journal of Marketing , 2* (46), 86-91.
Ministry of Transport. (1961). *Traffic in Towns: A study of the Long Term Problems of Traffic in Urban Areas.* HMSO:London. London: Reports of the steering group and working group Appointed by the Minister of Transport.
NS - Stations. (2016, January 01). *NS Stations - Organisatie*. Retrieved June 08, 2016 from NS Stations: http://www.nsstations.nl/ns-stations/organisatie.html
NS GROEP. (2016). *NS Organisatie*. Retrieved June 08, 2016 from Werken Bij NS: https://werkenbijns.nl/over-ons/ns-organisatie/
NS. (2015). *Jaarverslag 2015.* Utrecht: NS.
NS-S. (2007). *Stations belevings monitor.* Utrecht: NS.
Nunnally. (1994). Psychometric Theory. In Nunnally, *Psychometric Theory* (pp. 1-736). McGraw-Hill.
Overduin, J. (2012). *Een stapje verder alstublieft. Gedragsbeinvloeding van mustreizigers op Nederlandse perrons.* Universiteit van Twente, Psychologie van Risico, Veiligheid en Conflict. Twente: UT.
Pasman. (2016, 03 05). ProRail & Platform roof lighting. (Oerlemans, Interviewer)
Philips. (2016, January 01). *Revit Libary*. Retrieved April 05, 2016 from Philips Lightning: http://www.lighting.philips.com/main/support/support/revit-library.html
ProRail. (2005). *Basisstation 2005, deel A en B.* Utrecht: ProRail Spoorontwikkeling.
ProRail. (2016, April 1). *infrastructuur*. Retrieved July 8, 2016 from ProRail: https://www.prorail.nl/vervoerders/infrastructuur
ProRail. (2016). *ProRail Beheerplan 2016.* Utrecht: ProRail.
ProRail. (2013). *Spoorkaart*. Retrieved March 7, 2016 from Prorail: http://www.prorail.nl/sites/default/files/spoorkaart_prorail_april_2013.pdf
ProRail. (2005). *Spoorontwikkeling - Basisstations.* Utrecht: ProRail.
Research Company. (2014). *Het berekenen van de steekproefomvang.* Research Company. Rotterdam: Research Company.
Reverso-Softissimo. (2016, 01 01). *Reverse*. Retrieved April 13, 2016 from Reverse: http://dictionary.reverso.net/english-definition/comfort%20zone

Rhodes, S. (2002). Collecting behavioural data using the world wide web: consideration for researchers. *Epidemiol Community Health* , 68-73.

Roelofs, P. (2010). *De Reisfocus. Welk spoor volgt de NS-reiziger? De invloed van het reisdoel van de reiziger op de stationsbeleving en imagovorming.* Universiteit Twente. Enschede: NS/Ut.

Rose, C., Clegg, C. W., & Robinson, M. A. (2009). *Understanding Crowd Behaviours: Guidance and Lessons Identified.* University of Leeds, Emergency Planning College. York: Cabinet Office.

Schelhorn, T., O'Sullivan, D., Haklay, M., & Thurstain-Goodwin, M. (1999). *Streets: An Agent-Based Pedestrian Model.* London: UCL.

Spano, Sorrentino, & Scateni. (2015). *RiftArt: Bringing Masterpieces in the Classroom through Immersive Virtual Reality.* Cagliari: The Eurographics Association.

Spoorbeeld. (2015, November 16). *Nieuwe serie: Spoorbeeldverhalen afl. 2: Arnhem-Assen*. Retrieved Juli 20, 2016 from Spoorbeeld: http://www.spoorbeeld.nl/inspiratie/nieuwe-serie-spoorbeeldverhalen-afl-2-arnhem-assen

Teknomo. (2002). *Microscopic Pedestrian Flow Characteristics: Development of an Image Processing Data Collection and Simulation Model.* Tohoku University, Department of Human Social Information Science. Japan: Tohoku University.

Thiellier. (2015, May 3). Chosing a station. (Oerlemans, Interviewer)

Ton, D. (2014). *Navistation.* Delft University of Technology, Civil Engineering Transport & Planning. Delft: TUD.

Urmson, J. (1968, March 6). The objects of the fice senses. *Philosophical Lecture* , 117-131.

van de Ree, H. Domains and fields. *Domains and fields.* RHDHV, Utrecht.

van Hagen. (2008). *The influence of Colour and light on the experience and satisfaction with a Dutch railway station.* Twente: Association for European Transport and contributors.

Van Hagen, M. (2011). *Waiting Experience at train stations.* University of Twente. Enschede: UT.

van Hagen, M., & Exel, M. (2012). *De Reiziger Centraal.* NS, Bureau Spoorbouwmeester. Utrecht: Nederlandse Spoorwegen.

Verhoeff, L. (2014). Choice and Experience of the movement route. *Transportation Research Procedia 2* , 675-680.

Vos, L. (2013). *The effects on lightning and disorder on the perception of social safety of waiting passengers at a railway station platform.* Faculty of Behavioural Sciences. Twente: UT.

Wang, Y., Guo, J., Ceder, A., Currie, G., Dong, W., & Yuan, H. (2014). Waiting for public transport services: Queueing analysis with balking and reneging behaviors of impatient passengers. *Transportation Research Part B* (63), 53-76.

Wiggenraad, P. B. (2001). *Alighting and boarding times of passengers at Dutch railway stations.* Technical university of Delft, TRAIL research School. Delft: TRAIL.

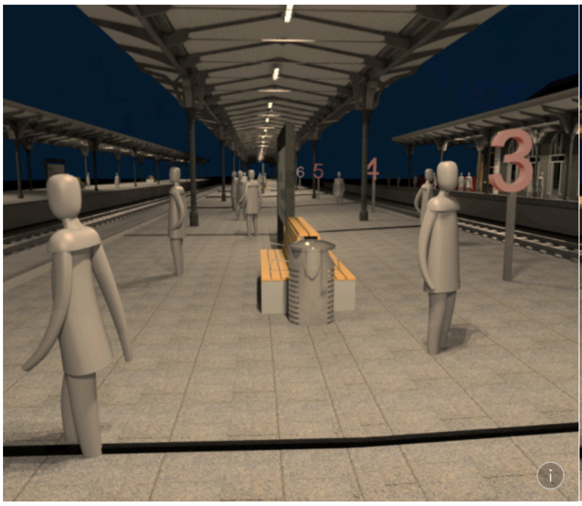
Wijermans, N., Jorna, R., Jager, W., & van Vliet, T. (2007). *Modelling Crowd dynamics, INfluence factors related to the probability of a riot.* Groningen: TNO.

Zhou, B., Tang, X., & Wang, X. (2015). Learning Collective Crowd Behaviours with Dynamic Pedestrian-Agents. *Computer Vision , 111*, 50-68.

Zhou, J., Guo, Y., Dong, S., Zhao, L., & Yang, R. (2016). Structural Equation Modeling fo Pedestrians' Perception in Intergrated Transport Hubs. *Procedia Engineering, 137*, 817-826.

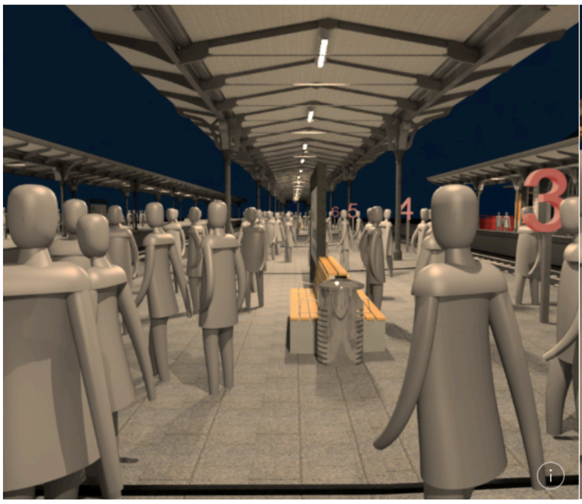
## Appendices

## APPENDIX 1: THE FOUR MODELS



Quiet- Dark

Quiet - Light



Busy Dark

Busy Light

One of these models will be randomly selected and showed to the respondent. The respondents do not know that there is more than one model.

# APPENDIX 2: INTRODUCTION PAGE RESEARCH

Beste bezoeker,

Dit onderzoek is mijn afstudeer onderzoek, dat ik uitvoer in samenwerking met de TU/e en RoyalHaskoningDHV. Door op de onderstaande "start" knop te klikken kunt u uw deelname starten en de vragenlijst invullen. Alvast bedankt voor uw medewerking!

Met vriendelijke groet, *Maarten*!

Start

Dear visitor,

This questionnaire is part of my graduation research project. I am doing this research in collaboration with the Eindhoven University of Technology and RoyalHaskoningDHV. By pressing the "Start - English" button, you can start the questionnaire.

Thank you in advance for your participation.

Kind regards, *Maarten*!

Start - English

## APPENDIX 3: THE RESEARCH PAGE