Delft University of Technology

Master of Science Thesis

Innovating Airport Passenger Terminals

Determining the feasibility of new terminal concepts based on seamless flow technology

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Annotation

During the execution of this research, the COVID-19 pandemic started. As a result, certain statements made about the aviation industry might not be applicable anymore, or at least for the coming years. The potential consequences of the findings in this research, in relation to the current circumstances, will be further elaborated in the discussion section of this thesis.

Preface

In front of you lies my thesis, the final delivery of the master program Transport, Infrastructure and Logistics at the Delft University of Technology. After seven years of studying, this was the last hurdle before acquiring my Master's degree. In the last couple of years, my interests in aviation grew as result of various courses in both the minor 'Airport of the Future' and the 'design' track of my master. After joining a seminar at NACO last year, I was inspired and decided that I wanted to do my thesis at this company. After the seminar, I talked to various NACO employees and gained as much information as I could about possible research topics and approach tactics. A few weeks later, I was invited to the office to talk about my proposed research ideas. After half an hour, we agreed on a research topic and decided that I was going to start in two weeks time. Consequently, my first big word of thanks goes out to Bunno Arends for immediately believing in me and my ideas.

This thesis would not have been here without the support of my supervisors from the TU Delft and my supervisor at NACO. I would like to thank Jaap Vleugel, John Baggen and Rene Hopstaken for the support and feedback throughout the execution of this research. I admire how you have dealt with my determination and often very optimistic planning. Besides that I want to thank Bert van Wee for pointing me into the right direction at every official meeting. Your way of giving feedback did really help me a lot. Lastly, I would like to thank Betty van Koppen for her great work in planning the various meetings with all the supervisors.

Besides my supervisor, various people at NACO did help throughout this research. In particular, I want to thank Niels Ridderbos and Koen Brinkman for their help. It was great to have the opportunity for a quick chat every now and then. Moreover, a word of thanks goes out the the various interviewees for their time and sharing their personal experiences. Your input has been a great added value to this research.

Furthermore, a big thank you goes out to my girlfriend Marlou whom did read (almost) every single word of this thesis. Your criticism did definitely lift this thesis to a higher level. Finally, I want to thank all the people near me for letting me being me. Although worrying about my workload and the long days I made in order achieve my goals, you let me do my thing. And guess what, I did it!

Joost de Graeff
Den Haag, July 2020

Summary

The continuing growth in air travel passengers, in combination with enhanced security regulations, has led to unsustainable situations at airports. As a result, the passenger experience has become more complicated, congested and thereby more unpleasant for the passengers. While the passenger is a very important player within aviation industry, airports aim to improve the passenger experience. In order to handle the future amount of air travel passengers while complying to security regulations and enhancing the passenger experience, the terminal system must be innovated. One of the key innovations within the aviation industry is the seamless flow concept. Seamless flow is a future end-to-end continuous, efficient and secure method which uses passenger biometrics for identification throughout the airport processes. In this study, the opportunities of the seamless flow innovations within the passenger terminal are explored. Thereby the objective is to determine whether the seamless flow technology could lead to a new, and feasible, passenger terminal concept in comparison to the current terminal concept equipped with the seamless flow technology.

Theory on both opportunities in design phases and innovation adoption is used as theoretical lens in this thesis. As result of the opportunities in design phase theory, path dependency is bypassed in the design process of new terminal concepts. Consequently, unbiased terminal concepts based on the seamless flow technology are constructed. Subsequently, the newly constructed concepts are assessed on their feasibility by applying the political-economy framework. Within this framework, four important feasibility determinants are distinguished: Technical, Social, Political and Economical.
In order construct the new terminal concepts and assess them on the feasibility determinants, both qualitative and quantitative research methods have been used. Desk research and literature reviews are used to gain knowledge about the system's environment, including regulations, requirements and stakeholders. Subsequently, semi-structured interviews with experts out of the field were conducted in order to validate the research findings and gain more in-depth knowledge about the system's playing field and the current developments in seamless flow systems. Finally, a financial cost-benefit analysis executed in order to determine the economical feasibility from the airport's perspective.

The research findings indicate that the seamless flow technology can lead to feasible and efficient airport passenger terminal concepts in comparison to the conventional terminal concept equipped with seamless flow technology. However, certain conditions must be met. Regarding the system environment, the support of stakeholders, especially the border guard agency, is indicated to be important for a concept to be seen as feasible. Within the seamless flow system, collaboration between the different stakeholders is essential. As showed in this study, it requires support from stakeholders to b e able to alter current applicable requirements which make a concept currently not applicable. Thereby, early involvement of stakeholders in decision making processes, regarding terminal concepts, would rather lead to a generally feasible concept. Besides that, it is indicated that the new seamless flow terminal concept could result in financial benefits for the airport. While the passenger experience will be enhanced and the the terminal infrastructure and resources can be used more efficiently, spatial benefits could lead to a significant increase in non-aeronautical revenues.

This study mainly contributes as an exploratory research to the potential of new terminal concepts as result of the introduction of biometric technology on civil airports. It is indicated that the seamless flow innovation could lead to more efficient and experience enhancing passenger terminals. Consequently, it is recommended for airports to consider changing the current terminal concept whenever seamless flow technology is found to be ready for implementation.

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Acronyms

BHS Bagage handling system

LoS Level of Service

ADRM Airport Development Reference Manual

IATA International Air Transport Association

ACI Airports Council International

ICAO International Civil Aviation Organization

NACO Netherlands Airports Consultants

KPI Key performance indicator

PPP Public-Private Partnership

RTHA Rotterdam The Hague Airport

ST Socio-Technical regime

ABC Automated Border Control

ILT Inspectie Leefomgeving en Transport

KTDI Known Traveller Digital Identity

UN United Nations

ATM Air Traffic Movement

PAX Number of passengers

SSDOP Self-Service baggage Drop-Off Points

KMar Koninklijke Marechaussee

ADP Aéroports De Paris

CSF Central Security Filter

CAA Central Aviation Authority

CBA Cost-Benefit Analysis

NPV Net Present Value

1 Introduction

This chapter provides an introduction to this thesis. To start, subsection 1.1 will introduce the research topic by providing a general introduction on the systems environment. The seamless flow concept will be introduced in subsection 1.2. Next, the motivation behind this research is elaborated in subsection 1.3. In this subsection, the research gap and used theoretical framework will be introduced. In subsection 1.4, the research objective and corresponding research questions are provided. Subsequently, the scope of the research will be elaborated in subsection 1.5. After that, the methodology used for this research will be provided in subsection 1.6. Finally, the structure of the thesis will be presented in subsection 1.7.

1.1 General introduction

In the end of last century, the European aviation market was liberated. Together with the development of the internet, this made the rise of the low-cost carriers possible. Thereby, the aviation industry has changed for good (de Neufville, 2008). As result, an oversupply emerged on the aviation market which lead to extreme price competition within the sector. In combination with the growth of the global economy and trade, the demand for air travel grew massively (Raad voor Verkeer en Waterstaat, 2005). In the forthcoming years the aviation sector kept growing. In 2019, the International Air Transport Association (IATA) whose members comprise 82% the total air traffic, announced an annual growth in air passenger traffic of 4.2% compared to 2018. Moreover, the passenger numbers are expected to double in the next ten years (IATA, 2018b).

Besides the liberation of the aviation market and the rise of the internet, another event did significantly change the civil aviation market; the terrorist attacks of September 11. Following these attacks, (civil) aviation security procedures and regulations on airports changed in order to increase passenger safety. Hereby, two primary changes can be identified: the federalization of airport security and the requirement to screen all hold (checked) baggage. As result, air travelers experienced various changes in their journey through the airport. An example for this is passengers were instructed to arrive at the airport 2 hours before the take-off of their domestic flights. Furthermore, the passenger screening operations were enhanced and tightened (Blalock, Kadiyali, & Simon, 2007).

The combination of the growth in air travel passengers and enhanced security regulations creates an unsustainable situation at airports (IATA, 2018c). From passenger perspective, the 'passenger experience' has become more complicated, congested and thereby more unpleasant. While the passenger has become an important and dominant player within the aviation sector, airports aim to improve the 'passenger experience' (Harrison, Popovic, Kraal, & Kleinschmidt, 2012). The passenger experience is a subjective notion which represents the difference between expectations, based on previous experiences, and the actual journey. Hereby, the expectation of a passenger has a direct relation with the satisfaction corresponding the current journey (Harrison et al., 2012). In order to improve the deteriorating experience, today's passenger frustrations among which crowding and the amount of time spend at the various touchpoints should tempered or even eliminated (Arcadis, 2019).

In order to handle the future amount of air travel passengers while complying to security regulations and enhancing the passenger experience, one can think of enlarging terminal facilities. Although spatial expansion is often considered within the master planning of an airport, physical expansion is at many locations limited or considered costly and time expensive (de Neufville, Odoni, Belobaba, & Reynolds, 2013). Besides enlarging facilities, current passenger terminal infrastructure can be used more efficiently. This is often more effective, efficient and sustainable and could be accomplished by introducing new innovations in methods and processes (Gatersleben & Van der Weij, 1999).

1.2 Seamless flow concept

One of the key concepts in airport innovation is the so called 'seamless flow'. Seamless flow is a future end-to-end continuous, efficient and secure method which uses passenger biometrics for identification throughout the airport processes. Biometric recognition of passengers can offer different opportunities, namely; higher passenger throughput, lower operational cost and enhanced security (LAM-LHA, 2019). This is the result of self-service gates or corridors, which can already lead to a 50% time reduction, together with a fast biometric identification system (SITA, 2019). In theory, passengers will no longer experience any congestion during their journey through the airport, except for security screening. This method could thereby offer a new and better passenger experience and can be deployed in various degrees. Hereby, one can think of deployment on multiple collaborating airports, throughout multi-modal transport systems and by an airline group (LAM-LHA, 2019). However, a stand alone implementation, for example on a single airport, can already offer promising opportunities. Various airports are therefore already testing with biometric identification in order to optimize their processes.

In this thesis, an airport passenger terminal concept represents the successive steps each passenger must run through within an airport terminal. In Figure 2, the conventional departure terminal concept for an international passenger is graphically represented. In the same figure, a comparison is made to the seamless flow concept 'One ID'. In the beginning of 2018, IATA introduced their vision of the seamless flow concept. The One ID concept envisions the end-to-end passenger process in the year of 2035. In this process, the passengers identity is captured and verified as early in the process as possible. The passenger is made aware of sharing its personal information and is able to give consent. Subsequently, the control authorities are able to perform a robust risk analysis on the passengers. The passenger will then use his biometrics as a 'token' throughout the various processes across the journey (IATA, 2018c).

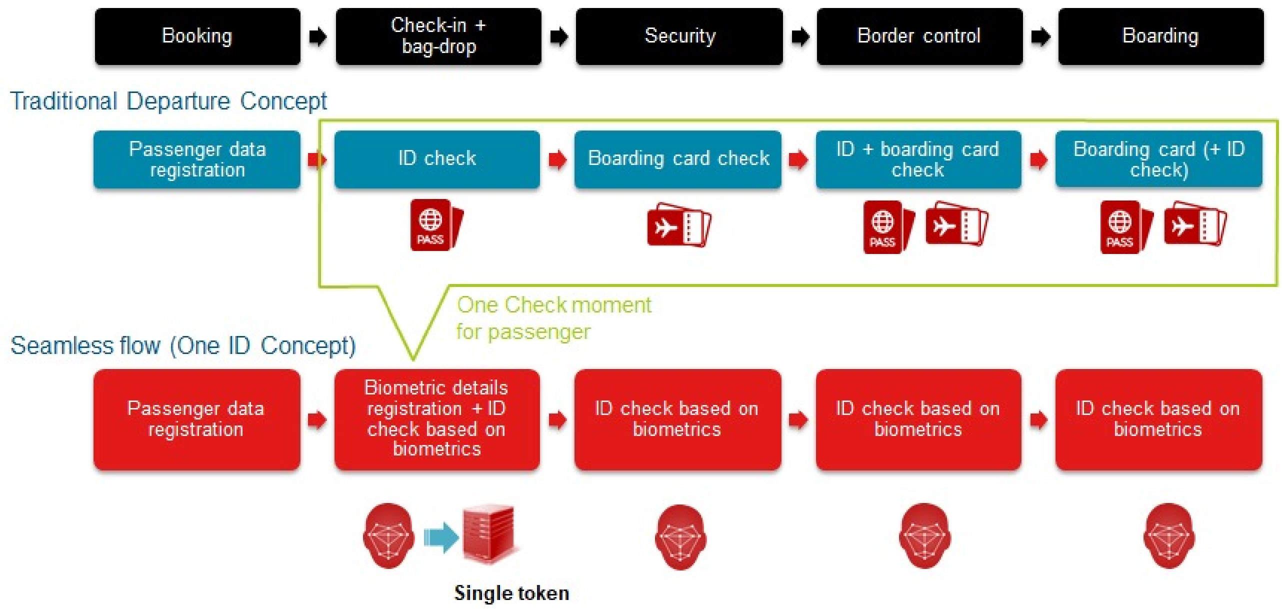

Figure 2: Passenger terminal departure concepts (International)

Various airports are already testing with seamless flow concepts similar to IATA's One ID. In February 2019, Schiphol Airport started a trial using facial recognition technology in the boarding process(Mayhew, 2019). Moreover, passengers on Schiphol Airport travelling with the airline Cathay Pacific could experience a whole 'travelling with facial recognition' journey. In this journey, passengers are asked to participate at the check-in kiosk after which facial characteristics are collected. Thereafter, the participating passengers can follow their way to the passport control where they go to a dedicated gate. At this gate, their face will again be scanned and compared to the previous scan from the check-in kiosk. If the passenger is recognised, the gate will open and the passenger can continue its journey (Schiphol, 2019). The seamless flow concept has also been implemented on Aruba International Airport under the name 'Happy Flow'. In this solution, passengers are only required to show their passport once, at the check-in kiosk. At this point, their biometric data is collected. After that, passengers can move through a sequence of self-service touch points where they are identified by facial-recognition cameras. Hereby, a seamless flow through the whole airport is achieved (Happy-Flow, 2017).

1.3 Research motivation

A lot of research has already been done to optimize the performance of a passenger terminal.Schultz and Fricke (2011) stated that efficient passenger handling and understanding passenger behaviour and flows are essential to create a reliable terminal. In a passenger simulation study, Takakuwa, Oyama, and Chick (2003) found that passengers spend an average of 25% of their dwell time in the airport terminal waiting. In order to suppress the bottlenecks and reduce the overall waiting time, tailored arrangements should be implemented. Hereby, one can think of the expansion of resources available or floor space. However, improving current processes can often be more effective, efficient and sustainable (Gatersleben & Van der Weij, 1999).

The passenger, and its experience, is very important in aviation and thereby at the different stages of the airport terminal design (Tosic, 1992). The dominant role can be expressed in various ways, for example: acceptance of new innovations, terminal design and terminal optimization. During the decision making processes of technological innovation, passengers interests are either represented through their own political voting behaviour or by institutions within the industry. Thereby, passengers could have direct or indirect influence on the acceptance of new innovations Feitelson and Salomon (2004).

Furthermore, terminals are frequently analyzed, optimized and designed with an passenger-centric approach (Arcadis, 2019). Starting in 2015, the Passme (2018) research aimed to make the passenger experience of air travel passengers on the airport less stressful by reducing the door-to-door travel time of air travel passengers by 60 minutes. Within this research, the focus lies with four distinctive breakthroughs, namely; Passenger demand forecast system, separated luggage flows, Redesigned passenger-centric airport and aircraft interiors, and personalised device and smartphone application. In 2003, Polillo (2002) introduced the 'secure flow' methodology. In this method, the security checks for people, baggage, and cargo at multiple checkpoints within the travel journey, such as: baggage check, terminal, aircraft etc., are integrated into one program. Hereby, the objective is to do one integral security check after which the object can be transported in a secure and moreover seamless flow from origin to destination. A similar process was also described by Kalakou, Psaraki-Kalouptsidi, and Moura (2015). In their paper, developments in technology and business plans of airlines and airports are studied in order to project short and long term terminal developments. In the long term projection (beyond 2020), biometric identification is used for passenger identity verification. Subsequently, the passenger will be screened with the help of an international data base and used a token throughout the automated end-to-end process. In this end-to-end process, the passenger walks through a minimum scanning corridors to enter other security zones. This implies space gains at the security area and moreover faster passenger process times (Kalakou et al., 2015). The resulting passenger flow concept is comparable to IATA's One ID concept, as described in subsection 1.2. Moreover, IATA envisions merging or even removing physical touchpoints within the passenger terminal (IATA, 2018c).

Subsequent to the upcoming interest in biometric passenger identification, research on privacy consequences started. From passenger perspective, stated that passengers need to be in control in order to travel comfortable (Poot, 2017). Therefore, Poot (2017) did research to the potential contribution of Blockchain technology in enhancing the passenger experience. When an airport stores the gathered biometric data in a database, passengers lose control over their personal data which also conflicts with the strict privacy legislation. The Blockchain technology could offer the possibility to share only the required data with the concerned party and only with the passengers consent. Hereby, the passenger is in full control of its personal data which is also called a 'sovereign identity'(Poot, 2017). This idea is also implemented in the Known Traveller Digital Identity (KTDI) initiative. In 2018, the governments of both Canada and the Netherlands committed to started piloting components of the KTDI (World Economic Forum, 2020). Furthermore, IATA elaborated more on this topic by addressing more Blockchain possibilities for aviation in its 2018 report. In this report, the identity management as described by Poot (2017) is also mentioned. Further possibilities can be found in topics like: payments systems, asset management and smart contracts (IATA, 2018a).

Research Gap

Previous research is focused on fitting the new seamless flow technology in with current, or legacy, airport processes. Although IATA envisions merging or removing physical touchpoints in the future, the One ID concept is laid over current airport terminal concepts (as can be seen in subsection 1.2). When looking at the current airport passenger terminal concept, and its processes, this can be seen as the result of the conceptual design phase for the conventional passenger terminal. Within this conceptual design phase, technology available at that moment in time were considered in decision making processes which could indicate the presence of path dependency (further elaborated in subsection 2.1). As described by Hsu and Liu (2000) and Wang et al. (2002), the decisions made in the conceptual design stage do have a significant influence on the performance of system and could hardly be compensated by decisions later in the design process. This implies that implementing the seamless flow technology in current passenger terminal concepts could lead to a sub-optimal system. It is therefore interesting to study whether the seamless flow technology could lead to a new, and feasible, passenger terminal concept.

1.4 Research questions

The objective of this research is to find out whether the seamless flow technology could lead to a new feasible airport passenger terminal concept. In order to determine the feasibility of this innovation, this new concept will be compared to the conventional concept, equipped with seamless flow technology. If a feasible terminal concept is determined, this could be used for both redesigning an existing airport terminal and as inspiration when designing a new airport terminal. In order to be able to quantify the impact of the new concept, a case study is selected. Together with NACO, the commissioning company of this research, Rotterdam The Hague Airport (RTHA) is selected to project the feasibility of the seamless flow concept. This choice will be substantiated in subsection 1.5. Consequently, the following research question is defined:

What is the feasibility of a passenger terminal concept based on seamless flow technology compared to the conventional concept equipped with seamless flow technology?

In order to answer the research question, multiple sub-questions will be answered.

1. What are the most important determinants of feasibility?
2. What are the functions of a passenger terminal and what processes and facilities can be distinguished?
3. What are the passenger terminal's stakeholders and what are their interests?
4. What (legal) requirements can be identified in the conventional terminal design?
5. What are the (future) requirements and Key Performance Indicators for RTHA?
6. What technology is used in the seamless flow concept?
7. What terminal concepts can be constructed as result of the seamless flow technology?
8. How do the constructed concepts score on the identified feasibility determinants?

The sub-questions have been arranged in order to answer the research question in a structured manner. First, the determinants of feasibility will be determined. In the second sub-question, the conventional terminal and it's design is explored. Thereafter, the systems environment is elaborated by identifying stakeholders and their interests in sub-question three. Subsequently, the (legal) requirements in the current terminal design are elaborated. This will give insight in the reasoning and regulation behind the current terminal layout. As result, opportunities of the seamless flow concept regarding to the current regulation can be determined. In sub-question five the (future) requirements and key performance indicators (kpi's) in terms of passenger amounts and service standards for RTHA are identified. Now that all the requirements are identified, the technology used in the seamless flow concept will be analyzed in the sixth sub-question. Subsequently, seamless flow concepts can be constructed considering the opportunities of the new technology. Finally, the concepts will be assessed on the identified feasibility determinants in sub-question eight. Thereby, the stakeholder interests and both the (legal) requirements and the system's environment will be used.

1.5 Scope

Although airports are frequently analyzed, optimized and designed with a passenger-centric approach, the main actor or stakeholder in this research is the airport owner. While passengers are the most important user of an airport, they do form an important role within the playing field of this research (further elaborated in subsection 3.3). As discussed in subsection 1.4, the aim is to construct a new passenger terminal concept based on the seamless flow technology and to determine the feasibility of this concept. This concept consists of the successive core processes of passengers through the airport terminal: check-in, baggage drop-off, security, border control and boarding. Thereby, this research provides results on a strategic level. Passenger flow simulations and further analyses and optimization will not be part of this research.

When constructing a passenger terminal concept based on the seamless flow concept and technology, various diverse alternatives can be generated. Hereby, one could think of concepts which are similar to the conventional terminal design but also of more out of the box concepts like a large terminal hall equipped with high-tech technology which is capable of executing all airport processes. While the objective of this research is to determine whether the seamless flow technology could lead to new and feasible terminal concepts, the focus will not be on generating alternatives and determining the 'best' concept. Instead, concepts will be chosen and used to study whether a change in the conceptual design can lead to a different, feasible and better performing system(subsection 1.3). Within this chosen concept, different variants and implementation methods will be evaluated.

In collaboration with NACO, the decision is made to study concepts in which domestic and international passengers will no longer be separated at (airside) terminal facilities. The segregation of passengers at terminal facilities has become a major issue for airport designers. With passengers requiring different levels of customs and emigration checks, the number of flows to consider to separate in the airport design increases (AT, 2010). A lot of airports have separated (airside) facilities for domestic and international passengers. While the peak hour for both types of flight services is often different, the airport's overall capacity is not used efficiently. Mixing domestic and international passengers at airside facilities could therefore lead to more efficient use of resources. This new concept is a result of the opportunities offered by the new biometric identification and screening technology of the seamless flow concept.

When looking at security and passenger experience, the departure process contains the biggest challenges for airports. In this process, security screening and border control processes are very important. Furthermore, the dwell time of passengers in the terminal is significantly higher than that of the passengers in the arrival process. Therefore, only the departure process is considered in this research. This includes all terminal processing steps from (online) check-in until boarding the aircraft. In Figure 3, the traditional departure concept and the concept studied in this research are graphically compared. It must be noted that the exact sequence of processes may differ per country. Furthermore, an airport has to deal with different passenger personas containing different needs and demands. It is decided to only study the 'ordinary' passengers which follow the common airport journey. In other words, passengers which are not entitled to get a special treatment and therefore have to run through all terminal processes. Hereby, entities such as airport staff, airline crew, diplomats and VIP's are not included.

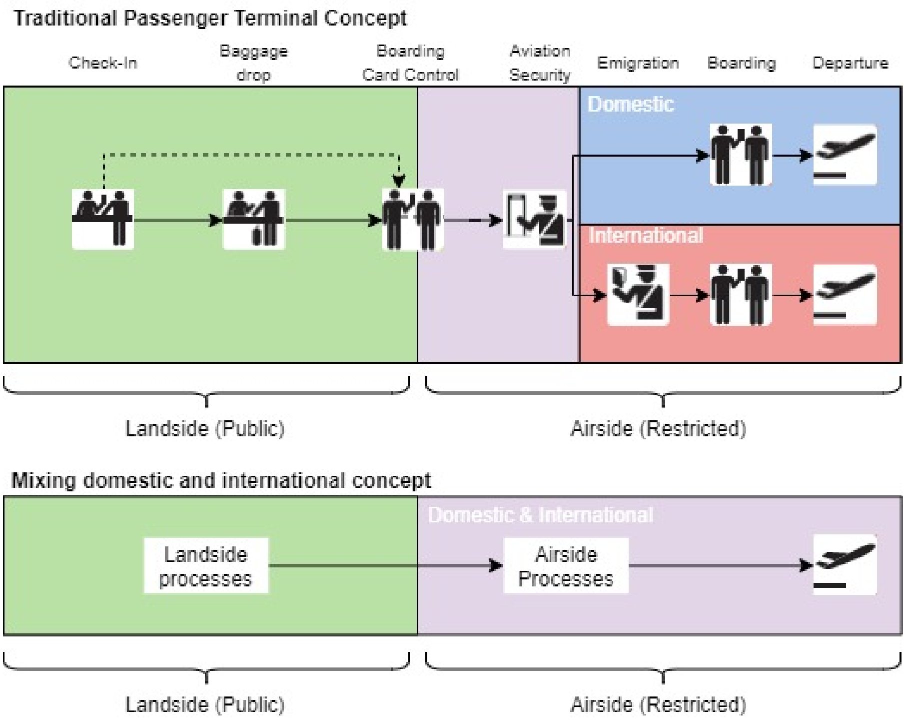

Figure 3: Traditional departure concept and research concept

While the aim of this research is to determine whether the seamless flow technology could lead to a new feasible terminal concept, it is chosen to conceptually implement the concept on a simple straightforward airport terminal. This will give quick insights into the impact of the new concept on the passenger terminal. The case study airport does however need to meet the requirement of handling different passenger types which require different levels of emigration checks, such as domestic and international. Consequently, the true potential of the new concepts can be determined.
As shortly introduced in subsection 1.4, Rotterdam The Hague Airport (RTHA) is used as a case study. RTHA is a regional airport from which point-to-point flights are executed. Passengers therefore use the airport only as their point of origin or destination. Thereby, RTHA does not facilitate transfer traffic. Nevertheless, RTHA handles a variety of passengers. As a result, the departure terminal contains both 'Schengen' and 'non-Schengen' airside facilities, which is similar to difference between international and domestic facilities (elaborated later in subsection 3.2 and subsection 4.2). These characteristics make RTHA an convenient Airport to determine whether the new concept could lead to a new feasible passenger terminal concept.

According to Feitelson and Salomon (2004), feasibility consists of four determinants, namely: economic, political,

technical and social (further elaborated in subsection 2.2). Consequently, these determinants are studied within this research. In order to make the feasibility study achievable within the timespan of this research, the studied area within each of the four determinants will be bounded. Within the economic feasibility, only the financial discipline from airport perspective will be determined. Thereby, a general financial costs and benefit analysis for the airport will be executed. The focus of this analysis lies with the spatial footprint of the processes, CAPEX and OPEX, and non-aeronautical revenues. Potential costs for other side activities will not be quantified in this study. However, the possible scenario's will be addressed. Although passenger conditions are important within the airport system, direct costs and benefits from passenger perspective are also not included in the economic feasibility.
When looking at the political feasibility, this research focuses on the interests of the industry and interests groups, interests of the public, and the law and regulations concerning airport terminal functions, processes and facilities. Within the latter, both local and international (ICAO) legislation will be considered. While RTHA is chosen as case study, both Dutch and European legislation are considered as local and will be analyzed. Furthermore, legislation concerning the exact technology used and privacy will be out of scope while this research aims to explore the potential impact of the new technology on the airport system.
Technical feasibility consists of the availability of the required technology. Here, the focus will be on the functions of this technology and whether these envisioned functionalities are already developed in available systems, or will be developed in the near future. The detailed technology and the operational flaws and possible shortcomings of this technology will be out of scope. Dealing with special cases, such as identifying children and facial masks, will thereby not be treated. It is assumed that the industry will develop suitable solutions for the technological flaws.
Lastly, social feasibility will look at the acceptability of the overall concept by the public. This will be exploratory measured by comparing the concept to the interests and objectives of passengers. Similar to the technical and legal feasibility, the focus will here be on the functions and processes of the new system. Thereby, the detailed technology specifications and implementation will be out of scope.

1.6 Methodology

In this section, the methodologies used to answer the research question are elaborated. First, the approach of the research, and each sub-question, is clarified in subsubsection 1.6.1. Thereafter, the introduced methodologies will be elaborated separately in more detail.

1.6.1 Approach overview

In order to answer the sub-questions and thereby the main research question, first a terminal concept based on the seamless flow concept needs to be constructed and conceptually implemented on the case study airport; Rotterdam The Hague Airport (RTHA). Thereby, a similar design process as described by Santolaya, Serrano, and Biedermann (2016) is executed. In their paper, different stages in a design process are identified, namely; the strategic definition stage and the design concept stage. In the strategic definition stage, the objective is to identify a problem, a need or an opportunity for the system or product improvement. Furthermore, the systems environment and corresponding legislation is investigated (Santolaya et al., 2016). The design concept stage continues on the conclusions reached in the strategic definition stage. Subsequently, alternatives and concepts are constructed. After the design concept stage, a concept is selected and a detailed design is developed (Santolaya et al., 2016).
Besides the 'design' of the new concept, the feasibility of the new concept is evaluated. This is determined by the approach of Feitelson and Salomon (2004). Within this approach, a political economy framework is proposed which aims to explain why certain innovation have been adopted where others have not. Thereby four determinants are distinguished: Technical, Social, Political and economic. This will be further elaborated in subsection 2.2. In the following paragraphs it is explained how the different sub-questions can be answered and what function each answer has in answering the main research question.

The most important determinants of feasibility are identified in sub-question one by performing a literature review. In this review, theories for the adoption of technology innovations are studied. Subsequently, a fitting theory will be elaborated and used as a theoretical lens throughout this study.

In the second sub-question, the passenger terminal is examined. By identifying the different functions, processes and facilities, the system is explored. This is one of the objectives of the strategic definition stage as described by Santolaya et al. (2016). In order to answer the question, a literature study on the airport passenger terminal will be executed. Hereby, the most important document to be reviewed is the Airport Development Reference

Manual (ADRM) from IATA and ACI (2019). Furthermore, interviews will be conducted with senior airport consultants at NACO in order to get a more realistic view on the literature findings.

During the research on the passenger terminal, various stakeholders involved in or responsible for certain facilities or processes within the passenger terminal will be identified. This forms the basis of answering sub-question three. By performing a desk research on those stakeholders, their interests will be determined. Via interviews with both NACO's airport consultants, the airport operations manager of RTHA, and the aviation security advisor of Schiphol Airport, the findings will be sharpened when applicable.

The (legal) requirements in the conventional terminal design are identified in the fourth sub-question. Continuing on the identified functions and facilities from sub-question one, the requirements for each design phase are elaborated. To answer this question, the reasoning behind every design choice throughout the process is elaborated and translated into concrete requirements. Consequently, literature reviews will be executed to gather the required information. In order to identify the requirements of each facility or process, the Airport Development Reference Manual (ADRM) from IATA and ACI (2019) will again be reviewed. The legal requirements, or legislation, will be identified by studying both local and international aviation regulation documents. With the result, the strategic definition stage as described by Santolaya et al. (2016) is completed.

In the fifth sub-question, RTHA is introduced as a case study and the (future) requirements are determined. By answering this question, the environment and corresponding requirements of this airport and its surroundings are analyzed and discussed. This information is gathered by a desk research to the airports statistics, interviewing the operations manager of RTHA, and by using NACO resources. NACO maintains a good relation with RTHA while they executed various projects for the airport in the past. In more detail, NACO recently provided a master plan and passenger terminal capacity study for RTHA. Therefore, required data such as ground plans, the envisioned level of service and passenger numbers are relatively easy to acquire.

The technology behind the seamless flow concept is explored in sub-question six. To do this, interviews will be held with tech-company SITA. As earlier mentioned in subsection 1.2, SITA is a manufacturer of facial recognition equipment designated for airport passenger terminals. Together, with a desk research on available technologies from other companies, a clear review of the technology, and its availability, can be elaborated.

To answer sub-question seven, the first step in developing a new design is completing the design concept stage (Santolaya et al., 2016). While the decision for a concept in which international and domestic passengers are mixed in airside facilities is already made (subsection 1.5), alternative concepts are not generated. Instead, different terminal variants within this concept will be constructed in collaboration with NACO consultants (experts). Hereby, characteristics of the used technology are used to construct the terminal concepts in which domestic and international passengers are mixed in the airport's airside facilities.

In sub-question eight, the technical, social, political and economic feasibility of the constructed concepts is determined (as determined in sub-question 1). Thereby, this sub-question continues on the results of the previous sub-questions. Based on these results and the theoretical framework by Feitelson and Salomon (2004) (further elaborated in subsection 2.2), it is determined whether the concepts are feasible in each discipline. This will be done using both qualitative and quantitative research methods. For the technical, social and political determinants, the qualitative results of the previous sub-questions will be used together with literature review and interviews.
The economic feasibility of the new terminal concepts is quantitatively determined by identifying the costs and benefit. To start, the costs for equipping the current infrastructure with seamless flow technology will be determined. In order to be able to do so, the new seamless flow passenger terminal concepts from sub-question seven must be conceptually implemented on RTHA in order to determine the required equipment quantities. As stated in subsection 1.5, the focus is on the strategic level which does not include passenger flow simulations. To make the right assessments, interviews will be conducted with aviation security specialists and financial assessment specialists at NACO. Furthermore, the costs for the technology will be retrieved in the interview with SITA and a renowned access gate manufacturer. Finally, a (financial) Cost-Benefit Analysis (CBA) will be constructed to determine the economic feasibility from the airport's perspective.

1.6.2 Desk research

According to Neuman (2014), an essential step in a research is to study accumulated knowledge on your subject. By reviewing available knowledge, a researcher will avoid reinventing the wheel. Neuman (2014) distinguishes six types of literature reviews in his paper. In this thesis, three of them are used: Context review, integrative review and theoretical review. In context review, a broad range of knowledge about the research subject will be reviewed after which the study is linked to this available knowledge. This is done in the research motivation

(subsection 1.3). Integrative review contains the current state of knowledge about the research subject. This is often combined with the context review, which is also the case in this research. In the theoretical review, theories and concepts applicable within the research are presented and their applicability is discussed. This review is contained in the theoretical framework section (section 2).
Desk research is not limited to scientific papers or literature. Instead, multiple sources which are not scientifically researched can be used in order to gather facts and data. This brings the advantage that relatively new subjects, which are not yet scientifically researched, can be studied. Thereby, non-scientific desk research complements the literature review (Imperial, 2017). In this research, this type of research is used to gather information about stakeholders, seamless flow technologies and the case study Rotterdam Airport.

In order to find relevant literature, multiple search engines were used. Google Scholar, Science Direct and Scopus were all conducted to find the relevant academic literature. Thereby, the English language is predominantly used. Examples of frequently used keywords are: airport(s), passenger terminal, terminal concepts, biometric technology, facial recognition, passenger experience, airport design, Level of Service. Furthermore, additional search operators such as 'AND' and 'OR' were used. Moreover, both backward and forward snowballing is used to find more relevant literature. Thereby, peer-reviewed literature was used predominantly.
Next to scientific literature, various reports are used. One outstanding report used is the Airport Development Reference Manual(ADRM) by IATA and ACI. The ADRM is recognized as on of the most important guides in the aviation industry for both planning a new airport and extending existing airport infrastructure. Besides that, ICAO's Annexes 9 and 17 publications are used. Within these annexes, the aviation standards and recommended practises are defined.

1.6.3 Interviews

Interviews are used multiple times as a method to acquire information. Within this study, so-called semi-structured interviews are conducted. In this method, the interviewer does prepare a list of predetermined questions but the actual interview is conducted in a conversational manner. This allows the participants to address issues that they feel are important (Longhurst, 2003). As a result, the detailed structure of the interview is worked out during the interview which could lead to exploring the subject from different angles. Thereby, semi-structured interviews is a flexible and effective method for small-scale research (Drever, 1995).

Within the semi-structured interviews of this study, open-questions will be asked regarding personal and corporate experiences and visions. Thereby, the findings of the desk research can be put in an practical and realistic perspective. According to Bogner, Littig, and Menz (2009), interviewing experts of the industry is an efficient method to gain knowledge about a subject. Thereby, interviews offer researchers an effective mean to quickly obtain good results (Bogner et al., 2009). In this research, interviews are used to explore the civil aviation system and to obtain experiences and visions of different players within the system's playing field. Besides that, obtained results will be validated via interviews. Furthermore, the interviews are used to get in contact with the right persons within organizations which lead to acquiring data. In Table 1, an overview of the conducted interviews is presented.

Table 1: List of interviews

Company	**Function**	**Subject**
NACO	Senior airport consultant	Facilities
	Senior airport planner	Experiences seamless flow
	Director airport strategies	Airport strategies (financial), validation
	Consultant aviation security	Equipment, validation
	Architect	Capacity study RTHA
SITA	Product manager	Seamless flow technology
RTHA	Airport operations manager	Vision, feasibility, stakeholders and validation
Schiphol	Senior advisor aviation security	Current state, feasibility
Gate manufacturer	Consultant	Costs of a biometric system

1.6.4 Cost-Benefit analysis

In order to fully answer sub-question eight, a Cost-Benefit analysis will be executed. A CBA is a quantitative method which includes systematic cataloguing of pros and cons. These pros and cons are quantified in monetary value and can thereby be described as benefits (pros) and costs (cons) (Boardman, Greenberg, Vining, & Weimer, 2017). By identifying all the consequences of a proposed action and assigning monetary costs and benefits to each consequence, it can be decided whether the costs and benefits balance. Thereby, this analysis rests on the assumption that everything can be attached with value. Besides that, this method is seen as controversial while the researcher makes a fair amount of assumptions (Neuman, 2014). In this research, a financial CBA is constructed to determine the economic feasibility of new seamless flow passenger terminal concepts from the airport's perspective.

1.7 Structure

In Figure 4, the structure of this thesis is graphically presented. On the left side, the process of this research is concisely shown. Arrows from the process section to the thesis layout section show which process step is elaborated in which chapter. Furthermore, the arrows between the thesis layout and the research questions show which sub-question(s) is/are answered in a chapter. Lastly, the red arrows between different chapters represent the flow of information (results) between the different chapters.

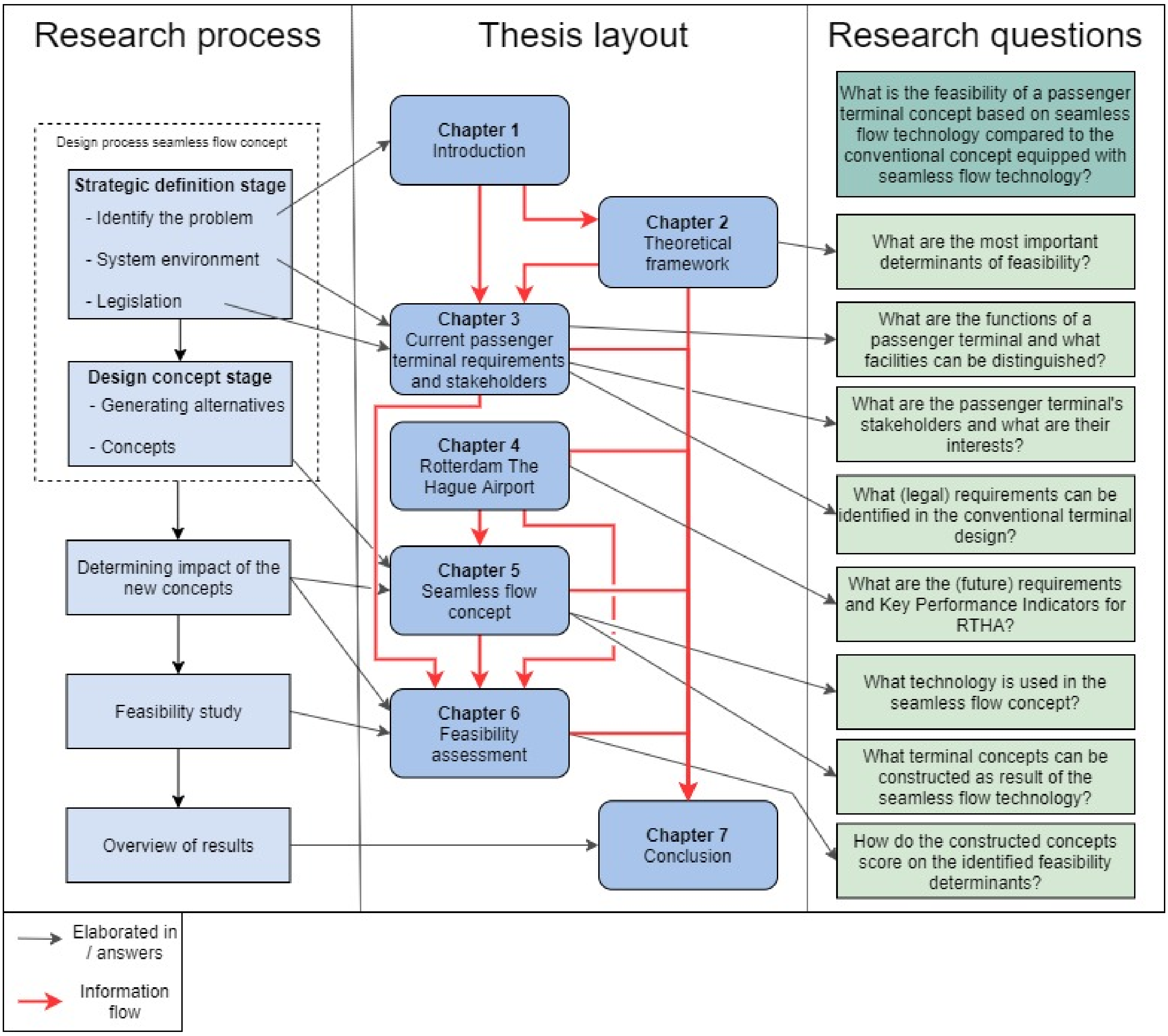

Figure 4: Thesis structure

2 Theoretical Framework

In the previous chapter, the objective of this research is defined, namely: exploring whether seamless flow technology could lead to a new, and feasible, passenger terminal concept. When looking at this research objective, one can distinguish two different parts. On one hand, this research is going to explore whether the new technology could lead to new passenger terminal concepts. Thereby, this part contains parts of a design process. On the other hand, the feasibility of such a concept is studied. This part is looking at the adoption of an innovation in an existent system. Both parts require a different theoretical approach, or lens, which will be elaborated in this chapter. In subsection 2.1 the approach on the design process is elaborated. The approach on the adoption of innovations is discussed in subsection 2.2.

2.1 Opportunities in different design stages

As elaborated in subsection 1.6, this research follows a design process in order to construct and assess a passenger terminal concept based on the seamless flow technology. A design process contains different phases among which the conceptual design phase and the detailed design phase (Santolaya et al., 2016). As stated by Wang et al. (2002), the conceptual design phase is probably the most crucial phase in the development of a product or system. In this phase, impact of decisions are very high which creates great opportunity. The decisions made in the conceptual design phase do have a significant influence on the costs, performance, reliability, safety and environmental impact of a product or system. Those design decisions can account for more than 75% of the final costs of a system or product (Hsu & Liu, 2000). Later in the design process, in the detailed design phase, it becomes nearly impossible to compensate for shortcomings of a concept generated in the conceptual design (Wang et al., 2002). This theory is graphically represented in Figure 5. In this figure, one can see that the amount of opportunities decrease when moving to phases where primary decisions are already made. The availability of tools, to support decision making, follows an opposite trend.

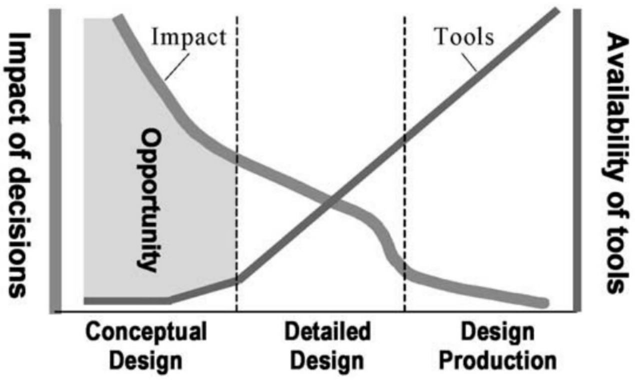

Figure 5: Opportunity in design stages (Wang et al., 2002)

2.1.1 Relation to research

When looking at the current airport passenger terminal concept, and its processes, this can be seen as the result of the conceptual design phase for the conventional passenger terminal. In this phase, regulations and available technology are important and eventual constraining factors in decision making. Subsequently, the system and its processes are further constructed in the detailed design phase and physically implemented in the production phase.

Implementing the new seamless flow technology in current passenger terminal processes means adopting the conventional terminal concept. Thereby, the new technology is not considered in the (early) conceptual design phase of the system in which it is implemented. Consequently, the seamless flow technology is introduced in a phase where primary conceptual decisions are already made and opportunities out of the early conceptual design phase are lost. This can also be referred to as path dependency. Path dependency is the concept in which the set of decisions, given any circumstance, is limited by decisions made in the past, even though past circumstances may not be relevant anymore (Praeger, 2007).
As earlier stated, the decisions made in the conceptual design stage can hardly be compensated by decisions later in the design process. Implementing the seamless flow technology in current passenger terminal concepts could thereby lead to a sub-optimal system. This also complies with the findings of Enoma, Allen, and Enoma

(2009). In their paper, it is stated that a redesign of the airport's facilities is necessary in order to be sure of effectiveness in the use of space and other related resources (Enoma et al., 2009).

2.1.2 Approach in this research

As result of the theory of Wang et al. (2002), a modified design approach will be used in this research. While the aim is to explore new concepts as result of a technology innovation, the seamless flow technology, identified requirements in the current system will not per definition be used as 'barrier' requirements for the new design. Instead, first new concepts will be constructed based on the technology after which the concept will be assessed with the identified requirements out of the current system. As result, path dependency is bypassed (to a certain level) which brings back the opportunity out of the early conceptual design phase.

2.2 Adoption of innovation

The second part of the objective is to assess whether the constructed concept is feasible and could thereby be adopted in the existent system. The seamless flow innovation, can be seen as a system innovation which needs to be adopted in the general system. Multiple theoretical frameworks, which can be found in literature, describe innovation transitions. The multi-level model of Geels (2002) is often used in research. This framework is however intended to study changes in the societal landscape and the socio-technical regime over time, which does not perfectly suit the seamless flow innovation. Moreover, Van Mierlo, Leeuwis, Smits, and Woolthuis (2010) defined an analytical framework for learning processes in system innovation environments like the model of Geels (2002). The scope of both frameworks are on societal changes which is too broad to use for the the seamless flow innovations on airports. The political economy framework of Feitelson and Salomon (2004), provides a multi-actor scope on system innovation which suits the seamless flow innovation. Feitelson and Salomon (2004) state that the implementation of most transport innovations should be viewed as an outcome of societal processes, often with significant government involvement. Looking at the seamless flow innovation, it is expected that both public and private stakeholders within the airport terminal system will play an important role in the adoption. As discussed in subsection 1.1, the security on airports is federalized and thereby a governmental responsibility. Moreover, airports are often owned, or partly owned, by governments. Thereby, it is expected that the adoption of the seamless flow innovation requires a public-private partnership which makes the political economy framework by Feitelson and Salomon (2004) suitable to use in this research. The framework is presented Figure 6.

Feitelson and Salomon (2004) proposed the political economy framework which explains why certain innovations have been adopted while others have not. Thereby, the adoption of an innovation refers to the actual use of an innovation that has already penetrated the market. This adoption is predicted by a series of factors. One of the most fundamental factors is the technical feasibility. In other words, that the innovation can be used and that others can be convinced of the usability of the innovation (Feitelson & Salomon, 2004). When an innovation is not perceived as technical feasible, it will most likely fail to be adopted in the system. Although technical feasibility is essential, it is on it's own not sufficient for an innovation to be adopted. There also has to be demand for the innovation. Furthermore, the costs and benefits of an innovation are analyzed. Hereby, the logical line of reasoning is that if an innovation provides relatively more benefits than costs it could possibly be adopted. Yet, if an innovation is proven to be cost-effective it will not per definition be implemented (Feitelson & Salomon, 2004).
Besides the technical and economic (cost and benefits) factors, other factors do also influence the possible implementation. These include: convincing the public and decision makers that taking action is necessary, convincing the public about the effectiveness of the innovation, and the distribution of the costs and benefits (Feitelson & Salomon, 2004). While decisions regarding implementing new innovations are most commonly made by existing institutions, the power of interests groups must also be taken into account. In Figure 6, the described factors are compiled into a political economy framework.

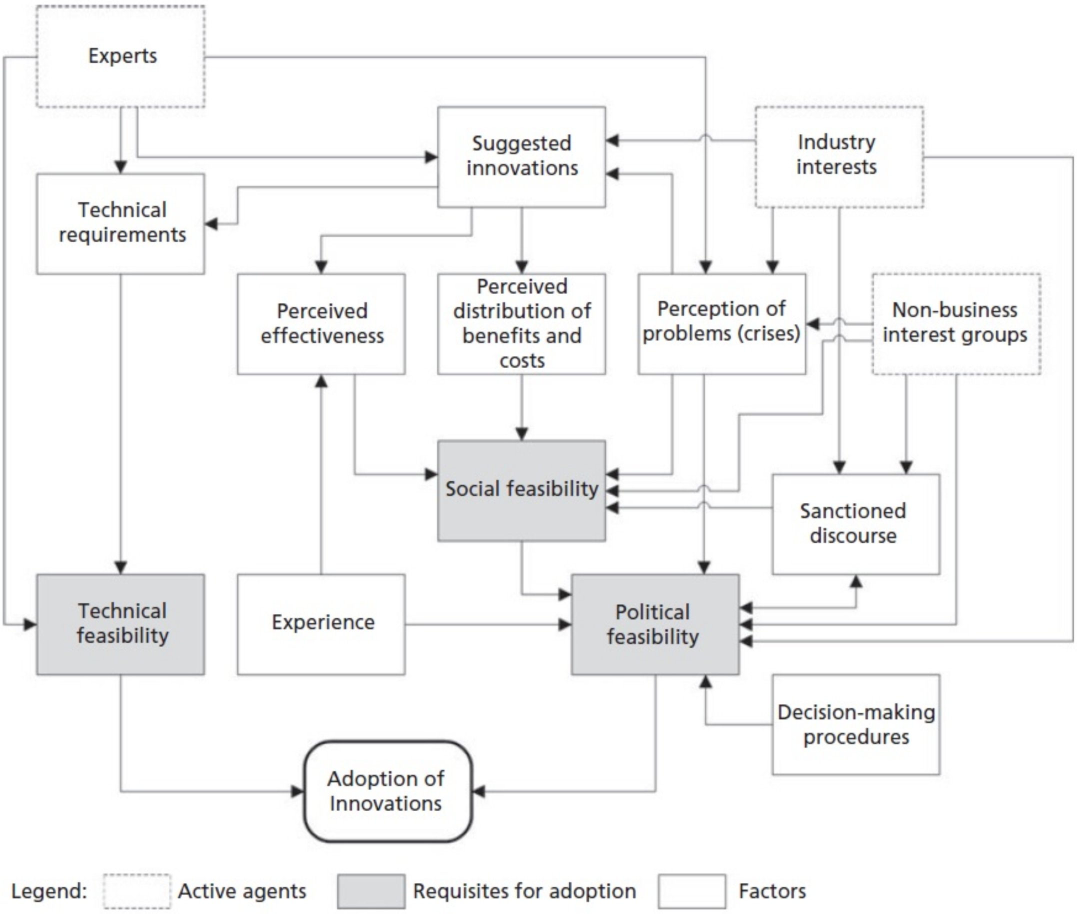

Figure 6: Political Economy model by Feitelson and Salomon (2004) (van Wee et al., 2013)

Feitelson and Salomon (2004) think that an innovation will only be adopted if it is seen as technically, economic, socially and politically feasible. These requisites are thereby highlighted (grey) in Figure 6. When looking at the technical feasibility, it is simply determined whether the innovation works and complies to the technical requirements. From an economic perspective, an innovation is feasible if it can pass a cost-benefit analysis. While this analysis contains a fair amount of assumptions, the result is a minimal requirement. However, an innovation that does not pass a rudimentary cost-benefit analysis is considered as socially infeasible while it is unrealistic.
Social feasibility is achieved if the majority of the voters are likely to support an innovation. Thereby, the voters are lead by their perception of the innovation in terms of: effectiveness, the problem, and the distribution of costs and benefits. Furthermore, the perception of voters is influenced by: experiences with similar innovations, publications, media attention, and lobby groups. The latter three are included as 'sanctioned discourse' within the framework. Political feasibility, is among other things determined by the social feasibility while politicians do take voter preferences into account. By hearing the preferences of voters, the industry, and interest groups, politicians want to maximize the likelihood to be re-elected.

2.2.1 Relation to research

As stated by Feitelson and Salomon (2004), either the industry or policy entrepreneurs (experts) advance transportation innovation. Industry innovation advances are driven by a profit motives or increasing productivity motives. The latter aims at innovations which structure businesses more effectively. A new passenger terminal concept as result of seamless flow technology can be categorized as an innovation which aims to increase the productivity of airport touchpoints LAM-LHA (2019). Thereby, the airports resources will be used more effective. Furthermore, the political economy framework by Feitelson and Salomon (2004) assumes the existence of interests groups which have their own perception on the innovation and power in decision making processes. As described in subsection 1.1, the airport terminal contains a variety of stakeholders which all have their own responsibilities and thereby interests and power within the industry. Furthermore, collaboration between the stakeholders is essential in order to implement the seamless flow system. The political economy framework, presented in Figure 6, is thereby an appropriate framework to analyze whether the new terminal concepts, as result of the seamless flow innovation, are feasible and could be adopted by the civil aviation industry.

2.2.2 Approach in this research

When looking at the findings of Feitelson and Salomon (2004), an innovation will be adopted if it is seen as feasible. The term feasible can be divided into four determinants: technology, economy, social and politics. Consequently, the newly constructed seamless flow concepts will be assessed on all four determinants. As already defined in subsection 1.5, the technical feasibility will determine whether the system is technically capable of executing their designated function. The economic feasibility will be determined by executing a cost-benefit analysis. Finally, the social and political feasibility will be determined with the help of a stakeholder analysis. Within this analysis, the power and interests of the various stakeholders within the passenger terminal system are identified and elaborated. Consequently, the characteristics of the seamless flow concept will be compared to the identified stakeholder interests.

2.3 Conclusion

In this chapter, two different theories are discussed, namely: the opportunities in different design stages by Wang et al. (2002) and the political economy framework by Feitelson and Salomon (2004). Both determine the the theoretical lens on the seamless flow subject and thereby the research approach. As result of the opportunity in different design stages theory, path dependency is bypassed in the design concept stage. Furthermore, the technical, economy, social and political feasibility determinants will be evaluated as result of the political economy framework. Thereby, sub-question one is answered.

While the system's (legal) requirements are not assumed in the concept design stage, the compliance to these will evaluated within the feasibility study. The influence of both the theories on the research process is graphically presented in Figure 7.

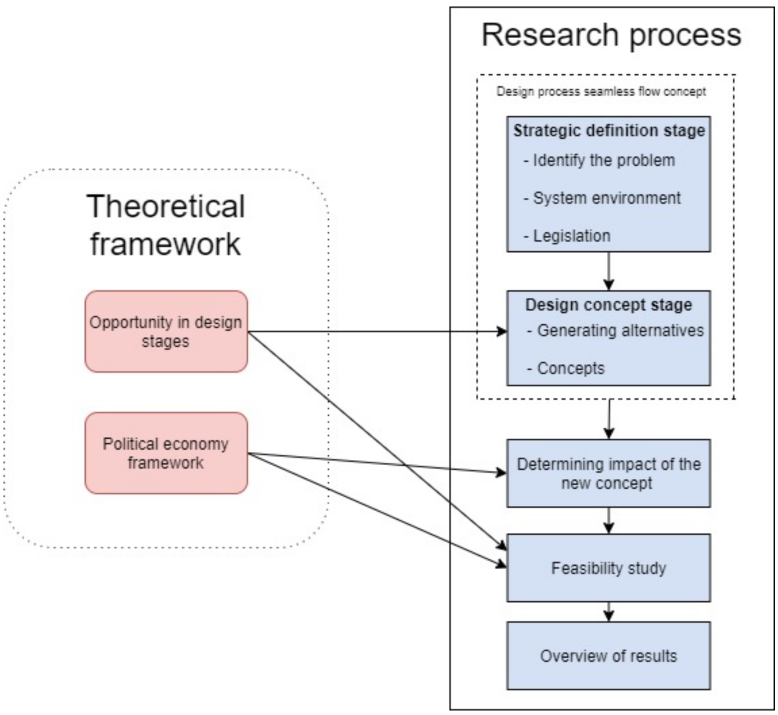

Figure 7: Influence of theory on research process

3 Current passenger terminal: requirements and stakeholders

When designing a new airport terminal concept, one first needs to understand the system and its environment. Therefore, the current airport terminal design considerations and regulations are explored. Hereby, the system requirements will be identified and stakeholders that fulfil a role or have interests in the process or final design of an airport's passenger terminal are addressed. In subsection 3.1, the principles of the passenger terminal design will be elaborated. Thereafter, current regulations corresponding to the passenger terminal principles will be addressed in subsection 3.2. To conclude, stakeholders will be identified together with their interest and corresponding objectives. Thereby, this chapter will answer sub-questions two,three and four.

3.1 Terminal design

In this section, the current airport terminal design will be analyzed. Generally, an airport terminal is designed according to the Airport Development Reference Manual (ADRM) of IATA and ACI (2019). In this manual, all the different facets of designing an airport are addressed. First, the ADRM and both the authors, IATA and ACI, will be introduced. Thereafter, the terminal design process and corresponding requirements will be elaborated.

3.1.1 Airport Development Reference Manual

The ADRM is recognized as one of the most important guides in the aviation industry(IATA & ACI, 2019). The manual is used by various parties involved in both planning a new airport and extending existing airport infrastructure. Within the ADRM, industries best development practices in many complex topics involved in airport projects are brought together in a comprehensive manner. This includes, recommendations of industry specialists and the promotion of sustainable airport facilities. While international standards vary from regional standards, the manual should be be used as a complementary source for airport design. The manual is constructed by the International Air Transport Association (IATA) and the Airports Council International (ACI) (IATA & ACI, 2019).

IATA

IATA is the responsive and forward-looking trade association of the international air transport industry. The association represents 290 airlines around the world, which accounts for 82% of the total air traffic. With the mission of 'Represent, lead and serve the airline industry', IATA establishes the cooperation between its airlines and the industry and thereby aims to offer a seamless service of the highest quality to all their members. Hereby one can think of ensuring the transportation of people, freight and mail to be as safe, simple and cost-effective as possible (IATA & ACI, 2019).

On airports, IATA is also involved in various activities. The Airports Infrastructures and Fuel (AIF) section for example aims for an early involvement of the airline community in airport projects. With the help of the Airport Consultative Committees (ACCs), who gathers airline requirements and recommendations, IATA ensures airport projects to be tailored, demand-led and fit to purpose. Furthermore, IATA offers consultation services for different phases in the airport's lifecycle, such as: planning and construction, commercialization, optimization and change in ownership (IATA & ACI, 2019).

ACI

The Airports Council International (ACI) is the worldwide association of airports. With a total of 1,751 member airports, from 573 airport associations, the ACI represents the interests of the world's airports. While the interests of airlines and airports are closely linked, IATA decided to construct the new ADRM version in collaboration with ACI. The mission of ACI is to promote the professional excellence in airport management and operations. In order to reach this goal, several objectives have been defined among which maximizing airport contribution on safety, security, environmental friendly and efficiency developments. Furthermore, active cooperation among the various parties both in and outside the aviation industry is highly promoted. The ACI maintains an important relationship with the International Civil Aviation Organization (ICAO) in which international aviation standards are debated and constructed (IATA & ACI, 2019).

3.1.2 Terminal design considerations

In this section, the terminal design considerations are elaborated. Challenges and requirements associated with passenger terminal designs and facilities will be identified and discussed. As already mentioned in section 1.4, this research focuses on the core passenger departure processes in the passenger terminal.

Key functions

The configuration of the passenger terminal is closely related to the surrounding infrastructure, such as the terminals airside infrastructure and the airport access infrastructure. While the function of a terminal is the major design criteria, the requirements of the airport operations such as the operations of the major users, airlines must be fully understood (IATA & ACI, 2019).

Although all airports are different and thereby must comply to a different set of requirements, similar key functions for the passenger terminal can be identified. In the ADRM, the passenger terminal complex is described as a series of interconnected subsystems. The following sub-systems are identified:

- Ground transportation systems
- Main terminal spaces, such as: forecourts, departure/arrival hall, commercial spaces
- Outbound and inbound inspection services, such as: security checks (departures), border control and customs control (arrivals)
- Primary lounges for airside waiting prior to boarding the aircraft
- Secondary lounges, e.g. gate lounges
- Baggage handling system (BHS)

Various criteria should be considered when selecting a terminal concept or planning a passenger terminal. Those criteria are mostly based on future developments. In the ADRM, modularity and the ability to expand are addressed as important notions. In order to accommodate to future developments, in terms of both capacity enhancement or change in security protocols, modular flexibility of facilities is essential to keep delivering a good passenger experience. In terms of terminal planning and design, all capital expenses must be backed by a business case or cost-benefit analysis. Hereby, the true monetized benefits of a decision are quantified (IATA & ACI, 2019).

Terminal facilities

Within a passenger terminal, various different facilities can be distinguished. Each facility has its own function and thereby its own requirements. Passengers will pass the facilities during their journey through the airport. This departure journey within the passenger terminal starts at the forecourts of the terminal and ends at the boarding gates. Although all airports contain the same facilities, the exact sequence of facilities may differ between countries. In this subsection, the different facilities are addressed and corresponding functions will be elaborated (IATA & ACI, 2019).

- *Forecourts*
  Both the departure and arrival forecourt form the interface between the landside infrastructure and the terminal building. In this area vehicular flows meet pedestrian flows. They are mostly used by private vehicles, such as cars, tax's shuttles and busses, to pick-up or drop-off passengers. Depending on the size and configuration of the airport, forecourts can both be single or multi-level.

- *Departure hall*
  The departure hall forms the entrance of the Airport for the departing passengers. Depending of the type and size of the airport, the area can be provided by various public and non-public areas. The facility is utilized for check-in procedures and baggage drop-off. Furthermore, offices are situated in the departure hall. Hereby one could think of the presence of pre-departure customs facilities which allow international passengers to document re-exported goods. Communication kiosks for information and ticket sales are also present.

- *Access control*
  The access control to secure areas facility, is the first facility of the so called control section which separates the public landside from the secured airside areas. The airport has the responsibility to prevent access by unauthorized persons to the secured areas. Therefore, passengers are required to have a valid boarding pass in order to enter airside facilities. This boarding pass check could be executed by airport personnel

but it is recommended to use automated access gates. In some cases, this control check may be combined with border control.

- *Security screening*
  The security screening facility forms, together with the access control and border control facilities, the control section which physically separates the landside and airside areas within a passenger terminal. All passengers, need to be security screened. The main goal of the security screening facility is to 'identify and/or detect weapons, explosives or other dangerous devices, articles or substances that may be used to commit an act of unlawful interference' ICAO (2017a). While the screening processes and procedures are constantly evolving, the facility (and surrounding area) should be designed to be 'future proof'. Furthermore, the security facility is dictated by both national and international safety regulations (subsection 3.2). This also influences the design of the facility.

- *Border control*
  After check-in, baggage drop-off, access control and security screening, international passengers proceed their journey to border control (emigration). At this facility, passport and border control services are executed by the government agency. The space must have the ability to separate passengers based on characteristics and dedicated interview rooms must be available. Often the emigration services are centralized in order to make the best use of resources. Note that the facility sequence is dependent on national regulations, in some countries emigration facilities are placed before the security screening.

- *Departure lounge*
  After security screening, the departing passengers arrive in the departure lounge. This lounge is meant to form a restful place in which passengers wait for the departure of their aircraft. The facility consists of lounges and boarding gate areas which can either be separated into different areas or integrated into one area. While most passengers are spending a substantial amount of time in this facility, it is equipped with entertainment and commercial offerings. The layout is naturally dependent on the characteristics of the passengers.

- *Boarding gates*
  The boarding gate is the last facility for the passenger to pass, prior to boarding the aircraft. At this facility, a last check is executed by the airlines to ensure that the right person enters the aircraft. Via an automatic reading system, the boarding card is checked on validity. Furthermore, the travel documentation is visually matched with the name on the boarding card. When both checks are successfully executed, the passenger can board the aircraft.

Size of terminal facilities

The size of each terminal facility is not simply determined by a basic formula or rule of thumb. A blend of research, calculation, simulation and experience is needed to determine the right size of each facility. Furthermore, improvements and innovations in terminal processes impact the different spaces in airport terminals. As result, passenger processing areas within the terminal will evolve and dedicated functions will change in the forthcoming years. The purpose of these changes is to remove the bottlenecks in current processing sequences and thereby increase the flow and capacity (IATA & ACI, 2019).

For decision makers in airport design, it is thereby important to understand future developments. They must design flexible spaces which are able to adapt to future developments. However, the most important factors for determining the size of terminal facilities are (IATA & ACI, 2019):

- The current and future airside capacity of the airport (runways and taxiways)
- Types of aircraft that serve the airport
- The peak hour in passenger flow

The above mentioned factors do all have a direct relation with the passenger flow volumes in the terminal. The frequency and density of the air services are limited by the airside capacity and types of aircraft and determine the peak hour passenger volume. Subsequently, the sizing of the terminal facilities is dependent on the demand.

In order to determine the right size, the concept of Level of Service (LoS) is used. The LoS is an aggregated framework used for the design and expansion of facilities and monitoring existing facilities (IATA & ACI, 2019). This framework contains different service levels which correspond to different passenger conditions in terminal facilities. The different service levels are: sub-optimum, optimum and over-design. Furthermore, different facilities are distinguished within the LoS framework, namely: processing facilities and holding facilities. In processing facilities, the service levels are determined by the waiting time and space per passenger. The less waiting time and the higher the space per passenger, the higher the assessed LoS. In holding facilities, waiting time is not applicable and is therefore replaced by other notions, such as seat ratios. Although the airport is free to choose their own LoS standard, the common objective is to not under or over provide in passenger facilities(IATA & ACI, 2019). The LoS guidelines are presented in Figure 18 in Appendix B.

Furthermore, it must be noted that other factors do also impact the terminal sizing. Hereby one can think of passenger persona's, the type of BHS, number of checked bags, arrival modalities, number of support offices, types and sizes of commercial activities and a reserve or buffer area which can be used in periods of massive delays or disruptions(IATA & ACI, 2019).

Passenger Flows

Passengers are the major users of the passenger terminal, which makes them an important factor in the terminal design and planning. As stated above, the sizing of passenger facilities is directly dependent on the passenger flows within the terminal. Passenger flows are constructed based on passenger characteristics, perceptions and behaviour. Each flow represents the journey of a certain passenger profile. As a result, a variety of different departing passenger flows can be identified on the airport, each with its own requirements and characteristics (AT, 2010). In an optimal terminal design, different passenger flows will not interfere with each other which optimizes the flow throughout the network. Consequently, it is preferred to minimize cross-flows within the terminal and thereby segregate different flows when possible (IATA & ACI, 2019).

Two outstanding departing passengers flows that can be distinguished are: domestic and international. Both passenger profiles require different levels of custom and emigration checks, which leads to a mandatory segregation of the two flows in airside terminal facilities (more elaborated in subsection 3.2). In Table 2, both domestic and international departing passenger flows are presented and applicable facilities, which they pass in their journey through the terminal, are indicated.

Table 2: Passenger flows through airport facilities

Passenger Flow	**Airport Facilities**						
	Forecourts	Departure Hall	Access control	Security screening	Border control	Departure lounge	Departure gates
Domestic	X	X	X	X		X	X
International	X	X	X	X	X	X	X

As can be seen in Table 2, domestic and international passenger flows do not follow the same journey, or route, through the terminal's facilities. While international passengers require border control, domestic passengers do not need to pass the emigration facilities. In line with the regulations, as will be described in subsection 3.2, the two flows will thereby be physically separated in airside facilities after their flows become 'different', i.e. after passing the border control facility. As a result, boarding gates will be committed to one user group, either to domestic or international passengers. While the peaks of domestic and international flights do often differ, the airport's resources are used inefficiently (IATA & ACI, 2019). Consequently, a flexible arrangement such as the so called 'swing gate' should be incorporated when applicable. The swing gate principle enables gates to be used for both types of passengers. This can be accomplished in various ways which is dependent on the airports current infrastructure. At smaller terminals, the swing gate could be accomplished by movable glass walls which move throughout the day to tactically distribute the available capacity. Larger terminals, such as Melbourne Airport, contain multiple levels and will thereby use ramps to allow different passengers using one certain gate (The Airport Professional, 2018).

Besides separating the different passenger flows based on the security level, obtained throughout the process, terminal design has to account for the fact that each passenger follows its own journey through the airport terminal. In this journey, clear and straightforward way-finding is desirable for the passenger and enhances the passenger flow. The best terminals provide a clear and direct path from entering the terminal to boarding the aircraft. In order to accomplish such a journey, enhancing passenger orientation by limiting decision points and the presence of physical directional clues is highly effective. Furthermore, passenger cross-flows, travel distance and level changes should be limited or avoided throughout the journey (IATA & ACI, 2019).

3.1.3 Conclusion

In this section, the ADRM is introduced and the terminal design considerations are discussed. Hereby, the key functions and facilities of the passenger terminal are identified. Thereby, this section answers sub-question one, two and partly sub-question four.
Modular flexibility, or the ability to adapt to future developments, is addressed as one of the key notions in the terminal design. Subsequently, each airport passenger terminal contains particular facilities, which have their own functionality and requirements. The size of those facilities is dependent on the passenger flow volumes that goes through the facility. In order to design, expand or monitor terminal facilities, the LoS framework is introduced which measures the service level within the facility. The flow volumes that passes a certain facility can be determined by analyzing the journey of the different passengers flows that exist within the terminal. Two outstanding passenger flows within a terminal are: domestic and international passenger flows. Both flows require a different level of emigration check. As result, their flows must be physically separated at airside facilities (further elaborated in subsection 3.2).

In this subsection, various requirements for the airport's passenger terminal are identified. The requirements are summarized in Table 3.

Table 3: Identified design requirements

	Design Requirements
1	The terminal should contain the following facilities: Forecourts, Departure hall, Access control, Security screening, Border control, Departure lounge and Boarding gates
2	The airport should be able to prevent unauthorized persons from accessing the secured (airside) area's
3	All passengers entering secured area's should be security screened
4	The departure lounge should contain commercial offerings, lounge(s) and boarding gate(s)
5	The size of each facility should comply to the LoS standards, set by the airport
6	After border control, domestic and international passenger flows should be physically separated in airside facilities

3.2 Regulations

In this section, the law and regulations concerning airport passenger terminal functions and facilities will be analyzed. In order to demarcate this regulation study, only regulations which are applicable for technologies used within the airports passenger processes and regulations applicable for the general concept (as presented in subsection 1.5), are treated. To get a clear overview, first the international regulations as defined by ICAO will be elaborated. Subsequently, local regulations applicable within the case study area (RTHA) will be discussed. All principles referred to in this section are included in subsection B.2.

3.2.1 International regulations

When looking at passenger terminal regulations, each terminal must comply to the international Standards And Recommended Practices (SARP's) defined by ICAO (as introduced in subsection 3.3). The SARP's are contained in 19 Annexes which are yearly published. Each Annex is focused on one particular subject within the ICAO responsibility area. Within the scope of this research, annex 9 'Facilitation' and annex 17 'Security' are applicable.

To comply to the general principles and security measures defined by ICAO, an airport must clearly distinguish the airside and landside within the terminal. In airside areas, only air travel passengers, in possession of a valid boarding card, are allowed. For landside facilities, ICAO defined no restrictions which means that both well-wishers and passengers are allowed. In landside facilities, allocating tasks and responsibilities over different responsible authorities, and the coordination between them, is very important to ensure security within the terminal. In order to prevent for unauthorized entry to the airside area, the two areas need to by physically separated by a control section (ICAO annex 17, ch. 4) (ICAO, 2017a).

Besides the clear distinction between the different areas in the passenger terminal, passengers and their belongings must be security checked. It is mandatory to screen air travel passengers and their cabin baggage to an appropriate level prior to boarding. After this screening unauthorized interference must be avoided in order to prevent for re-screening. This means that security screened passengers may not be mixed or physically in contact with other entities which are not secured to the same security level.

The same reasoning applies to the flow of hold baggage. The airport, or designated executive authority, should ensure the avoidance of unauthorized interference from point of screening the baggage until the departure of the aircraft. Furthermore, the passenger and hold baggage should be paired while transporting baggage without the corresponding passenger is not allowed (except for special cases). When baggage does pass the screening, local baggage reconciliation laws and regulation have to be applied (ICAO Annex 17, ch. 4) (ICAO, 2017a).

Each airport is allowed to develop their own tailored and efficient procedures, for the different passenger control processes, as long as the appropriate control measures defined by ICAO are met. While all passports shall be machine readable, ICAO recommends the airports to consider Automated Border Control (ABC) systems in order to speed up this control process. Subsequently, it is recommended to ensure that gates are sufficiently staffed in order to mitigate the consequences of a system malfunction. Furthermore, the airport shall, except for special circumstances, however not require passengers to share travel document data before arrival at the control point (ICAO Annex 9, ch. 3) (ICAO, 2017b).

3.2.2 Local regulations

As already described, international regulations for contracting states are defined by ICAO. In general, each contracting state is free to interpret and implement the ICAO principles in their own way, as long as it is established in a written national civil aviation security program. Within each state, a designated authority will be responsible for safeguarding the compliance to this civil aviation security program . Furthermore, it is required for this authority to define and allocate tasks and coordinate activities between the organizations involved within this program (ICAO annex 17, ch. 4) (ICAO, 2017a).

In the Netherlands, where RTHA is located, all published ICAO standards and recommendations are adopted and implemented. This implementation is mostly done via European regulations which are directly applicable, and thereby implemented, in contracting states. Those regulations are prepared and constructed by the European Union Aviation Safety Agency (EASA) and are based on ICAO's SARP's. The EASA is the core of the European Union's strategy for safe aviation (EASA, 2019). Furthermore, the regulations are included in the national aviation law published by the national ministry of Infrastructure and Water management called 'luchtvaartwet'. Within this legislation, national implementation prescriptions of regulations, which are either contained in the European regulations or which are not contained in the European regulations, are elaborated. The designated safeguarding authority (Civil Aviation Authority) in the Netherlands is the 'Inspectie Leefomgeving en Transport'(ILT). The ILT has the responsibility to continuously check the compliance to both ICAO and EU-regulations and requirements. Both ICAO and EASA also perform audit supervision and random inspections to ensure compliance of contracting states (Ministerie van Infrastructuur en Waterstaat, 2020b).

The 'local' regulations for the Netherlands consist of both European Regulations and National regulations. Within the Dutch national regulations, ICAO principles as discussed in subsubsection 3.2.1 are adopted and further elaborated in (Rijksoverheid, 2018). Within European regulations it is stated that equipment and authorities operating at or in the terminal must be certified (EU Regulation Article 35/37). A certificate declares that a certain piece of equipment or authority complies with delegated acts and essential requirements. Hereby, the European Union aims to avoid unacceptable risks for aviation safety at all times (European Union, 2018).

Besides the regulations on processes and facilities within the terminal, there are also regulations concerning international travelling rights. Within Europe, the agreement of Schengen is applicable. This agreement gives European passengers, and foreigners which are legally allowed to stay (temporary) within a Schengen country, the right to freely travel between the contracting states without border control. Pending on two states, Bulgaria and Romania, 28 countries are contributing to this agreement in the near future. The whole Schengen area can be found in Figure 19 in subsection B.2.

3.2.3 Conclusion

In this section, the law and regulations concerning the airport passenger terminal are elaborated. Thereby, this section answers sub-question three. Current civil aviation regulations are documented in both international ICAO principles and in local legislation. In the Netherlands, where RTHA is located, local regulations consists of both national and European Union legislation. In principle, all ICAO regulations and recommendations are locally adopted by the Dutch Government, either via EU or National regulations.

Within both regulations, it is stated that landside and airside areas must be physically separated by a control section which among other things prevents for unauthorized and/or unlawful interference. Hereby, task allocation and coordination between responsible authorities is very important. Subsequently, passengers and their belongings must be security checked after which unauthorized interference must be avoided. This means that security screened passengers may not be mixed or physically in contact with other entities which are not secured to the same security level. While not all passengers need to pass border control facilities, for example passengers travelling within the Schengen area (subsubsection 3.2.2), those passengers need to be separated from non-schengen passengers at airside facilities. ICAO recommends the use of Automated Border Control (ABC) systems in order to speed up the border control process. It is however not allowed to require passengers to share travel document data before arrival at the control point. Furthermore, all authorities and entities, including corresponding equipment, operating within the airport terminal must certified to execute their service. The main findings within this subsection are converted into legal requirements which are presented in Table 4. Furthermore, all regulations named or referred to in this subsection can be found in subsection B.2.

Table 4: Identified Legal Requirements

	Legal Requirements
1	Airside and landside area's within the terminal must clearly be distinguished
2	Airside and landside area's must be physically separated by a control section
3	Passengers and their baggage must be screened to an appropriate level prior to boarding
4	When unauthorized interference occurs, rescreening is mandatory
5	A piece of baggage may only be transported when linked to a travelling passenger
6	Airports may not require passengers to share travel document data before arrival at the control point
7	All equipment and authorities operating in the terminal must be certified

3.3 Stakeholder Analysis

In the previous sections, the airport passenger terminal regulations and design process considerations and requirements are elaborated. The passenger terminal forms a complex system while it serves a variety of stakeholders with diverging objectives, as identified in subsection 3.1 and subsection 3.2. As mentioned in section 2, stakeholders have a dominant role in the adoption of a technological innovation(Feitelson & Salomon, 2004). This section will thereby elaborate on the identified stakeholders and their interests in the passenger terminal and its processes. First, each stakeholder and corresponding interests will be treated separately. Thereafter, the integral playing field within the system will be analyzed.

3.3.1 Stakeholders

In this subsection, the identified stakeholders are elaborated in terms of their tasks and interests within the passenger terminal system. In subsection 3.2, both international and local regulations within the case study area have been distinguished. Consequently, the identified stakeholders are either international and local (European and Dutch) parties.

- *IATA*
  The international Air Transport Association (IATA) is the biggest airline association in the world. As already discussed in the previous section, their mission is to 'represent, lead and serve the airline industry'. In terms of passenger experience, IATA believes that accommodating to the massive passenger growth is a major challenge in the aviation industry. In order to deal with this challenge, IATA works with airlines and governments towards an end-to-end seamless passenger experience (IATA, 2020). Moreover, IATA shows their interest in the seamless flow developments by publishing the One ID concept and future vision.

- *ACI*
  The Airports Council International (ACI) is the world's airport association. Among other things, their goal is to maximize airport contribution on safety, security, environmental friendly and efficiency developments. Furthermore, the ACI has a benchmarking program for the passenger service on airports called Airport Service Quality (ASQ). With this program, the ACI emphasizes the importance of passengers and their experience on the the airports (ACI, 2020). The seamless flow thereby conforms the interest and goals of the ACI.

- *ICAO*
  The International Civil Aviation Organization (ICAO) is a United Nations (UN) agency which manages

the international aviation Standards and Recommended Practices (SARP's) and policies in the aviation sector. The SARP's ensure that all local aviation practices and operations are conform global standards. With their vision of achieving sustainable growth, the objective is to increase the capacity and improve the efficiency of the the global civil aviation system. The latter objective is focused on optimizing and upgrading the airport infrastructure to optimize performance (ICAO, 2020). The seamless flow concept is an example of such a development and thereby fits to the ICAO's objective.

- *EASA*
  The European Union Aviation Security Agency, is the EU agency for aviation safety. EASA aims to promote the highest safety standards in civil aviation (EASA, 2019). The agency develops safety rules, based on ICAO's SARP's, at European level. Furthermore, EASA monitors the implementation of the standards in all it's contracting states. Via regular inspections, the EASA aims to maintain a European level playing field which stands for equal regulation and implementation in all contracting states (Ministerie van Infrastructuur en Waterstaat, 2020b).

- *Government*
  The national government, fulfills various tasks on the airport. In general, a government publishes the national regulations via the national ministry of justice. Besides that, the government appoints a Civil Aviation Authority (CAA) which controls the air travel operations and defines regulations to maintain safety. At an airport, as earlier discussed in section 3.1.2, the national government appoints an agency which is responsible for both the passport and customs control. Moreover, the government agency guarantees the safety on airports. This means patrolling around the facilities and safeguarding strategic touch points.

- *Civil Aviation Authority (CAA)*
  The Civil Aviation Authority (CAA) is appointed by the national government and controls the air travel operations and defines safety regulations within the concerned state. In the Netherlands, the Inspectie Leefomgeving en Transport (ILT) is the safeguarding authority in the area of infrastructure and water management (Ministerie van Infrastructuur en Waterstaat, 2020a). Thereby, the ILT has the responsibility to make sure that both ICAO and EU-regulations are implemented. Furthermore, they define detailed process descriptions and instructions in order to be able to continuously check the compliance to applicable regulations (Ministerie van Infrastructuur en Waterstaat, 2020b).

- *Border Guard*
  The border guard is the government's agency that is responsible for, and performs, the border security. In the Netherlands, this agency is called the Koninklijke Marechaussee (KMar). The KMar guards both the Dutch and European border on aiports within the Netherlands (Ministerie van Defensie, 2020). Furthermore, the KMar is assigned to act as the police force on civil Dutch airports. Thereby, they supervise airport operations and are responsible to maintain law and order (Ministerie van Defensie, 2019).

- *Airport owners*
  Airport owners are in charge of the airport and thereby make the airport's policy decisions. Historically, governments owned and managed airports. However, since the 1950s a trend appeared of moving towards a greater influence of the private sector. This could either be fully privatization or a Public-Private Partnership (PPP). The interests of the airport owner is dependent on whether it is privately or government-owned. Privatized ownership will result in the aim of maximizing profit in the short term. On the contrary, government-owned airports usually look beyond the short-term financial gains and aim for sustainable benefits for consumers. Within the PPP notion, various implementing forms are possible which could balance the conflicting interests (Deloitte and IATA, 2018). In the Netherlands, Royal Schiphol Group is the owner of and operator of all civil airports, except for Eindhoven Airport. Royal Schiphol Group does however own a majority (51 %) of the shares of Eindhoven Airport. Although Royal Schiphol Group is an independent and commercial company, it is owned by the Dutch state (70% of the shares), the municipality of Amsterdam (20%), the municipality of Rotterdam (2%) and the groupe Aéroports de Paris (ADP) (8%) (Royal Schiphol Group, 2020).

- *Airlines*
  Airlines operate from the airports and facilitate the air transport services. As stated in subsection 3.1, the main design criteria of an airport is the functionality. Among other things, this means complying to the requirements of the airlines. Hereby, one can think of gate preferences and presence on the airport (for airlines based on a certain airport). For airlines operating in the civil aviation industry, passengers and their experience are very important. Naturally, a lack of customers will lead to a lack of revenue. Therefore, enhancing the passenger experience throughout the air travel journey will benefit the airlines. Furthermore, the airline is responsible for the boarding process where airline staff checks the validity of the boarding card and whether the boarding card matches with the travel documentation.

- *Passengers*
  Passengers are the main users of the airport passenger terminal. Thereby, they will most definitely benefit from the current developments within the aviation industry. Although the increasing number of passengers leads to the current capacity constraining situation. All future developments aim to handle the growth in a sustainable manner and increase the passenger experience at the same time. The seamless flow concept could offer a situation in which passengers will no longer experience any congestion throughout their airport journey, except for security screening.

3.3.2 The playing field

In Figure 8 the identified stakeholders are placed in the so called power-interest grid. The power-interest grid is a tool to categorize system stakeholders based on their power and interest in certain system changes. As result, insights are retrieved on which stakeholders are key stakeholders and can thereby make or break a new project. This can help in stakeholder prioritization for the problem owner (Sharma, 2020).

Stakeholders placed top-right can be categorized as key stakeholders. Cooperation of these parties is necessary while they have power to shut down developments. Parties placed top-left needs to be satisfied while they do have power but their interest is relatively low. Stakeholders on the bottom-left require minimum effort while both their interest and power in the system's development is relatively low. Lastly, stakeholders placed bottom-right require to be informed while they do have a lot of interest in the system developments. However, on their own they do hardly have power to change the system (Enserink et al., 2010).

Within this study, the general aviation industry is considered and a case study is selected in order to be able to determine the feasibility, and quantify the results, of the new concept. Therefore, the power interest grid, as presented in Figure 8, is composed from a worldwide civil aviation point of view. Parties which are categorized as powerful within this view, do have a lot of power regarding decision making in the civil aviation industry. Furthermore, parties involved on a local (national) level do not have a lot of power in this system. In case of a more decentralized point of view, i.e. European or National, these parties will have more power in decision making processes. In Figure 8, the power-interest grid is presented. It must be noted that the placement of the stakeholders is determined by 'logical thinking' and thereby not based on any calculation.

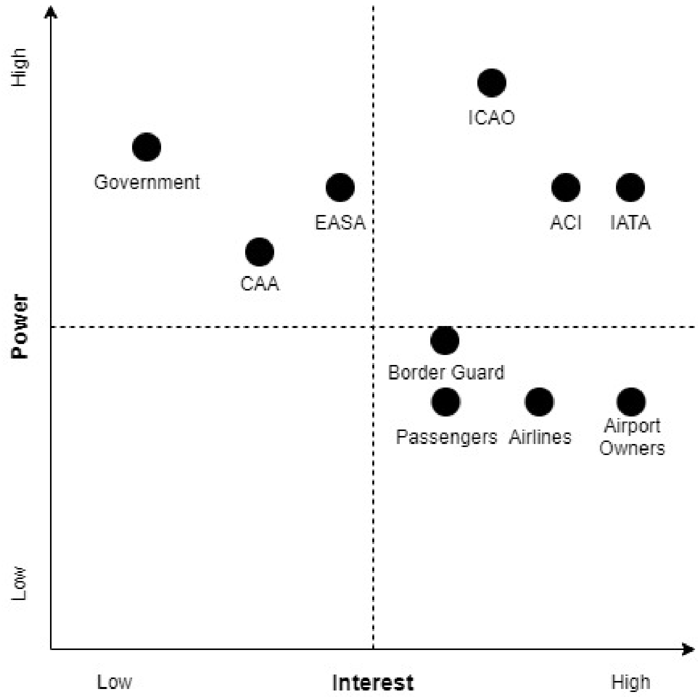

Figure 8: Power-Interest grid

When looking at the power-interest grid, one can see three key-players in this system; ICAO, ACI and IATA. This can be explained by the fact that this three parties are the representative authorities within the aviation industry. The most powerful authority is the ICAO. As earlier stated, the ICAO manages the international SARP's policies. In order to construct these SARP's, ICAO works with its member states and parties from the industry. Two major parties within the industry are ACI and IATA. These authorities represent the interests of all member airports and airlines. Thereby, the interests of the passengers are also accounted for indirectly. While the EASA and the CAA are safeguarding the compliance to the standards and recommendations on both European and National level, their interests in system developments is initially relatively low. When a certain policy decision is made, which has to be adopted in European or national Regulations, their interests will obviously increase. While the border guard is an agency of the member state's government, their interests are also represented.

Within the scope of this research, passengers, airlines and airport owners do not have a lot of power on their own. However, when their interests are bundled within authorities, such as ACI and IATA, their power increases significantly. Referring to the political economy framework by Feitelson and Salomon (2004), as described in subsection 2.2, this can be explained by the fact that decisions regarding implementation of an innovation are often made by existing institutions. Without the support of the interest groups within the industry, political feasibility will not be achieved. Consequently, adopting new system innovations such as the seamless flow concept, is dependent on the cooperation of these parties.

3.3.3 Conclusion

This subsection elaborated on the stakeholders concerning the airport passenger terminal system. Thereby, subquestion three is answered. After identifying the interests of each stakeholder separately, all stakeholders were placed in a power-interest grid in order to get a clear overview of the system's playing field. Within this playing field, three key players can be distinguished: ICAO, IATA and ACI. The other identified stakeholders do all have a strong relation with one of these key players. When looking with an regulation perspective, governments, EASA and CAA are all dependent on ICAO's SARP's. Furthermore, IATA and ACI are representing the interests of airlines airports and passengers. Thereby, the political feasibility, as described by Feitelson and Salomon (2004), is highly dependent on ICAO, IATA and ACI. Without the cooperation of those parties, new innovations in the civil aviation industry, and thereby the passenger terminal system, will not be adopted.

4 Rotterdam The Hague Airport: characteristics and requirements

Besides the general requirements applicable for all passenger terminals, each airport has its own operational and functional requirements and characteristics. This chapter elaborates on the case study airport: Rotterdam The Hague Airport. To start, a general introduction to the airport will be given in subsection 4.1. Thereafter, the traffic demand, including types of passengers and peak hours, will be analyzed in subsection 4.2. In subsection 4.4, the terminal facilities will be identified and the current terminal concept will be elaborated. Finally, this section will be concluded in subsection 4.5. Thereby, the requirements and KPI's for RTHA are identified which will answer sub-question five.

4.1 Introduction

Rotterdam The Hague Airport (RTHA) is a regional airport in the Netherlands, located between Rotterdam and The Hague. After construction in 1956, the airport was initially named 'Zestienhoven'. The airport contained one runway and was used to execute flights to southern England. In the end of the 1980s, the economic perspective of the airport became clear after which, in collaboration with Schiphol (owner since the 1990s), a new aviation strategy was constructed. Starting from the 1990s, RTHA should be specialized in business scheduled traffic whereby other business and holiday flights were also executed. This new strategy came with a new name: 'Rotterdam Airport' (Rotterdam The Hague Airport, 2020a).

As described by de Neufville (2008), both the liberation of the aviation market and the economic growth in the 1990s, resulted in an economic stimulus for the aviation industry. This was also applicable for Rotterdam Airport. The number flights grew and the airport became more popular under business and holiday travellers. In the year 2000, the annual number of processed passengers rose above the 750.000, which turned out to be an indication for the lasting yearly growth. This growth eventually lead to the internationally oriented new name: Rotterdam The Hague Airport (RTHA) (Rotterdam The Hague Airport, 2020a).

RTHA is owned and exploited by Royal Schiphol Group, which also owns Schiphol and Lelystad airport and is the biggest shareholder in Eindhoven Airport. In 2019, RTHA processed more than 2.1 million passengers to more than fifty (European) destinations. These numbers numbers make RTHA, after Schiphol and Eindhoven Airport, the third airport of the Netherlands (Rotterdam The Hague Airport, 2020d). Furthermore, the airport is responsible for more than 1800 full time jobs and offers great opportunities for (regional) business and connectivity (Rotterdam The Hague Airport, 2020d).

4.2 Traffic demand

In 2019, the annual passenger numbers rose to above 2 million passengers on RTHA. More than fifty percent of these flights are holiday oriented which leads to seasonality in traffic demand. For the year of 2019, this is graphically presented in Figure 9. In this figure, the traffic demand is defined in both the number of passengers (PAX) and the number of Air Traffic Movements (ATM).

Figure 9: Annual traffic pattern RTHA in 2019 (NACO, 2020)

As can be seen in Figure 9, the busiest period of the year is from may until October. This period can therefore be identified as the high season for RTHA. With a total of 269,000 passengers, August is the busiest month of the year for the airport (NACO, 2020).

On RTHA, the total number of passengers can be divided into two groups: Schengen and Non-Schengen passengers. As already mentioned in subsubsection 3.2.2, travellers between contracting Schengen countries do not need to pass border control processes. On the other hand, passengers travelling to Non-Schengen countries are required to pass emigration control. This situation is thereby similar to earlier described airports with domestic and international passengers.

4.2.1 Peak hour

In section 3.1.2, the importance of the aircraft types and peak hour in airport terminal design, more specific in facility sizing, was addressed. In 2020, NACO (2020) executed an passenger terminal capacity analysis on RTHA. Within this study, NACO was asked to study the future (2021) scenario in which Transavia, which is the major airline operating from RTHA, changed their current fleet to newer and bigger aircraft (B737-700 to B737-800). In this scenario, the flight schedule of 2019 is altered with a predicted increase of three flights per day. Subsequently, the additional number of passengers, as result of the bigger aircraft, are added afterwards (NACO, 2020).

With the help of the industries well known methods, such as: IATA's representative day and ICAO's designer passenger peak hour, the design peak hour on a representative day on RTHA is determined. The design peak hour is the 30th. busiest peak hour of a year. Taking this particular hour is recommended by ICAO in order to prevent for over-designing terminal facilities, as already mentioned in section 3.1.2 (NACO, 2020). In Figure 10, the number of passengers throughout the representative day is graphically represented.

Figure 10: Number of passengers on the representative day in 2021 (NACO, 2020)

As can be seen in Figure 10 the peak hour for both Schengen non-Schengen departing passengers starts at 7 AM. The peak hour measures the passenger peak in airside facilities. For landside facilities, such as check-in and security, an additional show-up pattern is used to determine the needed capacity. In Table 5, the design peak hour for both passenger groups and total passengers are provided. The methods used by NACO (2020) to compute these results are further elaborated in Appendix C.

Table 5: Design peak hour RTHA for 2021 scenario (NACO, 2020)

Departures	**PAX**	**Start Peak**	**End Peak**
Schengen	1050	07:01	08:00
Non-Schengen	374	07:01	08:00
Total	1424	07:01	08:00

When looking at Table 5 and Figure 10, one can notice that the design peak hour for both Schengen and Non-Schengen departing passengers, are set at the same time. Thereby, the general peak hour for RTHA is also from 07:01 AM until 08:00 AM. In this hour, 1424 passengers are present in the airside facilities. Thereby, the capacity requirements for RTHA's airside facilities have been identified. During the rest of the day, the number of departing passengers is significantly lower than in the peak hour.

4.3 Key Performance Indicators

The vision of RTHA is to facilitate the ultimate passenger experience while optimising all processes in terms of efficiency and sustainability (Rotterdam The Hague Airport, 2020c). In order to accomplish this vision, the airport wants to facilitate an environment to test new innovations or ideas for the aviation industry. At the end, RTHA envisions to be the pride of the region. This can be accomplished by identifying stakeholders, and corresponding interests, and actively involve them in decision making processes (Rotterdam The Hague Airport, 2020c).

In order to provide the ultimate passenger experience, the airport set standards to comply to. As already introduced in subsection 3.1, these standards are defined by IATA and presented in the Level of Service guidelines (subsection B.1). In Table 6, the key performance indicators of different airport facilities are presented for RTHA. These standards accord to the optimum Level of Service as defined by IATA and ACI (2019).

Table 6: Key Performance Indicators Rotterdam The Hague Airport (NACO, 2020)

Process	**Equipment**	**Waiting time (KPI)**
Check-in/Enrollment/ Baggage drop	Kiosk	3 min
	Check-in counter	20 min
	SSDOP	5 min
Security	Security lane	10 min
Border control	Counter	10 min
	E-gate	5 min

4.4 Terminal Facilities

RTHA has one terminal building which facilitates for both departing, Schengen and Non-schengen, and arrival processes. To accommodate the persistent passenger growth, the terminal needed some alterations. Starting in 2018, the terminal went through some rebuilding phases. Among other things, the BHS was moved to a new building outside the terminal and a new security section, called Central Security Filter (CSF), was constructed. In the autumn of 2020, the last phase, expanding the departure hall, will be finished (Rotterdam The Hague Airport, 2020e). Although RTHA is planning on further expansion of the terminal, this study will use the terminal configuration as planned to be completed in the end of 2020. This situation is presented in Figure 11. In Appendix C, a more detailed ground plan of the terminal is provided.

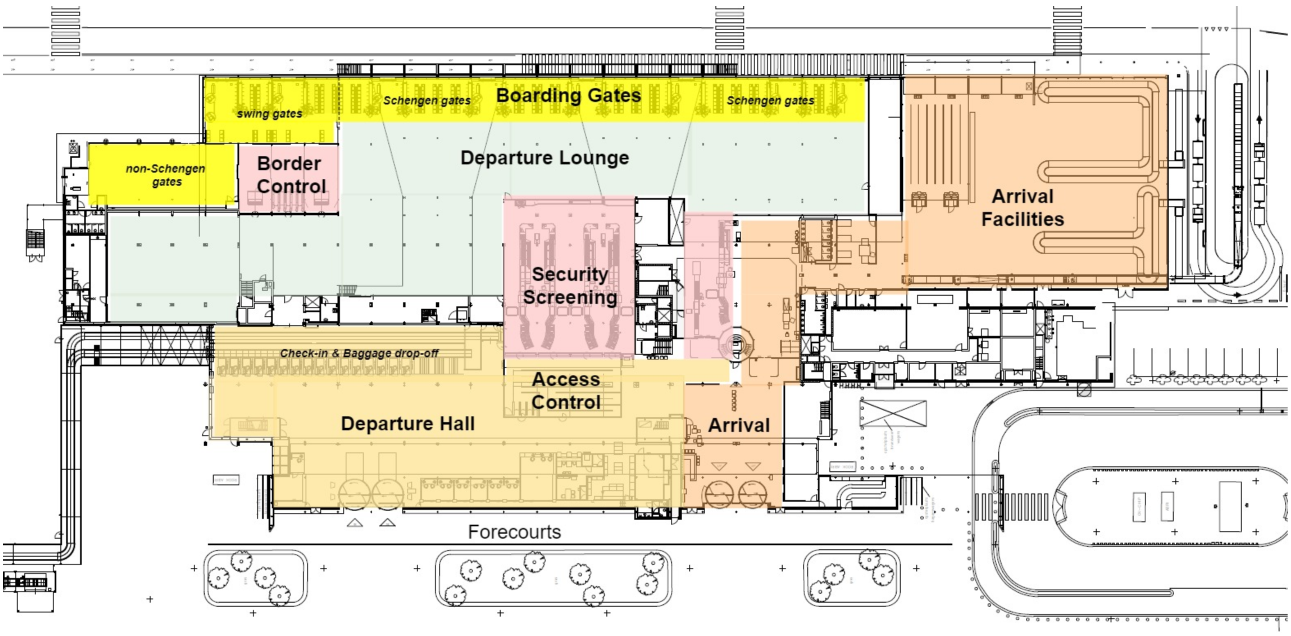

Figure 11: Layout RTHA (end of 2020)

As can be seen in Figure 11, the terminal of RTHA contains both departure and arrival facilities. When looking at the departure facilities, the terminal's departure hall provides both check-in and baggage drop-off points. The check-in facilities consist of sixteen conventional check-in counters and the baggage drop-off facility has six Self-Service baggage Drop-Off Points (SSDOP). Central in the terminal, one can see the CSF. This control section forms the security screening and features four security lanes applicable for all passengers. Furthermore, a separate control section is created for 'specials', such as airport/airline crew and groups. The departure lounge is one open area that consists eleven gates, from which: 6 Schengen gates, 3 non-Schengen gates and 2 swing gates (as introduced in section 3.1.2). The non-Schengen gates can be accessed via the border control section which is also situated in the departure lounge. This border control section features 4 manual control counters and 5 E-gates(NACO, 2020).

4.4.1 Terminal concept

In Figure 12, the passenger terminal concept of RTHA, for both Schengen and non-Schengen passengers, is graphically presented. What stands out is that the border control, applicable for non-Schengen passengers, is decentralized and placed just before the boarding gates. Thereby, both passenger groups are mixed in the departure lounge and only separated just before boarding the aircraft.

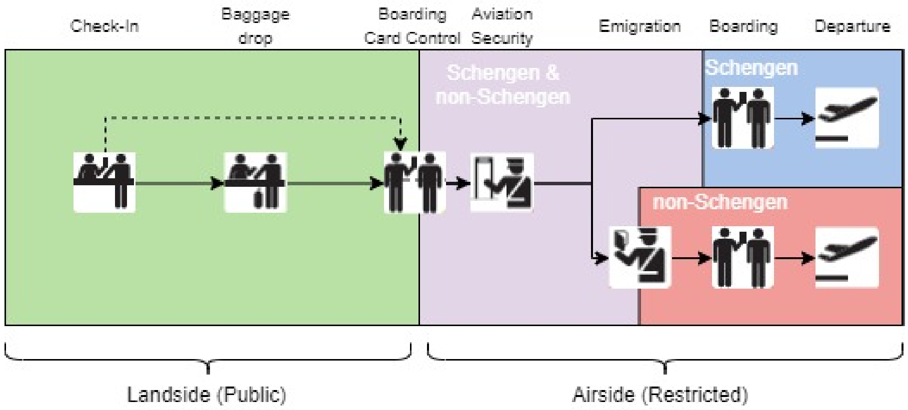

Figure 12: Terminal Concept RTHA

4.5 Conclusion

In this section, Rotterdam The Hague Airport (RTHA) and it's facilities are elaborated. Thereby, sub-question five is answered.

The persistent growth in the aviation industry also concerns RTHA. In 2019, RTHA handled over 2.1 million passengers. While more than fifty percents of all flights are holiday oriented, the passenger demand for RTHA encounters seasonality. The period from May until October, can be marked as the high season. Within this period, the design peak hour can be determined. For both Schengen and non-Schengen, the peak hour is between 07:01 and 08:00 AM. In this period a total of 1,424 passengers, of which 1050 Schengen and 374 non Schengen passengers, are present in the terminal's airside facilities.

RTHA envisions to facilitate the ultimate passenger experience, thereby an optimum Level of Service, as described by IATA and ACI (2019), is required. The exact requirements to comply to this LoS can be derived from Figure 18 (Appendix B) and are presented in Table 6 as KPI's. Furthermore, the airport wants to facilitate a testing ground for new innovations or ideas in the aviation industry.

5 The seamless flow concept

In the previous chapters, the current terminal system and corresponding environment is explored. Hereby, the system's requirements and the requirements of the case study airport, RTHA, have been identified. This section focuses on the new seamless flow concept in general. After exploring the seamless flow system and technologies, two new seamless flow concepts will be constructed and assessed on the compliance to the in section 3 identified design- and legal requirements. Subsequently the concepts will be conceptually implemented on the case study airport. Lastly, the findings of this chapter will be concluded in a conclusion.

5.1 Seamless flow principle

This section elaborates on the seamless flow principle. First, the seamless flow innovation will be explained. Thereafter, the technology used within the seamless flow system will be identified.

5.1.1 Seamless flow

The seamless flow term stands for a seamless end-to-end passenger experience through the airport passenger terminal. The concept envisions to offer passengers a frictionless journey through the airport terminal. By using biometric recognition technology, seamless flow brings simplification in the terminal processes while the technology only needs to recognise and verify a person by its biometrics in order to retrieve the required information. Thereby, passengers will no longer need to present their physical travel documents at any touchpoint within the airport terminal. This will result in process efficiencies in almost every step in the passenger journey through the airport (IATA, 2018b).

Within the seamless flow principle, coordination between the individual stakeholders within the passenger terminal system is required. Consequently, a single travel token can be generated for each passenger which complies to the requirements of each individual stakeholder and can therefore be used at the different touchpoints throughout the terminal. The seamless flow principle would thereby allow physical touchpoints to be combined, removed or placed outside the airport. As a result, passengers will spend less time at airport touchpoints which will lead to a decrease in, or even disappearance of, waiting time in non-security screening facilities within the passenger terminal (IATA, 2018b). Furthermore, seamless flow would benefit stakeholders acting in the civil aviation industry. The reduction in time spent on physical touchpoints will lead to staffing efficiencies and thereby an increase in capacity (LAM-LHA, 2019). Hereby, one could think of baggage drop-off and boarding processes which could be either self-service or automated. Staffing efficiencies are also applicable for border guards. As the primary inspection will be automated, only special cases need to be treated by the agents (IATA, 2018b).

As already introduced in subsection 1.2, IATA's vision on the seamless flow concept is called: One ID. This concept represents their envisioned end-to-end seamless passenger journey in the year of 2035. Thereby, no additional steps or processes are added to the existing passenger concept. In the One ID concept, passenger terminal stakeholders interact with each other towards a unified, and passenger-centric, system. The majority of the passengers, will be able to maintain walking their walking pace while moving through the system's processes and using their biometrics as access 'token'. Furthermore, passenger identity data is captured and verified as early in the process as possible (after booking the ticket). This will allow control agencies to enhance the security screening. At the airport, hold baggage will be linked to the passenger identity which will also enhance the airport security (IATA, 2018c).

5.1.2 Technology

With One ID, IATA envisoned their key principles of the seamless passenger journey for the year of 2035. However, they did not provide prescriptions of the technology that should be used and how it should be deployed. This section will provide an indication of the functions of (current) technologies that could be used in a seamless flow concept (not per definition the end state as described in subsection 5.1). In order to do so, an interview is conducted with the tech company SITA. In addition, a desk-research is performed.

The seamless flow concept is build on various technologies and equipment among which a comprehensive service platform used by airports, airlines and border authorities (Meleiro, 2016). Through collaboration between the multiple stakeholders, the platform makes required information available for every stakeholder within the system. According to IATA, such a platform is conceived according to the privacy by design principle. This principle ensures that each stakeholder has access to the passenger data they 'need-to-know' and are 'authorized-to-know' (IATA, 2018c). Based on biometric transactions of the passenger with the system, passenger data can be virtually stored on this platform (Meleiro, 2016). Besides passenger information such as travel documentation and boarding passes, this database could contain other information, such as: passenger location, delays, position in the airport process. Thereby, the platform forms the connection between the hardware (Physical equipment) and the stakeholders.

Besides the platform, physical equipment is required which can identify the passenger by its biometrics. The preferred biometric benchmark is the facial biometrics. The main reason for this is that it is easy to deploy and implement. Moreover, no physical interaction with the equipment is necessary and the verification process is relatively fast (Thales, 2020). As a result, technology companies SITA and Vision-Box both chose to deploy the facial biometrics technology on airports. Thereby, they provide systems which use a camera and facial recognition software in order to identify passengers at the various touchpoints (Vision-Box, 2020) (SITA, 2018). In facial recognition software, various algorithms can be used. Hereby, one could think of a technique which converts the facial image into one dimensional vectors (PCA and LDA). Furthermore, a non-linear analysis such as the EBGM, which places small blocks of numbers over small areas of the image, can be used (Introna & Nissenbaum, 2010). In terms of implementation of the hardware, either integration with the current equipment (SITA, 2018) or detached equipment is possible (Vision-Box, 2020). According to a product manager of SITA, integration with the current equipment will significantly mitigate the costs compared to a complete new implementation.

The biometric facial recognition technology in combination with the service platform, will automate the entire passenger journey. Passengers can enroll into the system on their phone, at an assisted or self-service kiosk. In the enrollment process, the facial biometrics of each passenger will be linked to their boarding pass and travel documentation. This link and corresponding data will be stored on a database on the platform. Subsequently, at baggage drop, access control, border control and boarding, the passenger is identified and the required data is retrieved from the platform by the concerned party.

5.2 Seamless flow concepts

Now that seamless flow and the corresponding technology is elaborated, new seamless flow concepts can be constructed. In this section, both the current terminal concept equipped with seamless flow technology, later referred to as the base case, and new seamless flow concepts will be introduced. While the objective of this research is to determine whether the seamless flow technology could lead to a new and feasible terminal concept, two new seamless flow concepts are constructed and assessed on their feasibility. The two concepts are constructed in collaboration with NACO specialists. As mentioned in subsection 1.5, both concepts will mix international and domestic passengers in the terminal's (airside) facilities. In order to explore the passenger terminal system from different angles and create a comprehensive view on the feasibility of new concepts, one relatively familiar seamless flow concept was constructed and one out of the box seamless flow concept was constructed.

In the first concept, 'Merged Airside', the airside facilities for domestic and international passengers are merged into one by (re)moving the border control process. Although this concept uses the opportunities brought by the new technology, it does not entirely change the conventional terminal concept at the same time. Thereby, it is expected that most of the identified airport passenger terminal requirements are complied to. Assessing the merged airside concept on the different feasibility determinants will give insights in the effectiveness and ease of changing terminal concepts to complement new technological innovation.
In the second concept,'Public terminal', a significantly different and more out of the box concept is constructed which fully utilises the functions of the new technology. In this concept, a by NACO often envisioned futuristic public terminal concept is defined in which the whole terminal, except for the boarding gates processes, is publicly accessible. Due to the significant amount of differences with the base case, this concept is expected to be infeasible. Nevertheless, it is interesting to study what factors determine whether a certain terminal concept is feasible or infeasible. Studying the public terminal concept will thereby lead to a more complete overview of the passenger terminal system. In the following sections, the different seamless flow terminal concepts will be elaborated.

5.2.1 Current concept equipped with seamless flow technology: Base case

In subsection 1.5, the current or 'conventional' passenger terminal concept was presented. In the base case of this research, this concept is equipped with seamless flow technology. Thereby, this concept is similar to IATA's

One ID concept, as graphically presented in Figure 2. In Figure 13, the current concept equipped with seamless flow technology (base case) is graphically presented.

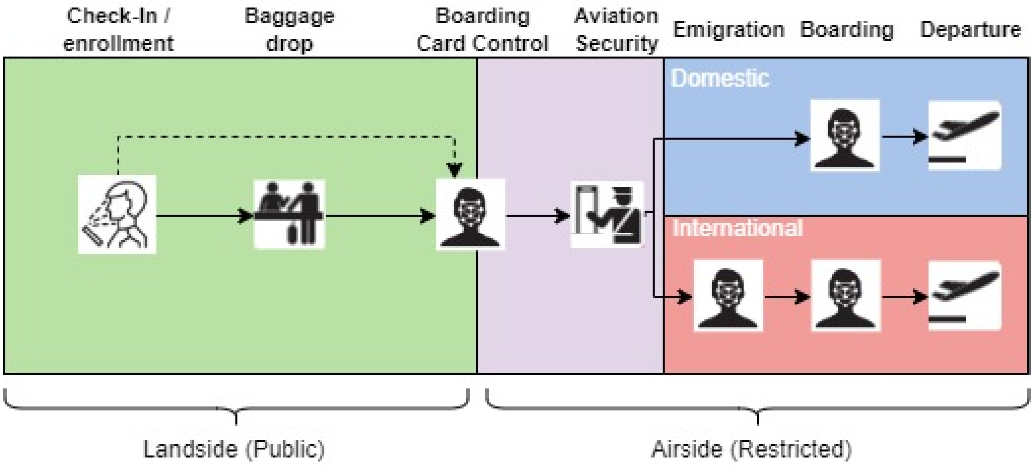

Figure 13: Current terminal concept equipped with seamless flow technology

When looking at the passenger journey, the first step for the passenger is the check-in and enrollment process. Within this process, passengers will link their facial biometrics to their boarding pass and travel documentation. This can either be done online or at the airport (at an assisted or self-service kiosk). Right after completing the enrollment process, the border guard agency could potentially start the emigration screening process remotely. Subsequently, the passenger proceeds (when applicable) to the baggage drop process. Here, their hold baggage will be retrieved and also be linked to the passenger's biometric profile. After the baggage drop-off, the passenger will continue it's journey to the access control touchpoint where their facial biometric will be used by the system to retrieve the boarding pass information. Subsequently, passengers go through aviation security and international passengers will pass the biometric border control. Finally, facial biometrics will be used at the boarding process.

Application

As can be seen in Figure 13, each conventional touchpoint is equipped with biometric technology in this concept. Besides this alteration, the current concept does not change. The implementation of the biometric technolgy will thereby not change the application of terminal area's and facilities. The international and domestic gate distribution, including potential swing gates, will remain the same. Furthermore, international and domestic passengers will be separated after border control.

5.2.2 Seamless flow concept 1: Merged Airside

In Figure 14, the first seamless flow concept 'Merged Airside' is presented. One can notice that this concept has a lot of similarities with the traditional concept equipped with seamless flow technology as shown in Figure 13. Besides the change in mixing the domestic and international passengers in airside facilities, the physically separated emigration touchpoint is removed. Instead, the emigration process is integrated in the access control touchpoint or executed remotely.

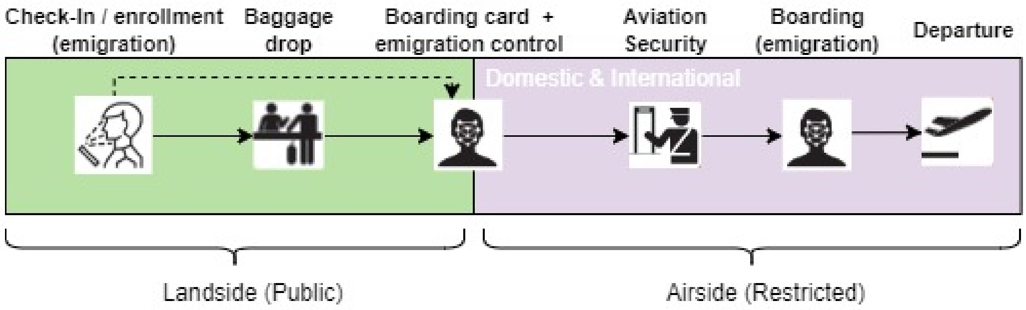

Figure 14: Merged airside concept

When looking at the passenger journey within this concept, the journey starts with the enrollment process where the passenger checks in. Similar to the base case, passengers will link their facial biometrics to their boarding pass and travel documentation (at the airport or online). Right after completing the enrollment process, the border guard agency could potentially start the emigration screening process remotely. The passenger continues its way to the baggage drop process (when applicable) where their hold baggage will be linked to the biometric profile. Subsequently, the passenger will move to the next control touchpoint. At this touchpoint, their facial biometric will be used by the system to retrieve the boarding pass and travel documentation, which will be checked. Subsequently, they go through aviation security. Finally, their facial biometrics will be used at the boarding process.

Application

As earlier mentioned, this concept is not very different from the current terminal concept. The main difference is the disappearance of the physical emigration touchpoint. Instead, the border control touchpoint will be integrated with the access control touchpoint. Another possibility is to remotely execute the emigration process. Consequently, the border guard agency can pick-out any suspicious passenger at any touchpoint where the passenger is identified, i.e. baggage drop, boarding card control and boarding.
As a result of the altered border control, international and domestic passengers do not have to be separated in airside facilities. Furthermore, all gates could be used for both international and domestic passengers. Prior to boarding, the passenger's boarding pass and travel documentation will again be checked on whether they are set to border the right aircraft and whether they are allowed to leave the country by the boarding agency (when applicable).

5.2.3 Seamless flow concept 2: Public terminal

The second seamless flow concept 'Public terminal' is presented in Figure 15. This concepts fully utilises the technological functions and is thereby more simplistic in comparison to the merged airside concept. In this concept, domestic and international passengers are mixed until boarding where all control checks are integrated into one single touchpoint and security screening is placed.

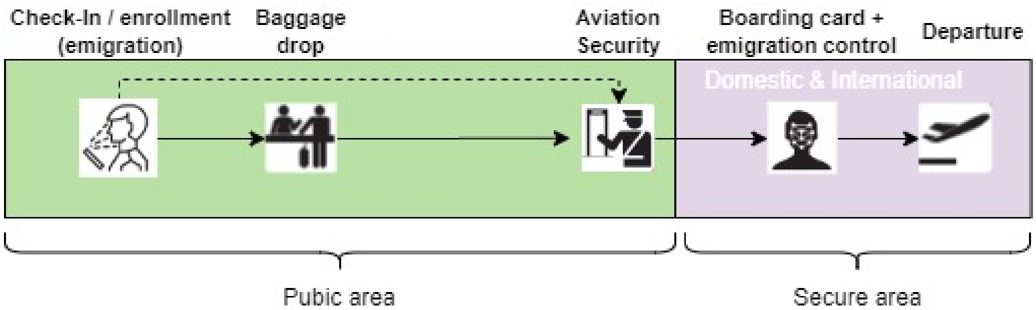

Figure 15: Public terminal concept

In this concept, the passenger journey starts the same as the journey in merged airside concept. First, the passenger enrolls itself into the system either online or at the airport. After completing the enrollment, the border guard agency could start the screening process remotely. Subsequently, they drop-off their baggage, which will be linked to their biometric profile. Right before boarding the aircraft, the passenger will move through aviation security in order to enter the so called 'secure area'. Thereafter, the passenger's boarding card and travel documentation will be checked at the boarding touchpoint.

Application

This concept is very simplistic and would thereby allow for a quite different implementation in comparison to the current terminal concept. Similar to the merged airside concept, the border guard agency could start it's screening process right after the enrollment. Subsequently, they can pick-out a suspicious passenger anywhere in the airport journey. The border control process could also be integrated at the boarding touchpoint. While the aviation security touchpoint is not placed after a boarding card control touchpoint, this concept would allow for an open space airport in which well-wishers are allowed until the boarding touchpoint. Thereby, well-wishers could accompany the passenger until the boarding process and could thereby also make-use of the airport's commercial facilities. At the boarding process, the passenger's boarding card and travel documentation is checked to make sure it is boarding the right aircraft and it is allowed to travel to another country.

5.2.4 Compliance to design- and legal requirements

In Table 7, the passenger terminal design and legal requirements, as identified in section 3, have been enumerated. Furthermore, the current concept equipped with the seamless flow technology and the two newly constructed concepts are evaluated on the compliance to the identified requirements. Thereby a '+' sign (green) represents the compliance to a requirement and the '-' sign (red) a violation. If the compliance to the requirement is dependent on the application of the concept, it is valuated as '+/-' (yellow). The grey coloured blocks, as can be seen in design requirement 5, can not be generally assessed due to the airport specific character. The consequences of requirement violations on the feasibility will be elaborated in section 6 (political feasibility).

Table 7: Compliance to design and legal requirements (identified in section 3)

Requirements	#	**Description**	**Current with new technology**	**Merged airside concept**	**Public terminal concept**
Design requirements	1	Facilities: Forecourts, Departure hall, Access control, Security screening, Border control, Departure lounge and Boarding gates	+	+	+/-
	2	Ability to prevent unauthorized persons to access the secured area's	+	+	-
	3	Passengers entering secured area's should be security screened	+	+	+
	4	Departure lounge: commercial offerings, lounge(s) and boarding gate(s)	+	+	+
	5	Facility size should comply to the LoS standards, set by the airport			
	6	After border control, domestic and international passengers flows should be physically separated	+	+/-	+
Legal requirements	1	Airside and landside must be clearly distinguished	+	+	+/-
	2	Airside and landside must be physically separated by a control section	+	+	+/-
	3	Passengers and baggage must be screened prior to boarding	+	+	+
	4	When unauthorized interference occurs, rescreening is mandatory	+	+	+
	5	Piece of baggage may only be transported when linked to passenger	+	+	+
	6	Airports may not require to passengers to share travel documentation data before arrival at the control point at the airport	+	+/-	+/-
	7	All airport equipment and authorities must be certified	+	+	+

Note: + means compliance to the requirement ; +/- means compliance under particular circumstances; - means violation of the requirement

The main difference between the constructed seamless flow concepts and the current concept equipped with the seamless flow technology is that domestic and international passengers are mixed in all terminal facilities until boarding. As can be seen in Table 7, One of the design requirements (design requirement 6), is that domestic and international passenger flows need to be physically separated after border control. However, when looking at the legal requirements it is stated that when unauthorized interference occurs, re-screening is mandatory. In both the merged airside concept and the public terminal concept, the system has the ability to re-screen or re-check passengers at the boarding process. Consequently, it does not make a difference if the emigration process is integrated another touchpoint or is executed remotely while it is automatically rechecked at the boarding touchpoint.

The current airport regulations, specific legal requirement 6, won't let airports require passengers to share travel documentation data before arriving at the border control touchpoint on the airport. This implies that the border control process must be physically available, integrated in a touchpoint, to comply to current legislation. Consequently, the earlier described passenger identity screening (border control process) on remote is not fully implementable yet.

As described in subsection 5.2, the public terminal concept would allow for well-wishers to accompany passengers until the boarding touchpoint. As a result, the airport does not contain an access control touchpoint and can not prevent unauthorized persons from accessing the secure area's. Moreover, one can notice the use of public area and secure area instead of landside and airside. On one hand, one could say that in the public terminal concept the clear line between airside and landside is faded or even vanished. On the other hand, according to ICAO (2017a) only air travel passengers, in possession of a valid boarding card, are allowed in airside facilities. Thereby, airside could be seen as the space between the boarding touchpoint and the aircraft. In the latter case, airside and landside are physically separated by a control section. Lastly, it is assumed that the technology used in both constructed concepts will be certified prior to implementation.

5.3 Conceptual implementation on RTHA

In this section, the in subsection 5.2 constructed seamless flow concepts will be conceptually implemented on the case study airport: Rotterdam The Hague Airport. As mentioned in subsection 1.5, the concepts are conceptually implemented in order to be able to strengthen the findings and quantify the results. Later, in subsection 6.4, the results of this section will be used to determine the economic feasibility of the new seamless flow concepts.

5.3.1 Conventional concept equipped with seamless flow technology: Base case

In this section the base case concept, as presented in Figure 14, will be conceptually implemented on RTHA. In Table 8, an overview of the current equipment and the equipment required for implementing the seamless flow technology on the current processes. In order to provide the optimum service level, as described in subsection 4.3, the desired processing times for the various touchpoint are retrieved from the capacity study of NACO (2020). As a result, the sufficient number of equipment for each touchpoint is determined. More information on the calculations can be found in Appendix D.

Table 8: Current concept equipped with seamless flow technology compared to current concept (NACO, 2020)

Process	**Current terminal concept**			**Current concept equipped with seamless flow technology**		
	Equipment	***Processing time (seconds)***	***Number***	***Equipment***	***Processing time (seconds)***	***Number***
Check-in/Enrollment / Baggage drop	Kiosk	60	0	Kiosk	60	0
	Counter	90	16	Counter	90	16
	SSDOP	73	5	SSDOP	60	5
Access control	Automatic gate	6	4	Biometric gate	3	2
Security	Security lane	22.5	6	Security lane	22.5	6
Border control	Counter/E-gate	30	4/5	Biometric gate	10	2
Boarding	Area	N/A	11	Biometric gate	3	11

As can be seen in Table 8, the introduction of the seamless flow technology will lead to a reduction in the number of equipment at two touchpoints: Access control and border control. This reduction can be explained by the lower processing times of the biometric gates in comparison to the conventional processes. As a result, less equipment is required in order to comply to the set KPI's (subsection 4.3). Furthermore, one can notice the introduction of a 'new' equipment at the boarding gates. In the seamless flow concept, each boarding gate is equipped with a biometric gate.

5.3.2 Seamless flow concepts on RTHA

In this section, the two new seamless flow concepts are conceptually implemented on Rotterdam The Hague Airport (RTHA). First, two implementation scenario's are introduced. Thereafter, both constructed seamless flow concepts will be conceptually implemented and the required number of equipment will be determined.

Scenario's

In order to increase the external validity of this research, different airport scenario's will be assessed. Thereby, the results of this study can be translated to other airports more easily. As can be seen in section 4, the peak hours for both Schengen and non-Schengen flights are between 7:01 and and 8:00 in the morning. However, as already addressed in subsection 1.5, the peak-hours of the different flight types often differentiate on airports. Consequently, two scenario's will be constructed: Peak hours at the same time and different peak hours.

Table 9: Flight scheme representative day 2021 (NACO, 2020)

Flight	Schedule time	Airline	Alliance	Domestic status	PAX	Aircraft	Gate
1	7:01	TRANSAVIA	LCC	Schengen	185	B737W8	A10
2	7:08	TRANSAVIA	LCC	Non-Schengen	175	B737W8	A4
3	7:12	TRANSAVIA	LCC	Schengen	178	B737W8	A8
4	7:14	BA	One World	Non-Schengen	37	ERJ190	A3
5	7:28	TRANSAVIA	LCC	Schengen	169	B737W8	A6
6	7:28	TRANSAVIA	LCC	Schengen	169	B737W8	A9
7	7:35	TRANSAVIA	LCC	Non-Schengen	162	B737W8	A2
8	7:37	TRANSAVIA	LCC	Schengen	164	B737W8	A7
9	7:41	TUIFLY	LCC	Schengen	186	B737W8	A5
10	8:02	TRANSAVIA	LCC	Schengen	175	B737W8	A10
11	8:44	TRANSAVIA	LCC	Non-Schengen	176	B737W8	A4

In Table 9, the departure flight scheme of the peak hour on a representative day in 2021 is presented. When looking at the flight scheme as presented above, one can conclude that the peak hour (between 7:01 and 8:00) contains 6 Schengen and 3 non-Schengen flights. As can be seen in Table 9, a flight can be appointed to a gate if the schedule time is at least 1 hour later than the schedule time of the previous flight on that gate. During the rest of the day the total number of executed flights within an hour is limited to 3 (NACO, 2020)(Appendix D). As result of these characteristics two scenario's are constructed: simultaneous peak hours and different peak hours.

Table 10: Design peak hour scenario's

Departures in peak hour	**Scenario 1: Simultaneous peak hours**		**Scenario 2: Different peak hours**			
			Peak Schengen		**Peak non-schengen**	
	Flights	***PAX***	***Flights***	***PAX***	***Flights***	***PAX***
Schengen	6	1,050	6	1,050	1	188
Non-Schengen	3	374	1	185	3	374
Total	9	1,424	7	1,235	4	562

As can be seen in Table 10, two different scenario are constructed. The simultaneous peak hours scenario is the forecasted peak hour as presented in section 4. The different peak hours scenario assumes that the Schengen and non-Schengen peak will not be in the same moment. As a result, 1 (non-) Schengen flight will be executed during the peak hour of the other type. The number of passengers for that one (non-) Schengen flight are determined by the largest passenger count for that type of flight on the representative day.

Merged Airside Concept

In the merged airside concept, the border control touchpoint is integrated in the access control touchpoint. As result, the physical border control touchpoint will disappear out of the departure lounge. While every gate is equipped with a biometric gate, which is able to check for both boarding card and travel documentation, all gates can be used for both Schengen and non-Schengen flights. In Figure 16, the conceptual implementation of the merged airside concept on RTHA is presented for the simultaneous peak hours scenario.

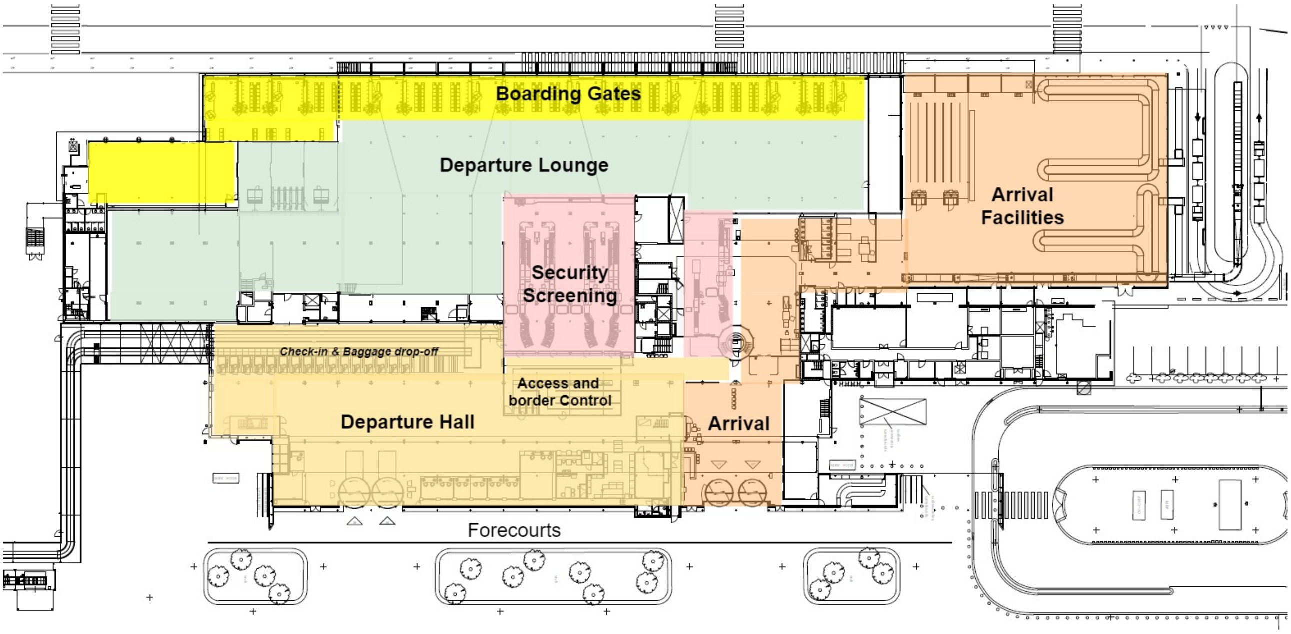

Figure 16: Conceptual layout RTHA merged airside concept (simultaneous peak hours)

As can be seen in Table 10, in scenario 2 the peak hours for Schengen and Non-schengen flights are different. Together with the fact that gates are no longer dedicated to one type of passenger only, this could result in the reduction in the number of gates. In comparison to the merged airside concept, the total number of flights within the peak hour is limited to seven. Thereby, two gates can be removed and their spatial footprint can be used for other purposes. A potential conceptual layout of the merged airside concept in the second scenario can be found in Appendix D

In Table 11, an overview of the equipment required to implement the merged airside concept, for both the simultaneous peak hours scenario and the different peak hours scenario, is presented. Similar to the conceptual implementation in subsubsection 5.3.1, the key performance indicators of the capacity study by NACO (2020) are used in order to determine the number of equipment (subsection 4.3).

Table 11: the merged airside concept: equipment

Process	**Simultaneous peak hours**			**Different peak hours**		
	Equipment	***Processing time (seconds)***	***Number***	***Equipment***	***Processing time (seconds)***	***Number***
Check-in/ Enrollment/ Baggage drop	Counter	90	16	Counter	90	16
	SSDOP	60	5	SSDOP	60	5
Access control/ Border control	Biometric gate	4.8	2	Biometric gate	4.0 (Schengen peak) 7.7 (non-Schengen peak)	2
Security	Security lane	22.5	6	Security lane	22.5	6
Boarding	Biometric gate	3	11	Biometric gate	3	9

When looking at Table 11, one can notice that the two scenario's are not very different in terms of equipment numbers. While the second scenario will allow the airport to use a lower number of gates, the number of biometric gates at the boarding touchpoint will naturally decrease proportionally. Furthermore, the calculations used to determine the quantities of Table 11 can be found in Appendix D.

Public terminal concept

In the public terminal concept all touchpoints within the passenger journey throughout the airport are placed at the boarding gates. Besides the security screening touchpoint, one biometric boarding touchpoint is present which is able to execute both access and border control processes. As result, the public area will reach until the gate. In Figure 17, the layout of the public terminal concept is conceptually implemented on RTHA for the first scenario (Table 10).

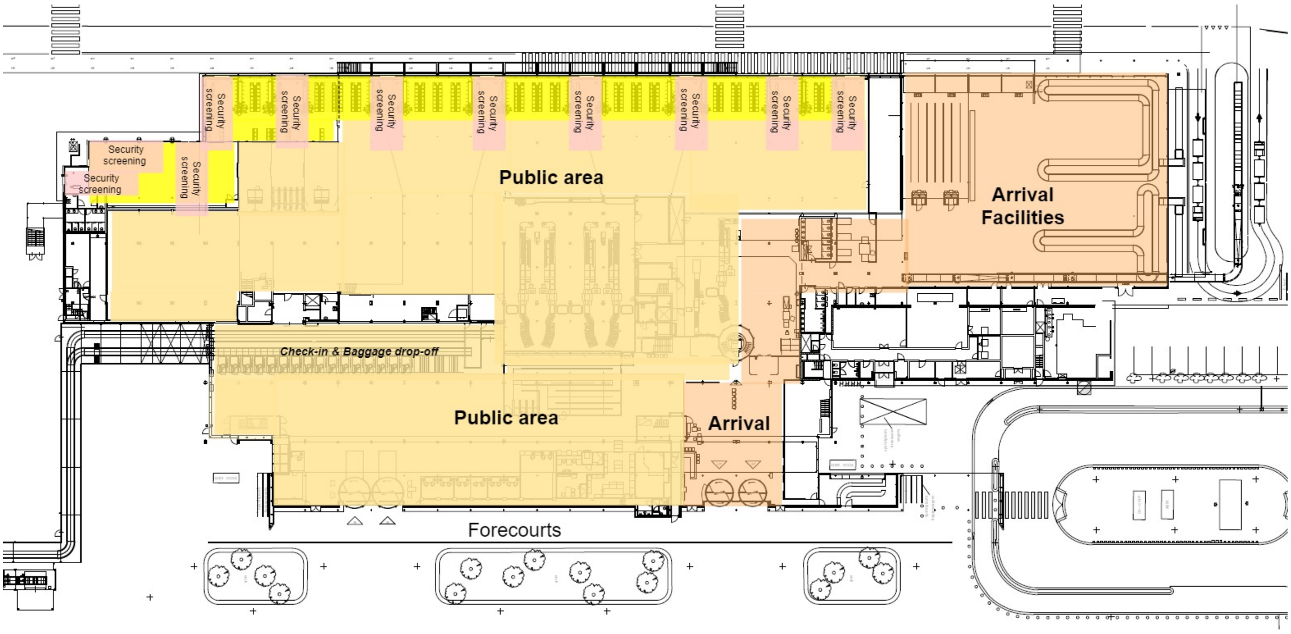

Figure 17: Conceptual layout RTHA public terminal concept (simultaneous peak hours)

In Table 12 an overview of the required equipment in the public terminal concept is presented. Hereby one can notice the significant increase in the number of security lanes. As earlier mentioned, each gate contains it's own security lane(s). Due to the high costs of such a lane (further elaborated in subsection 6.4) the airport will try to minimize the required number of lanes. The security specialist of NACO, mentioned the introduction of pre-boarding in order to minimize the number of security lanes (Appendix F). This pre-boarding includes doubling the boarding time from 20 minutes (as in the merged airside concept) to 40 minutes in order to distribute the passengers over time. Consequently, only two security lanes are required per gate.

Similar to the merged airside concept, the number of gates can be reduced by two in the second scenario. By using NACO (2020) KPI's for Rotterdam The Hague Airport (subsection 4.3), the required number of seamless flow equipment is determined for both scenario's. In Table 12 an overview of the equipment in both scenario is provided. Specific calculations and reasoning behind assumptions can be found in Appendix D.

Table 12: Public terminal concept: equipment

Process	**Simultaneous peak hours**			**Different peak hours**		
	Equipment	***Processing time (seconds)***	***Number***	***Equipment***	***Processing time (seconds)***	***Number***
Check-in/Enrollment/ Baggage drop	Counter	90	16	Counter	90	16
	SSDOP	60	5	SSDOP	60	5
Access control	Biometric gate	N/A	0	Biometric gate	N/A	0
Security	Security lane	22.5	22	Security lane	22.5	18
Boarding/ Border control	Biometric gate	3 (Schengen) 10 (non-Schengen)	11	Biometric gate	3 (Schengen) 10 (non-Schengen	9

Similar to the merged airside concept, the number of equipment in the public terminal concept does not differ a lot between the two scenario's. While the different peak hours scenario allows the airport to abolish two gates, the number of required equipment at the gates decrease proportionally. This correspondents with a decrease of four security lanes and a decrease of two biometric gates.

5.4 Conclusion

In this chapter the seamless flow principle and the technology to accomplish such a system is elaborated. Furthermore, two new airport terminal concepts, as result of the seamless flow technology, have been constructed and conceptually implemented on the case study airport: Rotterdam The Hague Airport. Thereby, this chapter answers sub-question six and seven.

The seamless flow technology consists of physical equipment that contains a camera and software that can identify passengers by their facial biometrics. All physical equipment is connected through a service platform which contains a database where passenger data is stored. This service platform is accessible by the various stakeholders responsible for airport processes to retrieve the need-to-know passenger information.

As result of this technology, two new seamless flow concepts are constructed: 'Merged airside' and 'Public terminal'. In the merged airside concept, the physical border control section is removed and the border control process is either integrated at the access control touchpoint or executed remotely. As a result, international and domestic passengers will be mixed in airside facilities.
In the public terminal concept, the passenger terminal will become a large public area and all the required checks will be executed at the boarding gates. As result, passengers and their well-wishers are mixed until the boarding gates.

When conceptually implementing the seamless flow concepts, a reduction in the number of required biometric gates can be seen while the border control touchpoint is removed. Moreover, each boarding gate can be used for both international and domestic flights. As a result, different peak hours for international and domestic flights would amplify this reduction while boarding gates can be abolished. In terms of security lanes, the public terminal concept does however require more equipment than the base case concept.

6 Feasibility assessment

In this section, the feasibility of the in subsection 5.2 constructed seamless flow concepts will be determined in comparison to the base case concept. Subsequently, various success and failure factors will be identified and validated.
As described in subsection 2.2, feasibility contains four determinants, namely: economic, technical, social and political (Feitelson & Salomon, 2004). In this study, the technical social and political determinants are qualitatively determined while the economic feasibility determinant is quantitatively determined. As a result, the economic feasibility is analyzed in a different way than the other determinants.

6.1 Technical feasibility

According to Feitelson and Salomon (2004), an innovation is technical feasible when it works and complies to the technical requirements. In this research, the focus will thereby be on whether the technology, as described in subsubsection 5.1.2, is able to execute the desired functionalities to make the concepts out of subsection 5.2 possible in real life.

Starting with the in subsubsection 5.1.2 described technology. This technology is currently available and even already implemented on various airports, either in pilots or operational on small scale. Thereby, the current concept equipped with seamless flow technology (Base case concept), as presented in Figure 13, could from technological perspective already be implemented on airports. This is also confirmed by the aviation security advisor of Schiphol Airport (Appendix F).
When looking at the different processes in the base case concept, one can see that the seamless flow technology is able to execute both the boarding card control and the border control process. At both touchpoints, the same technology is used to acquire the required passenger information and subsequently verifying the validity. Moreover, both checks are executed simultaneously at boarding touchpoint where they are integrated into one touchpoint. Looking at both the merged airside concept and the public terminal concept, the border control process is integrated in another touchpoint in the terminal (either at the access control or boarding). As seen at the base case concept, such a multidisciplinary touchpoint is technically feasible. This is also confirmed by the interviewees of Schiphol airport, RTHA and SITA (Appendix F). Both the merged airside concept and the public terminal concept use such a multidisciplinary touchpoint. While the base case concept is confirmed to be technological feasible and the two new concepts do not require more technological functions or contain new elements, it can be stated that both concepts are technically feasible in comparison to the base case.

However, based on the interviews with various stakeholders and specialists it was made clear that the technology, in general, is not completely reliable yet. Although SITA (2018) claims to accomplish a matching percentage of 99% (SITA, 2020) and facial recognition based Automatic Border Control (ABC) gates are recommended by ICAO and already used on various airports across the world, the technology is lacking on other disciplines. The operational manager of RTHA (subsection F.3) stated that the availability of the data system and IT infrastructure (service platform) is not reliable enough. Consequently, the new system not always as seamless as imagined. A trial with a similar biometric border control system at Auckland Airport can confirm this. Throughout this live trial, almost 31% of all occasions included major interaction errors and slightly more than 1% of the occasions were wrongfully accepted (Robertson, Guest, Elliott, & O'Connor, 2016). Moreover, the complete reliance on technology will bring additional challenges to the terminal system. Equipment or power outages requires the airport to think about a back-up system in which the operations can be maintained on an acceptable service level. The concerned parties must agree on a certain level of redundancy which must be integrated into the system design (IATA & ACI, 2019). Nevertheless, in comparison to the base case both the new seamless flow terminal concepts do not require more functionalities of the technology and are not less reliable. Thereby, they can both be seen as technical feasible.

Besides the technological side of the system, the innovation must also work in terms of system performance. In the merged airside concept, the physical border control section is removed. While the border control touchpoint was situated right before the entrance of the departure lounge, the disappearance will not affect the passenger arrival pattern of other touchpoints. It is therefore expected that the removal of the physical border control touchpoint will not result in a higher passenger load for other touchpoints. Instead, passengers will spend slightly more time in the departure lounge. Consequently, the terminal system handles the same number of passengers with less equipment. Moreover, the accumulated waiting time for passengers will decrease.
In the public terminal concept, all terminal processes are decentralized to the boarding gates. Thereby, the passenger load is distributed over a larger number of equipment. As a result, the system will be less vulnerable for system malfunctions which increases the overall performance. Furthermore, due to the reduction in number

of touchpoints and the passenger distribution, the accumulated waiting time for passengers will also decrease in this concept.
The positive impact on the airport performance was also indicated by the interviewees from both RTHA and Schiphol Airport. Thereby, both constructed concepts can be seen as technical feasible.

6.2 Social feasibility

Social feasibility looks at the acceptability of the public, which in the aviation industry correspondents with the passengers. According to Feitelson and Salomon (2004), social feasibility is determined by the perception of the passenger in terms of the problem and the effectiveness of the innovation in solving the problem. Furthermore, these perceptions can be influenced by experiences, researches and media attention.

As mentioned in section 1, the passenger journey has become more complicated, congested and thereby more unpleasant (Harrison et al., 2012). This resulted in poor airport evaluations by passengers. Among other things, the reasons for such poor evaluations are incompetence of airport staff and the long waiting times(Bogicevic, Bujisic, Bilgihan, Yang, & Cobanoglu, 2017). Self-service airport technologies have been proven to be effective to enhance the passenger experience while it reduces the waiting times and avoids contact with the airport staff. Bogicevic et al. (2017) researched the relation between passenger oriented technology within the airport, such as self-service processes, and the overall satisfaction about the airport. They concluded that the self-service technologies have a positive impact on the satisfaction of the passenger while the waiting time is lower, the passenger is more relaxed and experiences a more pleasant airport stay. The passenger experience throughout the airport is thereby enhanced (Bogicevic et al., 2017).
The seamless flow concept is an example of such a passenger oriented self-service technology. Furthermore, it gives passengers the choice to use the fully self-service technology or seek assistance by an assisted kiosk. Moreover, it reduces the waiting time and could even lead to less touchpoints throughout the airport journey which gives the passenger less stress. Consequently, the seamless flow innovation will be perceived by the passengers as an effective measure for their perceived congestion problem on the airport. This would indicate that the seamless flow innovation is socially feasible.

The statement that the seamless flow innovation is socially feasible, can be backed by findings in other research, interviews and statistics. According to NACO's airport planner, the seamless flow pilot at Sydney Airport really showed how passengers wanted the seamless system. This observation is confirmed by the statistics of SITA which present an opt-in rate of 90% of all passengers which could participate in their smart path solution (seamless flow)(SITA, 2020). Furthermore, Negri, Borille, and Falcão (2019) analysed the probability of passengers using biometric technology for check-in procedures. It was concluded that almost 83% of the passengers would use the biometric technology for the check-in process.

Furthermore, the passengers are required to share more personal information in the seamless flow journey than that they are used to in the conventional air travel journey. Naturally, the concern is growing over whether this information is treated in a decent manner and is not abused in a way which violates the individual right of anonymity (Prabhakar, Pankanti, & Jain, 2003). In other words, privacy and data sharing concerns will grow among passengers as result of the implementation of biometric technology. The concerns about the abuse of biometric information can be addressed by legislation (by governments and the public), self-regulation of the biometric vendors or autonomous enforcement by an independent regulatory organization (Prabhakar et al., 2003). According to IATA, the privacy by design principle is an effective manner to safeguard the passenger's privacy (IATA, 2018b). This can be seen as a form of self-regulation on top of the applicable privacy legislation. In this study, it is assumed that the industry will develop a suitable system which safeguards the privacy of passengers. As a result, the privacy concerns will not influence the social feasibility within this research.

Considering, the constructed seamless flow concepts in subsection 5.2, one can conclude that the merged airside concept and the public terminal concept are both socially feasible in comparison to the current concept equipped with the seamless flow technology (Base case). While the seamless flow technology would on it's own already enhance the passenger experience, less touchpoints throughout the journey will further amplify this enhancement. The merged airside would thereby offer a better experience for international passengers while the border control process is integrated with the access control touchpoint, or even executed on remote. When looking at the public terminal concept, both international and domestic passengers will perceive the benefits of less touchpoints throughout their journey. Besides that, passengers could spend almost all the dwell time on the airport together with their well wishers. This could enhance the experience even more. In terms of the discussed privacy concerns, the both seamless flow concepts do not differ from the base case. Thereby, both constructed concepts can be seen as socially feasible in comparison to the base case.

6.3 Political feasibility

An innovation can be seen as politically feasible if it is supported by a wide coalition of parties with specific interests (Feitelson & Salomon, 2004). Thereby, it is determined by the stakeholders within the passenger terminal system, such as: passengers, parties within industry and interest groups (Figure 6). Consequently, the stakeholder analysis of subsection 3.3 will be used to determine whether the seamless flow concepts complies to the interests of the stakeholders.
As result of the theory of Wang et al. (2002), elaborated in subsection 2.1, the constructed concepts were composed without considering the design- and legal requirements of the system. In Table 7, the compliance of both seamless flow concepts to these requirements is presented. The violation of a requirement could influence the political feasibility while it is assumed that either regulation or requirements must be changed in order to make the concept feasible. This can either be done by the government or designated authorities within the industry and often requires the support of other stakeholders within the system.

Assuming the seamless flow technology is technical feasible and is certified to be used at airports, the implementation of the seamless flow technology on the current passenger processes will not violate current passenger terminal regulations. Naturally, the design requirements of the passenger terminal will not be violated as well while the terminal design does not change. Considering the interests of various stakeholders within the passenger terminal system, one can state that the adoption of the new technology conforms the interests of the stakeholders. The key-players within the system, ICAO, ACI and IATA, all have the objective to either enhance the passenger experience or optimizing and upgrading airport infrastructure and performance. While the seamless flow concept is an innovation which can lead to both, these parties are already working on seamless flow solutions; i.e. IATA's One ID (IATA, 2018c).
Besides the key-players, other stakeholders such as the airlines and border guard agencies are also pleased with the new seamless flow innovation. The majority of the digitisation initiatives by airport ground handlers are focused on operational improvements and driven by cost pressures (Kovynyov & Mikut, 2019). The passenger-centric seamless flow innovation contributes to this cost reductions while boarder guards and airlines could save on staff which usually execute the processes at the touchpoints. Furthermore, it benefits the passengers through time savings and enhanced service quality (Kovynyov & Mikut, 2019). The latter is an important factor for the airport owners. The operations director of RTHA stated that the enhancing the net-promoter score, which indicates the passenger satisfaction and the quality of the passenger experience, is the holy grail for airports (Appendix F). Furthermore the statement that the seamless flow concept conforms the interests of all stakeholders is also backed by the senior airport planner of NACO. In her recent experience with a seamless flow trial at Sydney Airport, she did not perceive any negative attitude from the concerned parties (Appendix F). The aviation security advisor of Schiphol Airport indicated that the seamless flow initiatives on Schiphol airport are a result of the collaboration between the airport and all partners. These partners include all 'local' stakeholders including the government agencies and authorities, which makes it a public-private partnership (Appendix F). Thereby, the willingness of the aviation industry to participate on the seamless flow innovation is showed.

In Table 7, the constructed seamless flow concepts, merged airside and public terminal, are evaluated on the compliance to the identified design- and legal requirements in section 3. One of the legal requirements is that airports may not require passengers to share travel documentation data before arrival at the control point at the airport. As introduced in subsection 5.2, both concepts would allow for the border control process to be executed on remote. Thereby, passengers are required to share their travel documentation right after enrollment. Consequently, in order to fully implement this remote border control, the regulation regarding data-sharing must be altered. Considering, the recent movements in privacy concerns and regulation it is assumed that changing the regulation of sharing personal data will be a capricious process. As a result, a hybrid version can be constructed in which passengers who do not share their travel documentation with the airport prior to arriving at the control point at the airport, will not perceive fast processing times while the on the spot border control check requires more time.

When looking deeper into the border control process, one can notice that the physical border control touchpoint is removed in both constructed seamless flow concepts. In current airport processes, such as on RTHA, the border control process contains two lines. The first line represents the travel documentation check performed by the border guard agency. When a passenger does not comply to the set standards for leaving the country, the passengers is handed over to the second line agent whom will handle the situation. In the merged airside concept, the border control process is integrated into the access control touchpoint which is situated earlier in the terminal concept. As a result, the border guard agency will have plenty of time to handle possible risky or illegal passengers. This will even be increased when the border control process could be executed on remote.
In the public terminal concept, the border control process will be integrated with the boarding touchpoint.

Consequently, the border control check will be executed right before boarding the aircraft which will give the border guard agency a short amount of time to handle risky or illegal passengers. The latter could lead to rushed situations, in which the border guard agent does not have the sufficient amount of time to clear a passenger before aircraft departure. Based on the interview with RTHA and the performed desk research on the Dutch border guard agency, this situation goes against the principles of the border guard agency. Furthermore, the airlines and passengers would also not benefit from such a situation while a flight could be missed or delayed. Consequently, one can state that the public terminal concept is only politically feasible if the border control process is executed in remote. As earlier mentioned, the remote border control process can only be fully implemented if the data sharing regulation (legal requirement 6) will be altered. The latter is expected to be a capricious process.

Moreover, the public terminal concept contains decentralized passenger screening facilities. The security screening process will thereby take place directly prior to entering the boarding area. Advantages of this arrangement can be that the overall traffic per checkpoint is reduced. Moreover, airport-wide screening operations will not be stopped by an emergency situation at one checkpoint and the border guard authority could more easily adapt specific measures for each flight (IATA & ACI, 2019). Thereby, decentralized security screening facilities will bring more flexibility to the terminal system which could benefit the concerned stakeholders. However, various disadvantages could also be addressed. Hereby one could think of the need for more overall manpower and extensive movement through the airport of the staff which executes the screening. Besides that, private passenger search will become more complicated while temporary facilities need to be provided or passengers must be moved to dedicated facilities somewhere in the terminal (IATA & ACI, 2019). While decentralized security screening facilities come with both advantages and disadvantages, it is assumed that the concerned parties will not see this as an issue which significantly influences the feasibility of both concepts.

In comparison to the base case and the merged airside concept, the public terminal concept violates design- and legal requirements. In order to comply to the identified requirements the landside and airside must be clearly distinguished (legal requirement 1). Furthermore, the ICAO's requirement to be able to prevent unauthorized persons to access the secured area's must be removed or altered(design requirement 2). It is however unlikely that the border guard agency will support such a change in design requirements. As described in subsection 5.2, the public terminal concept contains a large public area which does not contain any mean to perform any type of access control. Besides that, passengers will only be screened at the boarding gates. When more people, among which passengers and well-wishers, are allowed to enter a significant larger part of the airport terminal, the task of the border guard agency will become more complicated. Consequently, it will become harder to control the crowd and thereby to safeguard the airport security and maintain law and order within the airport terminal.
As described in subsection 3.3, the border guard is a government's agency. Thereby, new legal regulations will be conform their interests. Besides that, ICAO collaborates with the member states while constructing the SARP's. Consequently, the border guard agency has a lot of indirect power within the passenger terminal system which make it unlikely that earlier mentioned requirements will be removed or altered without their support. In the interviews with both Schiphol and RTHA, this influential power of the border guard agency was confirmed. According to the interviewees, the border guard agency is involved in the early stages of decision making of seamless flow initiatives due to their executive role. Thereby, one can conclude that the public terminal concept violates a significant amount of requirements and does not have the required support to change these. Consequently, the public terminal concept is politically infeasible in comparison to the current concept equipped with the seamless flow technology.

6.4 Economic feasibility

In this section, the economic feasibility of the in subsection 5.2 introduced seamless flow concepts will be determined. According to Feitelson and Salomon (2004), an innovation is economically feasible if it could pass a rudimentary Cost-Benefit Analysis (CBA). As a result, this feasibility determinant is determined quantitatively which requires a different approach than used for the other feasibility determinants.
In a CBA, every consequence of a new alternative is quantified in monetary value (Boardman et al., 2017). As introduced in subsection 1.5, this study contains a financial CBA from the airport's perspective. Thereby, societal consequences are not considered. Consequently, the CBA can be seen as a financial business case.
While the goal of this research is to find out whether the new technology could lead to new and feasible terminal concepts, the economic feasibility will be assessed comparatively to the current passenger terminal concept equipped with seamless flow (base case). In this section, each type of consequence will first be elaborated and monetized after which the CBA is constructed for both seamless flow concepts.

6.4.1 Consequences

In order to construct a Cost-Benefit Analysis, first the consequences need to be addressed and monetized. In this study, two types of consequences will be distinguished: Equipment and Spatial footprint. Both consequences contain various items which can either lead to costs or benefits.

Equipment

Equipment comes at a price. Those costs can be categorized in two distinctive costs: Purchasing costs (CAPEX) and maintenance costs (OPEX). In this study both biometric gates and security lanes differ between the seamless flow concepts and the base case. Consequently, the costs of these type of equipment must be determined.

Information about the costs of a biometric gate is relatively scarce. Due to the current high interests in such systems, various parties were not willing to share this commercially sensitive information. In the interview with the consultant of a renowned access product manufacturer, the price range of 15,000 to 20,000 euro's was given. In consultation with the aviation security consultant, it was chosen to assume the purchasing costs of 20000 euro per gate. It must be noted that the true costs of a biometric airport system are not reflected by the costs of a single gate. The costs of an integral biometric airport system will thereby be significantly higher than the accumulated costs of all gates within the system.
Besides the purchasing costs, the consultant of the renowned manufacturer provided a range of the annual maintenance costs of such equipment: between 2,000 and 2,700 euro's. Consequently, in consultation with the aviation security consultant of NACO the maintenance costs are set to 2,350 euro's per gate per year.

The costs of a security lane are retrieved from the interviews with the aviation security consultant of NACO. For the security lane, there is a variety of possibilities in equipment. Hereby, one can think of a 'simple' metal detector or a full body scanner. Considering, the set standard on Schiphol Airport it is assumed that Rotterdam The Hague Airport will also choose for the state of the art aviation security equipment. This includes a CT scanner for baggage and a full body scanner for passengers. In combination with a conveyor belt, the total costs of a security lane will approximately be 700,000 euros. Furthermore, the maintenance costs per lane are estimated on 1,500 euros per lane.

Spatial footprint

From the previous sections it can be concluded that both the constructed seamless flow concepts are different from the current concept equipped with seamless flow technology in four processes, namely: Access control, security screening, border control and boarding. At these process, either equipment or an area is removed or added. In Table 13 a general overview of the spatial footprint of both the equipment and the area's are presented.

Table 13: Spatial footprint area's and equipment on RTHA (NACO, 2020)

Area	Item	Spatial footprint
Access control	Biometric gate	3 m2
Security screening	Waiting area	129 m2
	Lane supervising area	36.5 m2
	Security lane (central)	115 m2
	Security lane (at gate)	75 m2
Border control	Waiting area	104 m2
	Control counter	2.1 m2
	E-gate	4 m2
	Flow area	114.5 m2
Boarding gate	Biometric gate	3 m2
	Gate area	21 m2
	Boarding area	30 m2

Spatial benefits are determined by the spatial usage of equipment and the spatial usage of terminal area's. Thereby, the removal of an entire touchpoint (such as border control) and single piece of equipment can both accounted for. In terms of the removal of two gates (in the different peak hours scenario), the gate area and the boarding area are both considered as spatial benefits. As can be seen in Figure 23, the waiting area for the swing- and non-Schengen gates is significantly smaller than that of the Schengen Gates. Consequently, this

area will not be considered as a spatial benefit when a gate is removed while this area will be used to make the waiting area for the other gates fully-fledged.
When a touchpoint is removed, both the spatial footprint and corresponding area's are considered. For the border control this correspondents with the waiting area and flow area's (as can bee seen in Figure 23). For the security screening this correspondents with the waiting area and the lane supervising area (Figure 23).

Together with the number of equipment required in each seamless flow concept, which is already determined in subsubsection 5.3.2, the spatial consequences can be determined for each concept. In the capacity study of NACO (2020), it was concluded that the composition which is labeled as current terminal concept within this study is sufficient to offer the desired optimum Level of Service (LoS) to the passenger. However, the by RTHA desired amount of ground surface for commercial activities is not achieved. Consequently, spatial benefits in this study will be used for commercial activities. However, spatial benefits do come with reconstruction costs in order to use the spare terminal space for commercial purposes. Furthermore, the loss of space will result in a lower LoS and needs to be compensated in order to maintain the optimum LoS. Thereby, the terminal spatial footprint must be enlarged if the new concept turns out to take up more terminal space.

Considering spatial loss, it is assumed that the loss needs to be compensated by enlarging the terminal. According to Statista.com (2020), the average costs per square meter for building an airport terminal is between 2285 and 3950 British Pounds. When taking the mean of this price range, it is assumed that the enlargements costs are 3500 euros per square meter. This estimation is confirmed by the NACO financial specialist as an realistic benchmark assumption for an ordinary terminal enlargement.
When looking at spatial savings, the cleared up space must be rearranged in order to be able to use it for other purposes. Together with NACO experts it is determined that the rearrangement costs for the terminal space is 40% of the terminal enlargement costs, this correspondents with 1400 euros per square meter. When the space is used for a commercial store or stand the rearrangement costs increase to 50% of the terminal enlargement price; 1750 euros per square meter. Furthermore, it is assumed that only half of the spatial savings (50%) could effectively be used for commercial activities.

According to IATA (2018b), airports could perceive an increase in non-aeronautical revenues as result of the seamless flow concept. The combination of passengers being more relaxed and spending more time on airside facilities will lead to this increase. It was stated that a 1% increase in passenger satisfaction will result in a 1.5% increase in non-aeronautical revenues (IATA, 2018b).
In order to quantify the benefits of a commercial store or stand, a benchmark for the income per per square meter is used. The conducted interviews made clear that their are different models for airports to generate income out of commercial activities. Usually airports will give concessions to parties to exploit their commercial business in the airport terminal. Subsequently, the airport will retrieve a compensation in the form of rent or a percentage of the revenue. Thereby, retail and F&B enterprises usually pay a percentage of their revenue to the airport. While the spatial benefits occur within the main terminal areas, it is assumed that it will be used for retail and F&B businesses. The financial specialist at NACO, provided an estimated benchmark which would be representative for such a shop on Rotterdam The Hague Airport. Such a business could generate 10 to 15 thousand USD per square meter annually. When considering the mean and convert this number to euro's, this will correspondent with approximately 11,000 euro per year. On this sales, a concession margin of 20% is paid to the airport. As a result, the non-aeronautical revenue for the airport can be estimated on 2200 euro per square meter per year.

6.4.2 Cost-Benefit Analysis

Now that the different potential consequences are monetized, it can be checked whether the costs and benefits of a new seamless flow concept balance out in comparison to the current terminal concept equipped with seamless flow technology. By executing a financial Cost-Benefit Analysis (CBA), this check can be done from the airport's perspective. First, the structure of the CBA will be elaborated after which both seamless flow concept will be evaluated.

Structure

Before determining the costs and benefits of a certain innovation, one first needs to determine the time horizon over which the costs and benefits will be estimated. The time horizon is determined by the economic lifespan of the corresponding innovation. In the interview with the renowned gate manufacturer it was stated that from technical perspective the gates will have the same lifespan as the building in which it is placed. However, in reality the economic lifespan is often shorter than the technical lifespan (MkBA-Informatie.nl, 2015b). While seamless flow is still in its early stages, in terms of development and implementation, a time horizon of five years is assumed in this study. Although this is relatively short, it will give a clear view on the potential of the different seamless flow concepts.

In this study, all investments are made at the start of the studied period: year 0. These contain the investments in biometric gates, security lanes, terminal space and construction costs. Besides the investments in year 0, other consequences are experienced annually. These contain the Non-Aeronautical revenues which are generated out of new commercial activities and maintenance costs which can either reduced or increased in comparison to the current concept equipped with seamless flow airport.
For the annual returning costs and benefits, a so called discount rate is used. With the discount rate, future costs and benefits will be calculated back to the base year (year 0). The reason for this is the preference for one euro today over one euro next year. Therefore, future cost and benefits decrease in value (MkBA-Informatie.nl, 2015a). Based on guidance for other, similar, aviation industry projects a discount rate of 7% is adopted (Atkins International, 2018). Underneath, each contributing cost or benefit item within this study's CBA is elaborated.

- **Investment biometric gates:** This item is a typical example of a 'Year 0' CAPEX investment item and the quantity is determined by the number of biometric gates used in the whole terminal system. The difference in number of equipment between the current terminal concept equipped with seamless flow technology and the seamless flow concept is multiplied by the costs for 'one' biometric gate.
- **Terminal enlargement:** Spatial enlargement represents the spatial loss as result of implementing one of the seamless flow concepts. As discussed in subsection 6.4, the spatial loss needs to be compensated in order to maintain the envisioned optimum LoS. Thereby, the amount of additional space required by the seamless flow concepts for the processes is multiplied by the costs of enlarging the terminal per square meter. This item is included as a 'year 0' investment.
- **Non-aeronautical:** The non-aeronautical item represents the spatial benefits of a new concept. As stated in subsection 6.4, spatial benefits will be used to exploit commercial activities. Effectively, fifty percent of the spatial benefits can be used for commercial activities. This part is multiplied by the profit benchmark per square meter, provided by the NACO expert, and could be seen as annually returning profit.
- **Maintenance:** The maintenance item represents the maintenance costs for both biometric gates and security lanes. This item can be categorized as OPEX and is included annually. The difference in number of equipment, compared to the base case, is simply multiplied by the corresponding annual maintenance costs. Consequently, the two costs factors are added up to define the total maintenance costs of the seamless flow concept in comparison to the conventional concept equipped.
- **Construction costs:** Constructing costs represent the costs for re-arranging the internal terminal space. In this item, the distinction is made between two re-arrangements: conversion to terminal floor and conversion to commercial activity. Consequently, half of the spatial re-arrangements is multiplied with the costs for the rearrangement into 'regular' terminal floor and the other half is multiplied by the costs for rearranging the space into a commercial area. This item is included as a 'year 0' investment.
  Note that this item does not consider the spatial benefits but the space that requires re-arrangement. Thereby, spatial loss could also lead to re-arrangement costs if the terminal layout changes.
- **Investment in security lanes:** Similar to the investment in biometric gates, the investment in security lanes is also a 'year 0' investment which can be categorized as CAPEX. This number can be calculated by multiplying the difference in equipment numbers between the base case and the seamless flow concept by the costs per security lane. Note, that the existent security lanes can be re-used although currently located elsewhere in the terminal.

Seamless flow concept 1: Merged airside

In this section, the costs and benefits of the merged airside concepts are determined for Rotterdam The Hague Airport. In Table 14, the comparison between the base case and the merged airside concept is presented. The figures in this summarizing table are retrieved from Table 8, Table 11 and Table 13. Furthermore, the conceptual implementation is visually presented in Figure 14.

Table 14: Comparison between the base case and the merged airside concept on RTHA

Process	Current concept equipped with seamless flow technology			Merged Airside Concept					
				Simultaneous peak hours			Different peak hours		
	Equipment	***Number***	***m2***	***Equipment***	***Number***	***m2***	***Equipment***	***Number***	***m2***
Check-in	Counter	16	144	Counter	16	144	Counter	16	144
	SSDOP	5	35.5	SSDOP	5	35.5	SSDOP	5	35.5
Access	Biometric Gate	2	6	Biometric gate	2	6	Biometric gate	2	6
Security	Security lane	6	855.5	Security lane	6	855.5	Security lane	6	855.5
Border	Biometric gate	2	226.6	N/A	0	0	N/A	0	0
Boarding	Biometric gate	11	33	Biometric gate	11	33	Biometric gate	9	27
	Area	11	528	Area	11	528	Area	9	432

Together with the earlier monetized consequences, the costs and benefits of the merged airside concept on Rotterdam The Hague Airport can be determined. In Table 15, an overview of the costs and benefits is presented for the first scenario (as described in subsubsection 5.3.2). In this overview, positive quantities represent the benefits of the concept in comparison to the current concept equipped with seamless flow technology and negative quantities represents the costs.

Table 15: Overview of the costs and benefits of merged airside concept for the simultaneous peak hours scenario on RTHA

Year	**0**	**1**	**2**	**3**	**4**	**5**	**Total**	**Total**
Discount rate	**1.00**	**0.93**	**0.86**	**0.80**	**0.75**	**0.70**	**Costs**	**Benefits**
Investement Biometric gates	40,000	0	0	0	0	0	0	40,000
Terminal enlargement	0	0	0	0	0	0	0	0
Non-Aeronautical	0	231,811.80	215,584.97	200,494.03	186,459.44	173,407.28	0	1,007,757.53
Maintenance	0	4,371.00	4,065.03	3,780.48	3,515.84	3,269.74	0	19,002.09
Construction costs	-356,895.00	0	0	0	0	0	356,895.00	0
Investment Security lanes	0	0	0	0	0	0	0	0
Total							356,895.00	1,066,759.61

As can be seen, this combination of concept and scenario does not need extra investments in either terminal enlargement or extra security lanes in comparison to the current concept equipped with seamless flow technology. Instead, one could see that spatial benefits could be used for commercial activities. After the almost 360,000 euro investment in reconstructing the spare space, which is retrieved from the removed border control section, commercial profits will increase to approximately 230,000 euro per year.
Moreover, one can notice that the merged airside concept saves 40,000 euro's on biometric gates, while the number of required gates decrease by two (as elaborated in subsubsection 5.3.2). Subsequently, the annual maintenance costs will also decrease proportionally.

When looking at the second scenario, as presented in Table 16, one can notice that the costs and benefits seen at the first seamless flow scenario are amplified. As earlier described in subsubsection 5.3.2, the number of gates can be reduced while gates are no longer dedicated to either Schengen or non-Schengen flights. As result of the removal of two gates, the number of required biometric gates decreases proportional. Consequently, the maintenance costs will decrease even more compared to the current concept equipped with the seamless flow technology.
The removal of two gates will also bring additional spatial benefits. Initially, this results in more construction costs. However, in the future this will generate more profit as result of the increased amount of commercial activities within the airport terminal.

Table 16: Overview of the costs and benefits of the merged airside concept for the different peak hours scenario on RTHA

Year	**0**	**1**	**2**	**3**	**4**	**5**	**Total**	**Total**
Discount rate	**1.00**	**0.93**	**0.86**	**0.80**	**0.75**	**0.70**	**Costs**	**Benefits**
Investment Biometric gates	80,000	0	0	0	0	0	0	80,000
Terminal enlargement	0	0	0	0	0	0	0	0
Non-Aeronautical	0	336,157.80	312,626.75	290,742.88	270,390.88	251,463.52	0	1,461,381.83
Maintenance	0	8,742.00	8,130.06	7,560.96	7,031.69	6,539.47	0	38,004.18
Construction costs	-433,545.00	0	0	0	0	0	433,545.00	0
Investment Security lanes	0	0	0	0	0	0	0	0
Total							433,545.00	1,579,386.01

Table 15 and Table 16 both show that the merged airside concept will have more benefits than costs. Within a CBA it can often be seen that over time benefits will rise to or rise above the initial investments costs. In this study, this return on investment is not a clear criterion while two similar concepts, using the same technology, are compared. Thereby, initial system investments are equal for both concepts, causing a concept which barely requires investments or even perceives negative investments. However, a conclusion can be made on whether the costs and benefit of the new concept, in comparison to the base case concept, balance. In Table 17 an integral overview of the merged airside concept is provided.

Table 17: Overview costs and benefits merged airside concept

	Merged airside concept	
	Simultaneous peak hours	***Different peak hours***
Total costs	356,895	433,545
Total benefits	1,066,760	1,579,386
Net Present Value (NPV)	709,865	1,145,841
Benefit-cost ratio	2.99	3.64

When looking at Table 17, it can be concluded that the merged airside concept is beneficial in both scenario's. Thereby, the concept is economic feasible in comparison to the current passenger terminal concept equipped with seamless flow technology. In both scenario's the benefits significantly outweigh the costs. However, the above presented Net Present Value and Benefit-cost ratio can not be seen as valuable quantities while each additional year would add more value to the concept and would consequently lead to an increase in the benefit-cost ratio.

In addition to these findings, one can observe that non-aeronautical benefits do have the most significant influence on the total cost-benefit balance. Differentiating the sales per square meter benchmark, as earlier defined, does however not lead to different conclusions in terms of the feasibility of this concept. In Appendix E the detailed sensitivity analysis can be found.

Seamless flow concept 2: Public terminal

The cost and benefits are also determined for Rotterdam The Hague Airport. In Table 18, the base case and the public terminal concept are compared for both peak hours scenario's. The figures in this summarizing table are retrieved from Table 8, Table 12 and Table 13.

Table 18: Comparison between the base case and the public terminal concept on RTHA

Process	**Current concept equipped with seamless flow technology**			**Public Terminal Concept**					
				Simultaneous peak hours			**Different peak hours**		
	Equipment	***Number***	***m2***	***Equipment***	***Number***	***m2***	***Equipment***	***Number***	***m2***
Check-in	Counter	16	144	Counter	16	144	Counter	16	144
	SSDOP	5	35.5	SSDOP	5	35.5	SSDOP	5	35.5
Access	Biometric Gate	2	6	N/A	0	0	N/A	0	0
Security	Security lane	6	855.5	Security lane	22	1650	Security lane	18	1350
Border	Biometric gate	2	226.6	N/A	0	0	N/A	0	0
Boarding	Biometric gate	11	33	Biometric gate	11	33	Biometric gate	9	27
	Area	11	528	Area	11	528	Area	9	432

Similar to the merged airside concept, the costs and benefits of the public terminal concept are assessed. In Table 19, an overview is presented for the simultaneous peak hours scenario. Again, positive quantities represent benefits and negative quantities represent costs.

Table 19: Overview costs and benefits the public terminal concept for the simultaneous peak hours scenario on RTHA

Year	0	1	2	3	4	5	Total	Total
Discount rate	**1.00**	**0.93**	**0.86**	**0.80**	**0.75**	**0.70**	**Costs**	**Benefits**
Investment Biometric gates	80,000	0	0	0	0	0	0	80,000
Terminal enlargement	-1,966,650	0	0	0	0	0	1,966,650	0
Non-Aeronautical	0	0	0	0	0	0	0	0
Maintenance	0	-13,578.00	-12,627.54	-11,743.61	-10,921.56	-10,157.05	59,027.76	0
Construction costs	-1,514,940	0	0	0	0	0	1,514,940	0
Investment Security lanes	-11,200,000	0	0	0	0	0	11,200,000	0
Total							14,740,617.76	80,000

The public terminal concept requires many initial investments. Although the central security filter is removed, the decentralized screening process requires significantly more terminal space than the central facility. Consequently. an investment of almost 2 million euro's on terminal enlargement is required in order to comply to the desired Level of Service. Moreover, the costs for the conversion of the current central security filter to 'conventional' terminal area do also add up to approximately 1.2 million euro's. In combination with the removal of the border control the construction costs add up to more than 1.5 million euro's
When looking at the investment in equipment, the public terminal concept requires less biometric gates than the conventional concept equipped with seamless flow technology. However, the investment and corresponding maintenance benefits are overwhelmed by the costs of the security lanes. While security screening is decentralized, the public terminal concept requires a total of 22 security lanes in the simultaneous peak hours scenario (subsubsection 5.3.2). In comparison to current concept, this requires 16 additional security lanes which leads to an investment of more than 11 million euro's. Consequently, all financial benefits perceived by the lower number of biometric gates are overcompensated by the costs of the security lanes.

In Table 20, an overview of the costs and benefits of seamless flow concept two for the second scenario is presented. Similar to the observations from the merged airside concept, the different peak hours scenario scores better in terms of costs and benefits. The removal of the two gates result in an additional decrease in the total investment in biometric gates in comparison to the base case. This also applies for the number of security lanes. Together, the reduction in the number both biometric gates and security lanes will result in lower maintenance costs in comparison to the first scenario.
Besides that, one can notice the significant difference in costs for terminal enlargement in comparison to the first scenario. Due to the spatial benefits of removing two gates, significantly less new terminal space is required to comply to the desired LoS. This will however slightly increase the construction costs.

Table 20: Overview costs and benefits public terminal concept for the different peak hours scenario on RTHA

Year	0	1	2	3	4	5	Total	Total
Discount rate	**1.00**	**0.93**	**0.86**	**0.80**	**0.75**	**0.70**	**Costs**	**Benefits**
Investment Biometric gates	120,000	0	0	0	0	0	0	120,000
Terminal enlargement	-559,650	0	0	0	0	0	559,650	0
Non-Aeronautical	0	0	0	0	0	0	0	0
Maintenance	0	-3,627.00	-3,373.11	-3,136.99	-2,917.40	-2,713.18	15,767.69	0
Construction costs	-1,649,340	0	0	0	0	0	1,649,340	0
Investment Security lanes	-8,400,000	0	0	0	0	0	8,400,000	0
Total							10,624,757.69	120,000

In Table 21, an overview of the costs and benefits of the public terminal concept for both scenario's is presented. Similar to the merged airside concept, the in Table 21 presented quantities do need to be considered as indicative the time horizon highly influences the outcome.

Table 21: Overview costs and benefits public terminal concept

	Public terminal concept	
	Simultaneous peak hours	***Different peak hours***
Costs	14,740,617	10,624,758
Benefits	80,000	120,000
Net Present Value (NPV)	-14,660,618	-10,504,758
Benefit-cost ratio	0.005	0.011

As can be seen in Table 21, the public terminal concept is economic infeasible compared to the current concept equipped with seamless flow technology. The costs of equipping each gate with security lanes, terminal enlargement and re-arranging the terminal significantly outweigh the benefits generated out of the fewer biometric gates and the removal of the border control touchpoint and the central security screening. Although, the different peak hours scenario performs significantly better it is still far away from being economic feasible.
The purchasing costs of the security lanes do clearly dominate the total costs. Altering these costs in terms of a sensitivity analysis will however not change the general conclusion of the economic feasibility of this concept. This analysis is provided in Appendix E.

6.4.3 External validity

In this section, the external validity of the findings in the previous sections is elaborated. Thereby, it is discussed whether the outcome of the CBA can be expected to apply for other airports. Additional information of statements made in this section can be found in Appendix E.

To start, it can be seen that the benefits of seamless flow are enhanced in the different peak hours scenario on Rotterdam The Hague Airport. This could mean that airports with different peak hours for international and domestic (or Schengen and non-Schengen) will thereby perceive more benefits of a seamless flow concept than airports with one general peak hour for both passenger types (such as RTHA). While the benefits are the result of multi-deployability of the gates (for different flights) it is expected that the same results do also apply for other airports.

Looking at the consequences for the equipment on RTHA, both seamless flow concepts resulted in a reduction in the number of required biometric gates on RTHA. In both new concepts, this is the result of removing the border control touchpoint. In the public terminal concept, the removal of the access control touchpoint will lead to a further reduction in the required biometric gates. As earlier mentioned, RTHA is a small airport which handles relatively few passengers annually. Looking at other (bigger) airports, both the access control touchpoint and the border control touchpoint will be larger and will thereby contain more biometric gates. Investment and maintenance benefits, as result of removing those physical touchpoints from the passenger terminal, will thereby increase on larger airports.
Besides the biometric gate equipment, the security lanes were considered. In the public terminal concept, every boarding gate is equipped with a security lane. In the previous section it was found that this is very expensive and makes the concept economic infeasible. Bigger airports will contain more boarding gates which will further increase the security lane investment costs.

Next to the consequences regarding equipment, it can be seen that the new seamless flow concepts do have consequences for the spatial footprint of the terminal's processes. At RTHA, the departure lounge is already used by both Schengen and non-Schengen passengers while the border control section is located just before the non-Schengen boarding area. Thereby, RTHA does not perceive the dis-utility of building separate facilities for different passenger types. As addressed in subsection 1.5, one of the main benefits of the new seamless flow concepts is that resources could be used more efficiently. Thereby, it is expected that airports which do have separate facilities for different passenger types would perceive relatively more spatial benefits than seen at RTHA.

As earlier described, other airports could have larger touchpoints than seen at RTHA. Removing touchpoints, such as border control and access control, on such airports could thereby result in more spatial benefits. Those benefits can subsequently result in higher non-aeronautical revenues. Besides the larger touchpoints, bigger airports would operate larger aircraft. As described in subsection 3.1, the types of aircraft that serve the airport is one of the most important factors for facility sizing (IATA & ACI, 2019). At RTHA the largest operating aircraft is the B737-800 which can carry up to 189 passengers. Other airports could possibly facilitate aircraft which can carry up to 868 passengers (Airbus 380). Consequently, the boarding gate area's will be significantly larger. Altering the spatial footprint of the boarding gate area's will significantly influence the outcome of the CBA for airports with different peak hours (different peak hours scenario) for international and domestic flights (or Schengen and non-Schengen). In Appendix E, this sensitivity analysis is presented. In the merged airside concept, the non-aeronautical revenues will further transcend the construction costs. Thereby, the concept will be more beneficial on airports operating larger aircraft. In the public terminal concept, one can notice that airports which contain larger boarding gate area's could compensate for the spatial footprint of the decentralized security screening lanes. As a result, terminal enlargement could not be required to maintain the desired LoS, which reduces costs and brings opportunities for exploiting additional commercial activities. Thereby, the benefit-cost ratio of the public terminal concept will significantly increase at larger airports. Nevertheless, the costs still outweigh the benefits in the public terminal concept.

6.5 Success and failure factors

In the previous sections, the different feasibility determinants have been elaborated. Thereby, various success and failure factors which influence the adoption of the new seamless flow concepts in the aviation industry can be identified. This section will provide a comprehensive overview in which the identified factors will be discussed and validated. The validation is done by discussing the findings with experts out of the field. In Table 22 an overview of the success and failure factors is presented.

Table 22: Success and failure factors identified in system analysis

Feasibility determinants	**Factors**	
	Success	***Failure***
Technical	- Performance of the terminal system - Efficient use of touchpoints	- Desired functionalities - Availability of technology - Underdeveloped technology - Reliability of technology
Social	- Reduced Waiting times - Ease of the processes - Reduced number of contact points - Increased passenger satisfaction	- Privacy concerns
Political	- Pressure from stakeholders	- Conflicting interests of stakeholders - Impact on processes - Impact on security
Economic	- Increased Non-aeronautical revenues - Increased efficiency - Spatial savings - Investment costs	- Terminal expansion - Investment costs - Rearrangement costs

Underneath, the compliance to the in Table 22 introduced factors will shortly be discussed. Besides that, the findings will be validated and the importance of each factor will be indicated.

- *Technical*
  When looking at the technical determinant, one can conclude that both seamless flow concepts do not require more functionalities than the currently available technology could already provide. The only difference is that both new concepts require a simultaneous check on both boarding pass and travel documentation at one touchpoint, or a remote border control process. Both ways are technically feasible while the technology could already provide such functionalities. Thereby, the touchpoints are used more efficiently in both the merged airside concept as the public terminal concept. The overall technical feasibility of the seamless flow concept is not proven yet while the availability of data systems and IT infrastructure is unreliable. In terms of performance, the new concept will use the touchpoint more efficiently which will lead to a higher system performance. Thereby, both concepts can be seen as technical feasible.

  The interviewees agreed on the observations of this research. It was addressed that the reliability of the technology could have a massive impact on the performance of the system. Whenever technology will break down, the performance of the terminal will significantly decrease. When looking at the public terminal concept, all required passenger checks are executed at the boarding gates. Thereby, a failure at that one touchpoint at the end of the terminal process could disrupt the whole system. While their is no time to rectify such a disruption this will have a massive impact on the systems performance. It is therefore recommended to execute the required processes and checks as early as possible in the terminal concept. Nevertheless, the reliability of the technology will not differ between the base case and the seamless flow concepts. Thereby, the two concepts are technical feasible compared to the base case.

- *Social*
  The social determinant is determined by the acceptability of the innovation by passengers. The constructed concepts do amplify the factors which already make the seamless flow concept on current terminal concepts socially feasible. By introducing self-service technology to the airport, the ease of processes will increase, waiting times will reduce and passengers will perceive less stress which will lead to a better passenger satisfaction. When the border control touchpoint is eliminated (as in both constructed concepts) or every check is integrated into one touchpoint (Public terminal concept), the number of contact points decrease and passenger satisfaction will be enhanced even further. In terms of privacy concerns it is assumed that the industry will come up with a suitable privacy policy which will safeguard the privacy of the passengers. Consequently, both concepts can be seen as social feasible.

  The positive impact on the passenger experience is also addressed by the interviewees as one of the main benefits of the seamless flow concept. Furthermore, the privacy concerns of the passenger is confirmed to be a major point of interest. It is however expected that the industry will find a suitable solution to deal with the concerns. The interviewee does not expect that the implementation of the seamless flow technology, and thereby the constructed concepts, will be ceased as result of the privacy concerns.

- *Political*
  The political feasibility is determined by the social feasibility and the interests of stakeholders. When looking at the stakeholders interests, one can conclude that a seamless flow terminal does conform the industries interests. Thereby, the base case concept is politically feasible. Looking at the merged airside concept, the design requirement of physically separating domestic and international passenger flows after border control is resolved by re-checking the travel documentation of passengers at the boarding gate. Assuming that the border control process is physically available (integrated into a touchpoint), the merged airside concept conforms the stakeholders interests. In order to implement a remote border control process, regulations concerning data sharing need to be altered which is expected to be a capricious process. A concept with a border control process on remote is thereby seen as infeasible.
  In the public terminal concept, the design requirement to be able to prevent unauthorized persons to access the terminal's secured area's is violated. Integrating all passengers checks into the boarding touchpoint would create a chaotic situation at the boarding gates which will not be supported by both the border guard agency and the airlines. Furthermore, allowing well-wishers to the airports secure area's will make it harder for the border guard agency to control the crowd and maintain law and order within the terminal. This will have a negative impact on the security within the airport terminal. As a result, it is unlikely that the public terminal concept will get the stakeholders support for an alteration of the violated regulations. Moreover, the public terminal concept will not be supported by the important system stakeholders which will form a barrier for implementation.

  Next to the confirmation of the research findings, the interviewees emphasized the importance of complying to the interests of the border guard agency. By fully decentralizing the security checks, as can be seen in the public terminal concept, the border guard staff is required to spread over the terminal. Considering larger airports with finger piers, this would create an infeasible situation in which the staff is continuously on the move between different boarding gates. This will be at the expense of factors such as the occupancy rate at touchpoints and the response time which can be seen as important factors.
  Besides that, it was addressed that the security factor is most important. Currently, the security of the secured area is seen to be relatively in order. Subsequently, the separation of passengers and well-wishers tends to move further on to the entrance of the terminal. The further non-passengers are allowed into the terminal, the unfavorable from security perspective. As a result, allowing non-passengers to a larger part of the terminal, like in the public terminal concept, will not be supported by the border guard agency.

- *Economic*
  Looking at the economic determinant, it is shown in that the merged airside concept is economic feasible in comparison to the current concept equipped with seamless flow technology subsection 6.4. In both peak hour scenario's, benefits as result of fewer biometric gates and the removal of the border security touchpoint, which will lead to non-aeronautical revenues, significantly outweigh the costs for rearranging the terminal. Furthermore it can be concluded that this result is amplified on airports which perceive

different peak hours for domestic (Schengen) and international (non-Schengen) flights.
On the contrary, the public terminal concept is shown to be economic infeasible in comparison to the base case. Although, the reduction in the required number of biometric gates in both scenarios, the benefits are flooded with the investment costs for the additional security lanes. Moreover, the spatial usage of each security lane, will require the airport to enlarge the passenger terminal without increasing the non-aeronautical revenues.

The interviewees confirmed the research findings. Besides that, the inefficiency in the current passenger terminals was emphasized. By duplicating all processes and facilities in the terminal, a lot of money is wasted. Furthermore, the high investment costs for decentralized security screening was addressed. Equipping every gate with security lanes is extremely expensive. Moreover, a new terminal space must be build to compensate for the lost space. This is most certainly a showstopper for the implementation of the public terminal concept.

In Table 23 a general overview of the two concepts and their score on each feasibility determinant is presented. A green box, filled with a '+' sign, means that the concept is feasible on that determinant. The red '-' box means that the concept is infeasible on that determinant. Lastly, the orange '+/-' refers to feasible under particular circumstances.

Table 23: Overview of the feasibility of the seamless flow concepts

Seamless Flow Concept	**Feasibility**			
	Technical	***Social***	***Political***	***Economical***
Merged airside	+	+	+/-	+
Public terminal	+	+	-	-
Note: + means feasible; +/- means feasible under particular circumstances; - means infeasible				

6.6 Conclusion

In this chapter the feasibility of constructed seamless flow concepts, merged airside and public terminal, is assessed. Thereby, sub-question eight is answered.

In Table 23, an overview is presented of the feasibility of both seamless flow concepts. It can be concluded that the merged airside concept is feasible, compared to the base case, under condition that the border control process is available at a physical touchpoint. Looking at the public terminal concept, one can conclude that the concept is infeasible on the political and economic determinant. From political perspective, the multi-disciplinary touchpoint at the boarding gate would create chaotic situations which will not be supported by the border guard agency and airlines. Furthermore, allowing well-wishers to a significantly larger part of the terminal will make it harder for the border guard agency to safeguard the security within the airport. From economic perspective, security lane -,terminal enlargement - and rearrangement costs do significantly outweigh the biometric gate investment benefits. Consequently, the public terminal concept can be seen as infeasible in comparison to the base case.

7 Conclusion

This chapter contains the conclusion and recommendations of this research. First, the research question will be answered in subsection 7.1. Thereafter, recommendations for further research are elaborated in subsection 7.2.

7.1 General conclusion

In this research, the seamless flow concept is extensively analyzed. The objective is to determine whether the seamless flow technology could lead to a new and feasible passenger terminal concept. Thereby, the feasibility is determined in comparison to the current, or conventional, terminal concept equipped with seamless flow technology. As a result the following research question has been defined:

What is the feasibility of a passenger terminal concept based on seamless flow technology compared to the conventional concept equipped with seamless flow technology?

According to Feitelson and Salomon (2004), the adoption of an innovation can be predicted by four determinants: technical, economic, social and political feasibility. Consequently, an innovation such as the seamless flow concept will only be adopted if it is seen to be feasible on those determinants. To assess the feasibility of a new terminal concept based on seamless flow technology, two new concepts were constructed with NACO experts and compared to the conventional terminal concept equipped with the seamless flow technology (Base case). In order to bypass path dependency of the current terminal concepts, the new seamless flow concepts are constructed using the functionalities of the new technology (Wang et al., 2002). In the merged airside concept, the border control is integrated into the access control touchpoint or executed on remote. The public terminal concept contains a large public area after which all required control checks are situated at the boarding gates. By assessing the two concepts on the feasibility determinants the overall feasibility is determined. The research findings indicate that new terminal concepts can be feasible in comparison to the base case. Nevertheless, certain conditions are required to comply to.

The interviews and desk research showed that the constructed concepts work and do not require more functionalities of the technology than that the available technology could already provide. Thereby, multi-disciplinary touchpoints which integrate multiple airport processes are technologically feasible. Moreover, the system performance increases in both concepts. Both concepts can therefore be seen as technically feasible.
Besides that, literature studies and interviews show that the introduction of self-service technology, such as seamless flow, will enhance the passenger experience. Moreover, the waiting times on the airport decreases which leads to less stress among the passengers. Concepts which contain fewer touchpoints for the passengers will thereby amplify these consequences which will lead to further enhancement of the passenger experience. Consequently, these concepts are seen as socially feasible in comparison to the base case.

The interests of the various stakeholders and their power within the system is identified via literature review, desk research and interviews. Regarding the system environment, the support of stakeholders is indicated to be essential for a concept to be seen as politically feasible. When considering a new seamless flow concept, it is thereby recommended to involve the stakeholders within the passenger terminal system as early as possible in decision making processes, especially the border guard agency. Due to the executive role, the border guard agency has a lot of indirect power within the passenger terminal system.
Within the seamless flow principle, collaboration between the different stakeholders is essential. As showed in this study, it requires support from stakeholders to be able to alter current applicable requirements which make a concept not possible. Involving them early in the process could lead to a terminal concept which complies to the interests of all stakeholders. In order to be politically feasible, the seamless flow terminal concept should be able to prevent unauthorized persons from entering the terminal's secured area's. Besides that, a physical touchpoint where the border control process is executed (not on remote) should not be placed at the boarding gates. As elaborated within the public terminal concept, this could create chaotic situations in which passengers can miss their flights or a flight will get delayed as result of a passenger which does not meet emigration standards. Lastly, concepts in which the border control process is executed on remote do also need to integrate the process to a physical touchpoint while regulations won't let airports require passengers to share personal data in advance.

Regarding the financial aspect of the seamless flow concepts, the economic feasibility is determined by executing a rudimentary Cost-Benefit Analysis from the airport's perspective. With the help of various interviewees and desk research, assumptions have been made regarding the assessment of costs and benefits. From the analysis it can be concluded that the non-aeronautical revenues and the investment in security lanes significantly influence the economic feasibility in comparison to the base case. A concept which brings spatial benefits without decentralizing the security section to the boarding gates, such as the merged airside concept, can therefore be

seen as economic feasible in comparison to the base case. As a result of implementing the new concept, spatial benefits could result in an significant increase in non-aeronautical revenues which will quickly compensate for the costs for re-arranging the terminal. These benefits will be amplified for airports with different peak hours for international and domestic flights (or Schengen and non-Schengen).
On the contrary, concepts in which the security screening will be decentralized and moved to the boarding gates, such as the public terminal concept, have to deal with overwhelming investment costs in security lanes. Consequently, potential benefits of removing the physical border control touchpoint and the lower investment in biometric gates can not compensate for the investment in security lanes. Thereby, the costs for re-arranging the terminal is not even considered yet. This makes such concepts economic infeasible in comparison to the base case.

Based on the results of this study, one can conclude that the seamless flow technology can lead to feasible airport passenger terminal concepts in comparison to the conventional terminal concept equipped with seamless flow technology. The constructed merged airside seamless flow concept will enhance the passenger experience while using the airport infrastructure more efficiently. Consequently, it can be recommended for airport owners to consider such a terminal concept whenever the seamless flow technology is found to be ready for implementation on civil airports.

7.2 Recommendations for further research

This study mainly contributes as an exploratory research to the potential of new terminal concepts based on the new seamless flow technology. The findings can thereby be used as a motivation to do further research on the different determinants that determine whether a new innovation will be adopted. To start, it is recommended to do further research on the applicability of the theoretical framework on this type of innovation. This can be done by applying the framework on previous innovations within the passenger terminal system. As a result, a better understanding of the factors that determine feasibility within the terminal system is retrieved. This could lead to more in-depth recommendations for the aviation industry.

In this study, the number of required equipment in the new concepts is based on recent terminal simulation studies at RTHA. Within this simulation study, characteristics of the passenger flows through the current terminal concept on the airport are considered. However, introducing the seamless flow equipment could lead to different passenger flows which can change the performance of certain facilities. Consequently, it is recommended to do simulation studies on the impact of implementing the new biometric equipment. Thereby, more insights will be given into the effects on the passenger journey and into the potential bottlenecks of the new concepts. As a result, a more substantiated estimation can be provided for the spatial footprint of the (new) touchpoints and the impact on the passenger experience.

Besides, it is recommended to do further research on the impact of the new concepts on larger airports which contain for example multiple terminals, multi-level swing gates and transfer passengers. These airport characteristics lead to multiple additional opportunities, but also to additional requirements and constraints, which could lead to different results than seen at the relatively small case study airport of this research.

Moreover, this research looks at the in-terminal opportunities and consequences of the new seamless flow concepts. However, in terminal alterations, such as the removal of boarding gates and terminal expansion, could also have significant consequences for the environment outside the passenger terminal. Hereby, one could think of the size of the airport's apron and the number of contact stands on the airport. In order to create a more complete overview of the consequences of a new terminal concept for the airport, it is recommended to do further research on the consequences of the seamless flow concept on the outside of the terminal.

Lastly, this study contains a concise legislation study. In order to be able to provide a complete recommendation to the airport it is recommended to do more in-depth research on the current applicable legislation within the passenger terminal system. In particular, on the border control legislation, equipment certification and privacy regulations.

8 Discussion and reflection

By studying the feasibility of new terminal concepts, this research provides an out of the box perspective on the seamless flow concept. As described in subsection 1.3 current research is focused on fitting the seamless flow technology in with the current passenger terminal concepts. By combining the opportunity in conceptual design stage theory of Wang et al. (2002) and the political-economy framework by Feitelson and Salomon (2004), this research provides an overview of the feasibility of new terminal concepts in combination with new technology. As a result, it is showed that equipping the current terminal system with seamless flow technology leads to a sub-optimal system in terms of performance and spatial usage. Thereby, the existence of possible system inefficiencies as a result of path dependency is indicated for the airport passenger terminal system. Nevertheless, this study is limited on various aspects. In this section, the limitations of this study are addressed.

To start, this thesis study is executed within a period of six months. During this period, the covid-19 pandemic started. As result of this outbreak, 75% of the time spend on this research was spend at home. Consequently, it was sometimes hard to get in contact with the right persons to acquire the desired information. Due to the crisis, the aviation industry collapsed which downgraded the importance of a thesis for external companies. Thereby, various meetings were canceled last minute which did most certainly not contribute to the progress of this study. More time could have resulted in a more in depth analysis on the playing field of the system, in terms of stakeholder interests, and a more in depth validation.
Besides the consequences on the progress of this research, the covid-19 pandemic allows to look at this research findings from another point of view. This research looks at the seamless flow concept as an innovation which could enhance the passenger experience and would allow the airport to use their infrastructure more efficiently. While seamless flow does not require physical contact or handing over travel documentation at the various touchpoints, it could also be seen as an innovation which enhances the hygiene of the airport processes. As result, the current covid-19 outbreak could accelerate the need for seamless flow systems on airport passenger terminals. New terminal concepts which decrease the number of touchpoints and thereby the amount time spend in waiting lines, will become even more attractive. Due to these circumstances, stakeholders could to be willing to extensively collaborate which will accelerate the transition to the seamless flow airport and possibly new terminal concepts.

Considering the theoretical lens used within this research, a public-private theoretical framework was chosen. The political-economy framework of Feitelson and Salomon (2004) is developed to study the adoption of innovations in systems where both public and private parties do play an important role. As argued in subsection 2.2, it was expected that the public parties do play an important role within the airport system due to the federalization of the airport security and the fact that airports are often (partly) governmental owned.
Looking back on this research, it can be concluded that the governmental role within the adoption of the seamless flow innovation is not as prominent as expected. Although the border guard agency has a lot of (indirect) power, the governmental interference is limited. Besides a few regulatory constraints, the adoption of the seamless flow innovation is predominately determined by private parties. Thereby, a more private oriented theoretical framework might have suited this research better.

During the timespan of this research, the system environment was explored and the constructed concepts were assessed on their feasibility. In order to be able to execute the research within the available time, a research scope was set. As a result, certain important facets of the passenger terminal system are not accounted for in this study. One of the limitations of this research is excluding the transfer passengers. Introducing biometric technology to the transfer process could speed up this process which could lead to shorter transfer times. However, this will be dependent on whether different airports will work together on an integral seamless flow system. When a transfer passenger needs to enroll into the local seamless flow system, this would take up additional time which could lead to longer transfer windows.
Besides the transfer process, the arrival process is also not considered in this study. It is however expected that the implementation of seamless flow technology on the arrival process will not lead to huge benefits while this process contains only one touchpoint (for international passengers). Including this process would however create a complete overview for the airport. Excluding this process thereby limits the general validity of this study.

One of the most important factors which is not considered in this study is the the privacy concerns of passengers. Although, privacy and data sharing is a big topic in the seamless flow principle, this research looks at the potential of new concepts from the airport perspective. Thereby, the in-depth technological analysis and the potential consequences of this technology for system users are excluded. In previous studies to seamless flow systems, privacy concerns are widely addressed. As shortly mentioned in subsubsection 5.1.2, the 'privacy by design' is mentioned as a solution. However, the question remains whether passengers trust the new system with their confidential personal data. Including this factor, could thereby negatively affect the social feasibility which could also work through into the political feasibility of the seamless flow system.

Furthermore, the feasibility of a concept is determined in comparison to a certain 'Base case'. Although the base case is based on the general airport concept, various airports around the world will maintain a different passenger terminal concept. Different base case concepts will most probably lead to other results and could therefore lead to different conclusions about the constructed seamless flow concepts. Besides that, only data for RTHA was used for the conceptual implementation. Using data from other airports would put the found figures in into perspective in comparison to other airports. Due to the limited amount of time and the already available information on RTHA, this was not done in this research. Including different base cases and data from different airports would enhance the external validity of the findings in this thesis.

In order to determine the economic feasibility, a rudimentary Cost-Benefit Analysis was executed. Within this CBA, an extensive number of assumptions have been made in order to determine the financial feasibility. Despite the various attempts, manufacturers of biometric systems at airports were not willing to share detailed information about the costs and performances. As a result, the used assumptions are not validated by the actual manufacturers which limits the validity of the assumptions.
Furthermore, impact on passenger experience is not quantitatively considered in the CBA. As stated in the interview with RTHA, passenger satisfaction is very important for the airport. Thereby, excluding this factor limits the validity of the financial business case for the airport.

Another assumption made in this study is the costs of the airport are not distributed over the passengers. However, Investment costs that will not be earned back within a certain time frame, will most probably be distributed over concerned parties: Airlines and border police. It is expected that airlines will not directly pass on cost increases to the passenger. When airlines do , this could influence the social feasibility of the concept. It could be possible that air travellers are willing to pay extra in order to perceive a relaxed and fast airport experience. Another possibility is that travellers are not willing to pay for the new system. Nevertheless, considering the cost-distribution would add more depth in the stakeholder analysis and thereby the political and social feasibility.

Moreover, this study only considers the air travel passengers within the analysis. However, when looking at the public terminal concept, well-wishers are allowed to the former airside area's. When looking at the peak hour, additional entities within the terminal area than accounted for would result in a lower Level of Service (LoS). Including the well-wishers in this analysis would result in the extra need for terminal enlargement. On the other hand, people within the terminal are probably also extensively consuming when they are with their well-wishers. Including these scenario's would also enhance the validity of the financial business case for the airport.

Lastly, this research assumes a full implementation scenario of the new seamless flow concepts. However, in real-life this transition won't be happening overnight. Instead, a transition phase would be introduced in which the current terminal concept will gradually merge into the new concept. As a result, concepts which require a lot of terminal re-arrangements will take a lot of time to be fully implemented. The duration of the transition phase can result in a chaotic terminal situation which does not contribute to the passenger experience and could thereby lead to either direct or indirect costs for the airport owner.

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A Scientific paper

Innovating Airport Passenger Terminals
Determining the feasibility of new terminal concepts based on seamless flow technology

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Abstract

The continuing growth in air travel passengers, in combination with enhanced security regulations, has led to unsustainable situations at airports. In order to handle the future amount of air travel passengers while complying to security regulations and enhancing the passenger experience, the terminal system must be innovated. Seamless flow is a future end-to-end continuous, efficient and secure innovation which uses passenger biometrics for identification throughout the airport processes. Previous research is focused on fitting the new seamless flow technology in with the conventional airport processes. This research explores whether the biometric technology could lead to new, and feasible, passenger terminal concepts. Two new seamless flow concepts are constructed and assessed on their feasibility by conducting interviews with stakeholders, performing desk-research and executing a financial Cost-Benefit Analysis. The research findings indicate that the new technology could lead to feasible, efficient and experience enhancing passenger terminal concepts in comparison to the conventional terminal concept equipped with seamless flow technology. Thereby, the support of - and collaboration between - stakeholders, especially the border guard agency, is shown to be essential for the implementation of seamless flow technology on civil airports. Besides that, it is shown that more efficient terminal concepts could significantly benefit airports through increased commercial opportunities.

Keywords: Airport Design, Passenger experience, Seamless flow, Biometric technology, Terminal concept

1. Introduction

1.1. General introduction

In the end of last century, the European aviation market was liberated. Together with the development of the internet, this made the rise of the low-cost carriers possible. Thereby, the aviation industry has changed for good [1]. As a result, an oversupply emerged on the aviation market which lead to extreme price competition within the sector. In combination with the growth of the global economy and trade, the demand for air travel grew massively [2]. In the forthcoming years the aviation sector kept growing. In 2019, the International Air Transport Association (IATA) announced an annual growth in air passenger traffic of 4.2% compared to 2018. Moreover, the passenger numbers are expected to double in the next ten years [3].

Besides the liberation of the aviation market and the rise of the internet, another event did significantly change the civil aviation market; the terrorist attacks of September 11. Following these attacks, (civil) aviation security procedures and regulations on airports changed in order to increase passenger safety. Hereby, two primary changes can be identified: the federalization of airport security and the requirement to screen all hold (checked) baggage [4]. As result, air travelers experienced various changes in their journey through the airport. An example for this is passengers were instructed to arrive at the airport 2 hours before the take-off of their domestic flights. Furthermore, the passenger screening operations were enhanced and tightened [4].

The combination of the growth in air travel passengers and enhanced security regulations creates an unsustainable situation at airports [5]. From passenger perspective, the 'passenger experience' has become more complicated, congested and thereby more unpleasant. While the passenger has become an important and dominant player within the aviation sector, airports aim to improve this passenger experience [6]. Consequently, today's passenger frustrations, among which crowding and the amount of time spend at the various touchpoints, should tempered or even eliminated [7].

In order to do so, one can think of enlarging terminal facilities. Although spatial expansion is often considered within the master planning of an airport, physical expansion is at many locations limited or considered costly and time expensive [8]. Besides enlarging facilities, current passenger terminal infrastructure can be used more efficiently. This is often more effective, efficient and sustainable and could be accomplished by introducing new innovations in methods and processes [9].

1.2. Seamless flow

One of the key concepts in airport innovation is the so called 'seamless flow'. Seamless flow is a future end-to-end continuous, efficient and secure method which uses passenger bio-

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metrics for identification throughout the airport processes. Biometric recognition of passengers can offer different opportunities, namely; higher passenger throughput, lower operational cost and enhanced security [10]. Within the seamless flow principle, coordination between the individual stakeholders within the passenger terminal system is required. Thereby, a single travel token can be generated for each passenger which complies to the requirements of each individual stakeholder and can therefore be used at all passenger processes. Consequently, the seamless flow principle would allow physical touchpoints to be combined or removed. As a result, passengers will spend less time at airport touchpoints which will lead to a decrease in, or even disappearance of, waiting time in non-security screening facilities within the passenger terminal[3]. Furthermore, seamless flow would benefit stakeholders acting in the civil aviation industry by bringing staffing efficiencies and thereby an increase in capacity [10]. Hereby, one could think of baggage drop-off and boarding processes which could either be self-service or automated. Staffing efficiencies could also be applicable for border guards. As the primary inspection could be automated, only special cases need to be treated by the agents [3].

The seamless flow concept is build on various technologies and equipment among which a comprehensive service platform used by airports, airlines and border authorities. Through collaboration between the multiple stakeholders, the platform stores passenger data and makes required information available for every stakeholder within the system [11]. Such a platform is conceived according to the privacy by design principle which ensures that each stakeholder has access to the passenger data they 'need-to-know' and are 'authorized-to-know' [5]. Thereby, the platform forms the connection between the physical equipment and the stakeholders.
The physical equipment can identify the passenger by their facial biometrics. The main reason for using facial biometrics is that it is easy to deploy and implement. Moreover, no physical interaction with the equipment is necessary and the verification process is relatively fast [12]. As a result, various technology companies in aviation chose for the facial biometrics systems containing a camera and facial recognition software on airports. In terms of implementation of the hardware, either integration with current airport equipment or detached equipment is possible [13] [14].

1.3. Research

Previous research is focused on fitting the new seamless flow technology in with the current, or legacy, airport processes. Although IATA envisions merging or removing physical touchpoints in the future, their seamless flow concept 'One ID' assumes the traditional airport terminal concept. In this paper, the term 'terminal concept' is used to represent the successive steps each passenger must run through within an airport terminal. These contain the check-in, baggage drop-off, security, border control and boarding process. When looking at the current airport passenger terminal concepts, and its processes, this can be seen as the result of the conceptual design phase for the conventional passenger terminal. Within this conceptual design phase, technology available at that moment in time were considered in decision making processes. This could indicate the presence of path dependency. Decisions made in the conceptual design stage do have a significant influence on the performance of system and could hardly be compensated by decisions later in the design process[15] [16]. This implies that implementing the seamless flow technology in current passenger terminal concepts could lead to a sub-optimal system. The objective of this research is to explore whether the seamless flow technology could lead to new, and feasible, passenger terminal concepts in comparison to the current terminal concept equipped with seamless flow technology.

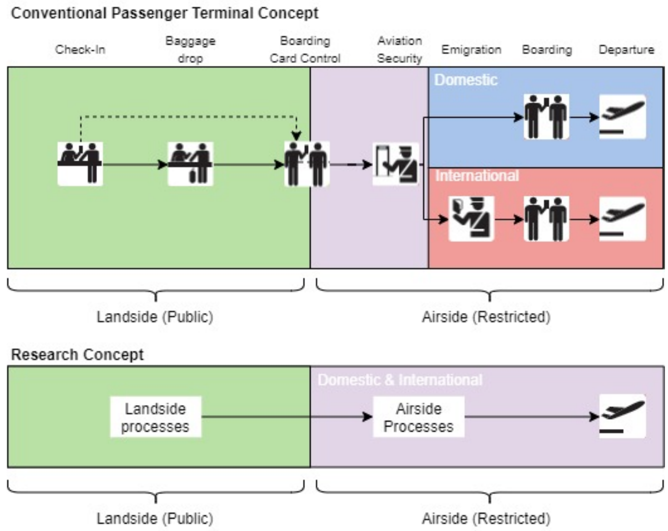

Figure 1: Conventional terminal concept and research concept

In Figure 1, the conventional departure terminal concept for an international passenger terminal is graphically represented. In the same figure, the research concept is presented. In order to explore whether the seamless flow technology could lead to new and feasible terminal concepts, two new concepts will be constructed and assessed on their feasibility. In collaboration with NACO, the commissioning company of this research, the decision is made to study concepts in which domestic and international passengers will no longer be separated at (airside) terminal facilities. A lot of airports have separated (airside) facilities for domestic and international passengers. While the peak hour for both types of flight services is often different, the airport's overall capacity is not used efficiently. Mixing domestic and international passengers at airside facilities could therefore lead to more efficient use of resources. This new concept is a result of the opportunities offered by the new seamless flow technology.

Due to the limited amount of time, this research focuses on the departure process. The feasibility is determined by four determinants, namely: technical, social, political and economic (elaborated in section 2). Within the technical determinant, the focus will be on the availability of technology and desired functionalities. In the social determinant, the acceptability of the new concept by the passengers is considered. The political determinant focuses on the stakeholder interests. Finally, within the economic feasibility determinant, a financial Cost-Benefit Analysis is executed from tha airport's perspective. In order to be able to quantify the impact of the new concept, Rotterdam The Hague Airport (RTHA) is selected as a case study airport.

2. Approach

This section provides the approach of this research. First, the theoretical lens of this study is provided in the theoretical framework section. Thereafter, the used methodologies are elaborated in the methodology section.

2.1. Theoretical Framework

Considering the research objective, one can distinguish two different parts. On one hand, this research is going to construct a new passenger terminal concept with the seamless flow technology. Thereby, this part contains parts of a design process. On the other hand, the feasibility of such a concept is studied. This part is looking at the adoption of an innovation in an existing system. Both parts require a different theoretical approach, or lens, which will be elaborated in this section.

2.1.1. Opportunities in design stage

A design process contains different phases among which the conceptual design phase and the detailed design phase [17]. The conceptual design phase is probably the most crucial phase in the development of a product or system[16]. In this phase, impact of decisions are very high which creates great opportunity. The decisions made in the conceptual design phase do have a significant influence on the costs, performance, reliability, safety and environmental impact of a product or system [16]. Those design decisions can account for more than 75% of the final costs of a system or product [15]. Later in the design process, in the detailed design phase, it becomes nearly impossible to compensate for shortcomings of a concept generated in the conceptual design [16].

When looking at the current airport passenger terminal concept, and its processes, this can be seen as the result of the conceptual design phase for the conventional passenger terminal. In this phase, regulations and available technology are important and eventual constraining factors in decision making. Subsequently, the system and its processes are further constructed in the detailed design phase and physically implemented in the production phase. Implementing the new seamless flow technology in current passenger terminal processes means adopting the conventional terminal concept. Thereby, the seamless flow technology is introduced in a phase where primary conceptual decisions are already made and opportunities out of the early conceptual design phase are lost. This can also be referred to as path dependency.
As result of the theory of [16], a modified design approach will be used in this research. While the aim is to explore new concepts as result of a technology innovation, identified requirements out of the current system will not per definition be used as 'barrier' requirements for the new design. First, new concepts will be constructed based on the technology. The concepts will thereafter be assessed on the compliance to the identified requirements out of the current system. As result, path dependency is bypassed which brings back the opportunity out of the early conceptual design phase.

2.1.2. Adoption of innovation

The second part of the objective is to assess whether the constructed concept (innovation) is feasible and could thereby be adopted in the existent system. Feitelson and Salomon (2004) state that the implementation of most transport innovations should be viewed as an outcome of societal processes, often with significant government involvement. Looking at the seamless flow innovation, it is expected that both public and private stakeholders within the airport terminal system will play an important role in the adoption. An indcation for that is that the security on airports is federalized and thus a governmental responsibility. Moreover, airports are often (partly) owned by governments. Thereby, it is expected that the adoption of the seamless flow innovation requires a public-private partnership which makes the political economy framework suitable to use in this research. The framework is presented Figure 2.

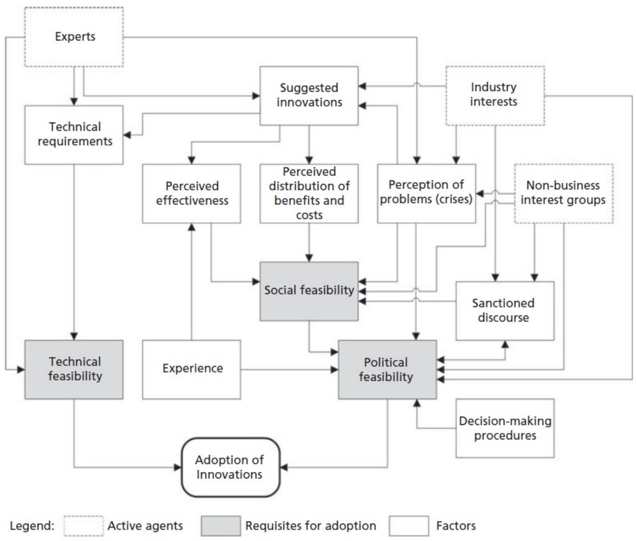

Figure 2: Political Economy model by [18] [19]

The political economy framework, as presented in Figure 2, explains why certain innovations have been adopted while others have not. Thereby, the adoption of an innovation refers to the actual use of an innovation that has already penetrated the market. Feitelson and Salomon (2004) think innovation will only be adopted if it is seen as technically, economic, socially and politically feasible. When looking at the technical feasibility, it is simply determined whether the innovation works and complies to the technical requirements. From an economic perspective, an innovation is feasible if it can pass a cost-benefit analysis. While this analysis contains a fair amount of assumptions, the result is a minimal requirement. However, an innovation that does not pass a rudimentary cost-benefit analysis is considered as socially infeasible while it is unrealistic [18].
Social feasibility is achieved if the majority of the voters are

likely to support an innovation. Thereby, the voters are lead by their perception of the innovation in terms of: effectiveness, the problem, and the distribution of costs and benefits. Furthermore, the perception of voters is influenced by: experiences with similar innovations, publications, media attention, and lobby groups. The latter three are included as 'sanctioned discourse' within the framework. Political feasibility, is among other things determined by the social feasibility while politicians do take voter preferences into account. By hearing the preferences of voters, the industry, and interest groups, politicians want to maximize the likelihood to be re-elected.

When looking at the framework of [18], an innovation will be adopted if it is seen as feasible on four determinants: technical, economic, social and political. In this study, the newly constructed seamless flow concepts will therefore be assessed on the four determinants. Thereby, the technical feasibility means whether the system is technically capable of executing their designated function. The economic feasibility will determined by executing a cost-benefit analysis. The social and political feasibility will be determined by a stakeholder analysis. Within this analysis, the power and interests of the various stakeholders within the passenger terminal system are identified and elaborated.

2.2. Methodology

In order to assess the constructed new seamless flow concepts, a design process is executed. In the first stage, the objective is to identify a problem, a need or an opportunity for the system or product improvement. Furthermore, the systems environment and corresponding legislation is investigated [17]. The design stage is executed by conducting a desk research on the passenger terminal system. Thereby, an outstanding report used is the Airport Development Reference Manual(ADRM) by IATA and ACI. The ADRM is recognized as one of the most important guides in the aviation industry for both planning a new airport and extending existing airport infrastructure. Besides that, ICAO's Annexes 9 and 17 publications are used. Within these annexes, the aviation standards and recommended practises are defined. In addition to the desk research, semi-structured interviews are conducted with experts out of the field, such as airports, gate manufacturers and aviation consultants. Thereby, the findings of the desk research can be put in perspective and experiences and visions of different players within the system's playing field are obtained.

Besides constructing the concepts, the feasibility of the new concepts is assessed. This will be done by using both qualitative and quantitative research methods. For the technical, social and political determinants, the qualitative methods such as desk research and semi-structured interviews will be used. The economic feasibility of the new terminal concepts is quantitatively determined by performing a financial Cost-Benefit Analysis (CBA) from the airport's perspective. Thereby, the concepts will first be conceptually implemented on the case study airport, Rotterdam The Hague Airport, after which the different costs and benefits will be determined. To make the right assessments, interviews will be conducted with aviation security specialists and financial assessment specialists at NACO. Finally, all findings will be validated by conducting interviews with different parties from within the aviation industry.

3. Results

This section provides the results of this research. First, the constructed concept will be presented. Thereafter, the feasibility of the constructed concepts will be assessed and success and failure factors regarding the adoption of the innovation will be elaborated.

3.1. Seamless flow concepts

In this section, both the current terminal concept equipped with seamless flow technology, later referred to as the base case, and new seamless flow concepts will be introduced. The two concepts are constructed in collaboration with NACO specialists [20]. As mentioned in subsection 1.3, both concepts will mix international and domestic passengers in the terminal's (airside) facilities. In the first concept, 'Merged Airside', the airside facilities for domestic and international passengers are merged into one by (re)moving the border control process. Although this concept uses the opportunities brought by the new technology, it does not entirely change the conventional terminal concept at the same time. Thereby, it is expected that the concept will comply to the current terminal requirements. Assessing the merged airside concept on the different feasibility determinants will give insights in the effectiveness and ease of changing terminal concepts to complement new technological innovation In the second concept,'Public terminal', a significantly different and more out of the box concept is constructed which fully utilises the functions of the new technology. In this concept, a by NACO often envisioned futuristic public terminal concept is defined in which the whole terminal, except for the boarding gates processes, is publicly accessible. Due to the significant amount of differences with the base case, this concept is expected to be infeasible. Nevertheless, it is interesting to study what factors determine whether a certain terminal concept is feasible or infeasible. Studying the public terminal concept will thereby lead to a more complete overview of the passenger terminal system. In the following sections, the different seamless flow terminal concepts will be elaborated.

3.1.1. Base case

In the base case, the conventional terminal concept is equipped with seamless flow technology. This concept is graphically presented in Figure 3.

When looking at the passenger journey, the first step for the passenger is the check-in and enrollment process. Within this process, passengers will link their facial biometrics to their boarding pass and travel documentation. This can either be done online or at the airport (at an assisted or self-service kiosk). Right after completing the enrollment process, the border guard agency could potentially start the emigration screening process remotely. Subsequently, the passenger proceeds (when applicable) to the baggage drop process. Here, their hold baggage will be retrieved and also be linked to the passenger's biometric

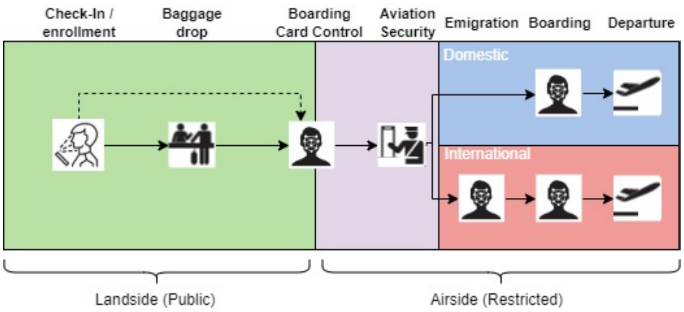

Figure 3: Current terminal concept equipped with seamless flow technology

profile. After the baggage drop-off, the passenger will continue it's journey to the access control touchpoint where their facial biometrics will be used by the system to retrieve the boarding pass information. Subsequently, passengers go through aviation security and international passengers will pass the biometric border control. Finally, facial biometrics will be used at the boarding process.

3.1.2. *Merged Airside concept*

In Figure 4, the first seamless flow concept 'Merged Airside' is presented. One can notice that this concept has a lot of similarities with the traditional concept equipped with seamless flow technology as shown in Figure 3. Besides mixing the domestic and international passengers in airside facilities, the physically separated emigration touchpoint is removed. Instead, the emigiration process is integrated in access control touchpoint or executed remotely. Consequently, international and domestic passengers do not have to be separated in airside facilities. Furthermore, all gates could be used for both international and domestic passengers. Prior to boarding, the passenger's boarding pass and travel documentation will again be checked.

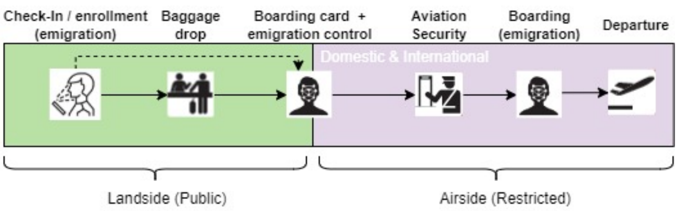

Figure 4: Merged airside concept

3.1.3. *Public terminal concept*

The second seamless flow concept, is presented in Figure 5. This concepts fully utilises the technological functionalities of the new technology and is thereby more simplistic in comparison to the merged airside concept. In this concept, domestic and international international are mixed until boarding where all control checks are integrated into one single touchpoint and security screening is placed. As a result, well-wishers could accompany the passenger until the boarding process and could thereby also make-use of the airport's commercial facilities. Finally, at the boarding process after security screening, access control and border control processes are executed.

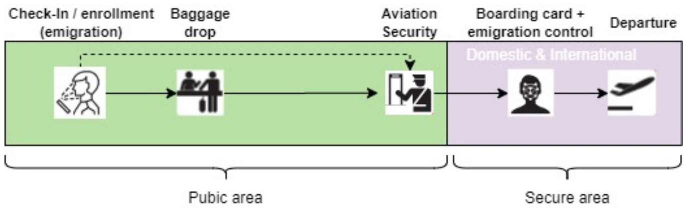

Figure 5: Public terminal concept

3.2. *Feasibility assessment*

In this section, the constructed concepts will be assessed on the feasibility determinants.

3.2.1. *Technical*

An innovation is technical feasible when it works and complies to the technical requirements [18]. The seamless flow technology is currently available and even already implemented on various airports, either in pilots or operational on small scale. Thereby, the base case concept, as presented in Figure 3, could from technological perspective already be implemented on airports. When looking at the different processes in the base case concept, one can notice that the same technology is able to execute both the boarding card control and the border control process. Moreover, both checks are executed simultaneously at boarding touchpoint where they are integrated into one touchpoint. Thereby, a multidisciplinary touchpoint is technically feasible. This is also confirmed by the interviewees of Schiphol airport, RTHA and SITA. Both the merged airside concept and the public terminal concept use such a multidisciplinary touchpoint which makes them technological feasible. Furthermore, the performance of the terminal system increases while it handles the same number of passengers while using fewer equipment.

On the contrary, based on the interviews with various stakeholders and specialists it was made clear that the technology, in general, is not that reliable yet. In particular the availability of the data system and IT infrastructure make the new system not always as seamless as imagined. Moreover, the complete reliance on technology will bring additional challenges to the terminal system. Equipment or power outages requires the airport to think about a back-up system in which the operations can be maintained on an acceptable service level. The concerned parties must agree on a certain level of redundancy which must be integrated into the system design [21]. Nevertheless, in comparison to the base case both the new seamless flow terminal concepts do not require more functionalities of the technology and are not less reliable.

Besides the technological side of the system, the innovation must also work in terms of system performance. Looking at the merged airside concept, it is expected that the removal of the physical border control touchpoint will not result in a higher passenger load for other touchpoints. While the border control touchpoint is usually situated right before the entrance of the departure lounge, the disappearance will not affect the passenger arrival pattern of other touchpoints. Instead, passengers will spend slightly more time in the departure lounge. Consequently, the terminal system handles the same number of passengers with less equipment. Moreover, the accumulated waiting time for passengers will decrease. In the public terminal concept, all terminal processes are decentralized to the boarding gates. Thereby, the passenger load is distributed over a larger number of equipment. As a result, the system will be less vulnerable for system malfunctions which increases the overall performance. Furthermore, due to the reduction in number of touchpoints and the passenger distribution, the accumulated waiting time for passengers will also decrease in this concept. Thereby, one can state that both constructed concept are technical feasible.

3.2.2. Social

Social feasibility looks at the acceptability of the public, which in the aviation industry correspondents with the passengers. As mentioned in the section 1, the passenger journey has become more complicated, congested and thereby more unpleasant [6]. Self-service airport technologies have been proven to be effective to enhance the passenger experience while it reduces the waiting times and avoids contact with the airport staff. Besides that, the self-service technologies have a positive impact on the satisfaction of the passenger while the passenger is more relaxed and experiences a more pleasant airport stay [22].The seamless flow concept is an example of a passenger oriented self-service technology. Moreover, it could lead to less touchpoints throughout the airport journey which gives the passenger less stress and reduces the waiting time. This would indicate that the seamless flow innovation is socially feasible. This indication is confirmed by the statistics of SITA which present an opt-in rate of 90% of all passengers which could participate in their smart path solution (seamless flow)[23]. Furthermore, [24] analysed the probability of passengers using biometric technology for check-in procedures. It was concluded that almost 83% of the passengers would use the biometric technology for the check-in process.

Passengers are required to share more personal information in the seamless flow journey than that they are used to in the conventional air travel journey. Naturally, the concern is growing over whether this information is treated in a decent manner and is not abused in a way which violates the individual right of anonymity [25]. The concerns about the abuse of biometric information can be addressed by legislation (by governments and the public), self-regulation of the biometric vendors or autonomous enforcement by an independent regulatory organization [25]. According to IATA, the privacy by design principle is an effective manner to safeguard the passenger's privacy [3]. This can be seen as a form of self-regulation on top of the applicable privacy legislation. In this study, it is assumed that the industry will develop a suitable system which safeguards the privacy of passengers. As a result, the privacy concerns will not influence the social feasibility within this research.

The merged airside concept and the public terminal concept can both be seen as socially feasible in comparison to the base case. While the seamless flow technology would on it's own already enhance the passenger experience, less touchpoints throughout the journey will further amplify this enhancement. The merged airside would furthermore offer a better experience for international passengers while the border control process is integrated with the access control touchpoint, or even executed on remote. When looking at the public terminal concept, both international and domestic passengers will perceive the benefits of less touchpoints throughout their journey. Besides that, passengers could spend almost all time on the airport together with their well wishers. This could enhance the experience even more.

3.2.3. Political

An innovation can be seen as politically feasible if it is supported by a wide coalition of parties with specific interests [18]. The key-players within the aviation industry: ICAO, ACI and IATA, all have the objective to either enhance the passenger experience or optimizing and upgrading airport infrastructure and performance. These parties are thereby already working on seamless flow solutions; i.e. IATA's One ID [5]. Other stakeholders such as the airlines and border guard agencies are also pleased with the new seamless flow innovation. The majority of the digitisation initiatives by airport ground handlers are focused on operational improvements and driven by cost pressures [26]. The seamless flow innovation contributes to this cost reductions while boarder guards and airlines could save on staff which usually execute the processes at the touchpoints. Furthermore, it benefits the passengers through time savings and enhanced service quality [26]. The latter is an important factor for the airport owners.

One of the identified legal requirements is that airports may not require passengers to share travel documentation data before arrival at the control point at the airport [27]. Both new seamless flow concepts would allow for the border control process to be executed on remote. Thereby, passengers are required to share their travel documentation right after enrollment. Consequently, in order to fully implement this remote border control, the regulations regarding data-sharing must be altered. Considering, the recent movements in privacy concerns and regulation it is assumed that changing these regulations will be a capricious process. Thereby, airports must still contain a physical touchpoint in which the border control process is integrated.

In both constructed seamless flow concepts the physical border control touchpoint is (re)moved. In the current airport terminals, the border control process contains two lines. The first line represents the travel documentation check performed by the border guard agency (or e-gate). Whenever a passenger does not comply to the set standards for leaving the country, the passenger is handed over to the second line agent whom will handle the situation. In the merged airside concept, the border control process is integrated into the access control touchpoint which is situated earlier in the terminal concept. On the contrary, in the public terminal concept the border control process is integrated later in the journey at the boarding touchpoint. This will give the border guard agency a short amount of time to handle risky or illegal passengers. This could lead to rushed situations, in which the border guard agent does not have the sufficient amount of time to clear a passenger before aircraft departure. The latter goes against the principles of the border guard agency. Furthermore, the airlines and passengers would also not benefit from such a situation while a flight could be missed or delayed. Consequently, one can state that the public terminal concept is only politically feasible if the border control process is executed in remote. As earlier mentioned, the latter can only be fully implemented if the data sharing regulations will be altered.

In comparison to the base case, the merged airside concept is politically feasible. On the contrary, the public terminal concepts violates various identified airport design- and legal requirements. In order to comply to the requirements, the airport must be able to prevent unauthorized persons from accessing the secured area's. When more people, passengers and well-wishers, are allowed in a significant larger part of the airport terminal, it will become harder for the border guard agency to control the crowd and thereby to safeguard the airport security and maintain law and order within the airport terminal. The border guard is a government's agency which make legal regulations conform their interests. Besides that, ICAO collaborates with the member states while constructing the regulations. Consequently, the border guard agency has a lot of indirect power within the passenger terminal system which make it unlikely that regulations will be altered without their support. According to the interviewees, the border guard agency is involved in the early stages of decision making of seamless flow initiatives due to their executive role. Thereby, one can conclude that the public terminal concept violates a significant amount of requirements and does not have the required support to change these. Consequently, the public terminal concept is politically infeasible in comparison to the current concept equipped with the seamless flow technology.

3.2.4. Economic

An innovation is economically feasible if it could pass a rudimentary Cost-Benefit Analysis (CBA) [18]. As a result, this feasibility determinant is explored quantitatively which requires a different approach than used for the other feasibility determinants. In a CBA, every consequence of a new alternative is quantified in monetary value [28]. This study contains a financial CBA from the airport's perspective.

Similar to the other determinants, the economic feasibility will be assessed comparatively to the current passenger terminal concept equipped with seamless flow (base case). In order to quantify the differences, the concepts are conceptually implemented on the case study airport RTHA. Thereby, two types of consequences will be distinguished: Equipment and Spatial footprint. Equipment costs can be categorized in two distinctive costs: Purchasing costs (CAPEX) and maintenance costs (OPEX). In this study both biometric gates and security lanes differ between the seamless flow concepts and the base case. The different cost items were monetized with the help of interviewees and desk research. As result the purchasing costs are estimated to be 20,000 euros per biometric gate and 700,000 euros for a complete security lane. Corresponding maintenance costs are respectively: 2,350 euro and 1,500 euro per piece of equipment per year [20].

Besides the difference in equipment numbers, equipment or an area is removed or added between the different concepts. It is assumed that current terminal concept is sufficient to offer the desired optimum Level of Service (LoS) to the passenger. Consequently, spatial benefits will be used to exploit commercial activities which could lead an annual revenue of 1,750 euro per square meter [20]. However, spatial benefits do come with reconstruction costs in order to use the spare terminal space for commercial purposes. Furthermore, the loss of space will result in a lower LoS and needs to be compensated in order to maintain the optimum LoS. This results in enlargement costs of 3,500 euros per square meter [20].

In order to increase external validity, both seamless flow concepts were conceptually implemented considering two different peak hour scenarios. In the simultaneous peak hours scenario, the peak hour for Schengen and non-Schengen flights are on the same time. In different peak hours scenario, the peak hours differ. While the boarding gates are no longer dedicated to one flight type, the different peak hours scenario allows the airport to abolish superfluous boarding gates.

Table 1: Overview costs and benefits seamless flow concepts on RTHA [20]

	Merged Airside concept		**Public Terminal concept**	
	Simultaneous peak hours	***Different peak hours***	***Simultaneous peak hours***	***Different peak hours***
Total costs	356,895	433,545	14,740,617	10,624,757
Total benefits	1,066,760	1,579,386	80000	120,000
Net Present Value (NPV)	709,865	1,145,841	-14,660,618	-10,504,758
Benefit-cost ratio	2.99	3.64	0.005	0.011

When looking at Table 1, it can be concluded that the merged airside concept is beneficial in both scenario's. Thereby, the concept can be seen as economic feasible in comparison to the base case. In both scenario's the benefits significantly outweigh the costs. The public terminal concept is economic infeasible compared to the current concept equipped with seamless flow technology. The costs of equipping each gate with security lanes, terminal enlargement and re-arranging the terminal significantly outweighs the benefits generated out of the fewer biometric gates and the removal of the border control touchpoint and the central security screening. Although, the different peak hour scenario performs significantly better it is still far away from being economic feasible. The presented Net Present Value and Benefit-cost ratio can however not be seen as valuable quantities while each additional year would add more value to the concept and would consequently lead to an increase in the benefit-cost ratio [20]

It can be seen that the benefits of seamless flow are enhanced in the different peak hours scenario on Rotterdam The Hague Airport (RTHA). This could mean that airports with different peak hours for international and domestic (or Schengen and non-Schengen) will thereby perceive more benefits of the constructed concepts than airports with one general peak hour for both passenger types (such as RTHA). While the benefits are the result of multi-deployability of the gates (for different flights) it is expected that the same results do also apply for other airports. Looking at other (bigger) airports, both the access control touchpoint and the border control touchpoint will be larger and will thereby contain more biometric gates. Investment and maintenance benefits as result of removing those physical touchpoints from the passenger terminal will thereby increase on larger airports. Besides that, bigger airports will contain more boarding gates which will further increase the security lane investment costs. Furthermore, bigger airports would operate larger aircraft. The types of aircraft that serve the airport is one of the most important factors for facility sizing [21]. At RTHA the largest operating aircraft is the B737-800 which can carry up to 189 passengers. Other airports could possibly facilitate aircraft which can carry up to 868 passengers (Airbus 380). Consequently, the boarding gate area's will be significantly larger. Altering the spatial footprint of the boarding gate area's significantly influences the outcome of the CBA for airports in the different peak hours scenario [20].

3.3. Success and failure factors

In the previous section, the different feasibility determinants have been elaborated. Thereby, various success and failure factors which influence the adoption of the new seamless flow concepts in the aviation industry have been identified. This section will provide a comprehensive overview in which the identified factors will be discussed and validated.

Table 2: Succes and failure factors identified in system analysis

Feasibility determinants	**Factors**	
	Success	***Failure***
Technical	- Performance of the terminal system - Efficient use of touchpoints	- Desired functionalities - Availability of technology - Underdeveloped technology - Reliability of technology
Social	- Reduced Waiting times - Ease of the processes - Reduced number of contact points - Increased passenger satisfaction	- Privacy concerns
Political	- Pressure from stakeholders	- Conflicting interests of stakeholders - Impact on processes - Impact on security
Economic	- Increased Non-aeronautical revenues - Increased efficiency - Spatial savings - Investment costs	- Terminal expansion - Investment costs - Rearrangement costs

Technical
When looking at the technical determinant, one can conclude that both seamless flow concepts do not require more functionalities of the technology than the current available technology could already provide. The only difference is that both new concepts require a simultaneous check on both boarding pass and travel documentation at one touchpoint or a remote border control process. Both ways are technically feasible while the current available technology could already provide such functionalities. Thereby, the touchpoints are used more efficiently in both the merged airside concept as the public terminal concept. The overall technical feasibility of the seamless flow concept is not proven yet while the availability of data systems and IT infrastructure is unreliable. In terms of performance, the new concept will use the touchpoint more efficiently which will lead to a higher system performance. Thereby, both concepts can be seen as technical feasible.

The interviewees agreed on the observations of this research. It was addressed that the reliability of the technology could have a massive impact on the performance of the system. Whenever technology will break down, the performance of the terminal will significantly decrease. When looking at the public terminal concept, all required passenger checks are executed at the boarding gates. Thereby, a failure at that one touchpoint at the end of the terminal process could disrupt the whole system. While their is no time to rectify such a disruption this will have a massive impact on the systems performance. It is therefore recommended to execute the required processes and checks as early as possible in the terminal concept. Nevertheless, the reliability of the technology will not differ between the base case and the seamless flow concepts. Thereby, the two concepts are technical feasible compared to the base case.

Social
The constructed concepts do amplify the factors which already make the seamless flow concept on current terminal concepts socially feasible. By introducing self-service technology to the airport, the ease of processes will increase, waiting times will reduce and passengers will perceive less stress which will lead to a better passenger satisfaction. When the border control touchpoint is eliminated (as in both constructed concepts) or every check is integrated into one touchpoint (Public terminal concept), the number of contact points decrease and passenger satisfaction will be enhanced even further. In terms of privacy concerns it is assumed that the industry will come up with a suitable privacy policy which will safeguard the privacy of the passengers. Consequently, both concepts can be seen as social feasible.

The positive impact on the passenger experience is also addressed by the interviewees as one of the main benefits of the seamless flow concept. Furthermore, the privacy concerns of the passenger is confirmed to be a major point of interest. It is however expected that the industry will find a suitable solution to deal with the concerns. The interviewee does not expect that the implementation of the seamless flow technology, and thereby the constructed concepts, will be ceased as result of the privacy concerns.

Political
When looking at the stakeholders interests, one can conclude that a seamless flow terminal does conform the industries interests. Looking at the merged airside concept, the design requirement of physically separating domestic and international passenger flows after border control is resolved by re-checking the travel documentation of passengers at the boarding gate. Assuming that the border control process is physically available (integrated into a touchpoint), the merged airside concept can be seen as politically feasible. In order to implement a remote border control process, regulations concerning data sharing need to be altered which is expected to be a capricious process. A remote border control process would thereby make the concept infeasible.

In the public terminal concept, the design requirement to be able to prevent unauthorized persons to access the terminal's secured area's is violated. Integrating all passengers checks into the boarding touchpoint would create a chaotic situation at the boarding gates which will not be supported by both the border guard agency and the airlines. Furthermore, allowing well-wishers to the airports secure area's will make it harder for the border guard agency to control the crowd and maintain law and order within the terminal. This will have a negative impact on the security within the airport terminal. As a result, it is unlikely that the public terminal concept will get the stakeholders support for an alteration of the violated regulations. Moreover, the public terminal concept will not be supported by the important system stakeholders which will form a barrier for implementation.

Next to the confirmation of the research findings, the interviewees emphasized the importance of complying to the interests of the border guard agency. By fully decentralizing the security checks, the border guard staff is required to spread over the terminal. Considering larger airports with finger piers, this would create an infeasible situation in which the staff is continuously on the move between different boarding gates. This will be at the expense of factors such as the occupancy rate at touchpoints and the response time, which can be seen as important factors.

Besides that, it was addressed that the security factor is most important. Currently, the security of the secured area is seen to be relatively in order. Subsequently, the separation of passengers and well-wishers tends to move further on to the entrance of the terminal. The further non-passengers are allowed into the terminal, the unfavorable from security perspective. As a result, allowing non-passengers to a larger part of the terminal, like in the public terminal concept, will not be supported by the border guard agency.

Economic

Looking at the economic determinant, the merged airside concept is economic feasible in comparison to the base case. In both peak hour scenario's, benefits as result of fewer biometric gates and the removal of the border security touchpoint, which will lead to non-aeronautical revenues, significantly outweigh the costs for rearranging the terminal. Furthermore it can be concluded that this result will be amplified in the different peak hours scenario.

On the contrary, the public terminal concept is shown to be economic infeasible in comparison to the base case. Although the reduction in the required number of biometric gates in both scenarios, the benefits are flooded with the investment costs for the additional security lanes. Moreover, the spatial usage of each security lane, will require the airport to enlarge the passenger terminal without increasing the non-aeronautical revenues.

The interviewees confirmed the research findings. Besides that, the inefficiency in the current passenger terminals was emphasized. By duplicating all processes and facilities in the terminal, a lot of money is wasted. Furthermore, the high investment costs for decentralized security screening was addressed. Equipping every gate with security lanes is extremely expensive. Moreover, new terminal space must be build to compensate for the lost space. This is most certainly a showstopper for the implementation of the public terminal concept.

4. Conclusion

The objective of this research is to determine whether seamless flow technology could lead to a new and feasible passenger terminal concept in comparison to the conventional terminal concept equipped with the new technology. Two new concepts were constructed and compared to the base case. In the merged airside concept, the border control is integrated into the access control touchpoint or executed on remote. The public terminal concept contains a large public area after which all required control checks are situated at the boarding gates.

When looking at the two concepts, the interviews and desk research showed that these concepts work and do not require more functionalities of the technology than that the current available technology could already provide. Thereby, both concepts can be seen as technical feasible. Besides that, the introduction of self-service technology, such as seamless flow, will enhance the passenger experience. Furthermore, the waiting times on the airport will decrease which will lead to less stress among the passengers. Concepts which contain fewer touchpoints will amplify these consequences and lead to a further enhancement of the passenger experience. Consequently, both concepts can be seen as socially feasible in comparison to the base case.

As showed in this study, the support of stakeholders, especially the border guard agency, is essential for the adoption of new terminal concepts. When considering a new seamless flow concept, it is thereby recommended to involve the stakeholders within the passenger terminal system as early as possible in decision making processes. In order to be politically feasible, the seamless flow terminal concept should be able to prevent unauthorized persons from entering the terminal's secured area's. Besides that, the physical border control touchpoint should not be placed at the boarding gates. As elaborated within the public terminal concept section, this could create chaotic situations which are not desirable for the border guard agency, airlines and passengers. Lastly, current regulations won't let airports require passengers to share personal data prior to arriving at the airport touchpoint. This implies that a physical border control touchpoint must be present within the passenger terminal.

Regarding the financial aspect of the seamless flow concepts, it can be concluded that the non-aeronautical revenues and the investment in security lanes significantly influence the economic feasibility. A concept which brings spatial benefits without decentralizing the security screening section, such as the merged airside concept, can therefore be seen as economic feasible. Spatial benefits could lead to a significant increase in non-aeronautical revenues which will quickly compensate for the initial investment costs. These benefits will be amplified for airports with different peak hours for international and domestic flights (or Schengen and non-Schengen).

On the contrary, concepts in which the security screening will be decentralized and moved to the boarding gates, such as the public terminal concept, have to deal with overwhelming investment costs in security lanes. Consequently, potential benefits of removing the physical border control touchpoint and the lower investment in biometric gates can not compensate for the costs. This makes such concepts economic infeasible in comparison to the base case.

One can conclude that the seamless flow technology can lead to feasible airport passenger terminal concepts in comparison to the conventional terminal concept equipped with seamless flow technology. The merged airside concept will enhance the passenger experience while using the airport infrastructure more efficiently. Consequently, it can be recommended for airport owners to consider such a terminal concept whenever the seamless flow technology is found to be ready for implementation on civil airports.

5. Recommendations for further research

This study mainly contributes as an exploratory research to the potential of new terminal concepts based on new technology. To start, it is recommended to do further research applicability of the theoretical framework on this type of innovation. By applying the framework on similar innovations within the aviation industry, a better understanding and interpretations of the different feasibility factors can be achieved.

Besides that, it is recommended to do simulation studies on the impact of implementing the new biometric equipment on the terminal system. Thereby, more insights will be given into the effects on the passenger journey and into the potential bottlenecks of the new concept which will give more substantiated results.

Moreover, it is interesting to do further research on the impact of the new concepts on larger airports which contain for example multiple terminals, multi-level swing gates and transfer passengers. These airport characteristics bring new challenges and opportunities which could lead to different results than seen at the relatively small case study airport of this research.

Furthermore, in-terminal alterations such as the removal of gate or terminal expansion, could also have consequences for the environment around the passenger terminal. In order to create a more complete overview of the consequences of a new terminal concept for the airport, it is recommended to do further research on the consequences of the seamless flow concept on the outside of the terminal.

Lastly, it is recommended to do more in-depth research on the current applicable legislation within the passenger terminal system.

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B Terminal Design

In this appendix, information used in section 3 is elaborated. First, the Level of Service guidelines will be presented in subsection B.1 after which the regulation principles are provided in subsection B.2.

B.1 Level of Service

Planning—Passenger Terminal

Exhibit 3.4.5.3: LoS Guidelines for Airport Terminal Facilities

LoS Guidelines		SPACE GUIDELINES [sqm/PAX]			MAXIMUM WAITING TIME GUIDELINES Economy Class [minutes]			MAXIMUM WAITING TIME GUIDELINES Business Class / First Class / Fast Track [minutes]			OTHER GUIDELINES & REMARKS		
	LoS Parameter:	Over-Design	Optimum	Sub-Optimum	Over-Design	Optimum	Sub-Optimum	Over-Design	Optimum	Sub-Optimum	Over-Design	Optimum	Sub-Optimum
Public Departure Hall		> 2.3	2.0 - 2.3	< 2.0		n/a			n/a		Optimum proportion of seated occupants: 15 - 20%*		
Check-In	Self-Service Kiosk (Boarding Pass / Bag Tagging)	> 1.8	1.3 - 1.8	< 1.3	< 1	1 - 2	> 2	< 1	1 - 2	> 2			
	Bag Drop Desk (queue width 1.4 - 1.6m)	> 1.8	1.3 - 1.8	< 1.3	< 1	1 - 5	> 5	< 1	1 - 3	> 3			
	Check-in Desk (queue width: 1.4 - 1.6m)	> 1.8	1.3 - 1.8	< 1.3	< 10	10 - 20	> 20	< 3	Business Class 3 - 5	> 5			
								< 1	First Class 1 - 3	> 3			
Security Control (queue width: 1.2m)		> 1.2	1.0 - 1.2	< 1.0	< 5	5 - 10	> 10	< 1	Fast Track 1 - 3	> 3			
Emigration Control (Outbound Passport Control) (queue width: 1.2m)	Staffed Emigration Desk	> 1.2	1.0 - 1.2	< 1.0	< 5	5 - 10	> 10	< 1	Fast Track 1 - 3	> 3			
	Automatic Border Control	> 1.2	1.0 - 1.2	< 1.0	<1	1 - 5	>5		n/a				
Gate Holdrooms ***	Seating	> 2.2	1.8 - 2.2	< 1.8		n/a			n/a		Optimum proportion of seated occupants: 50 - 70%*		
	Standing	> 1.5	1.2 - 1.5	<1.2									
Immigration Control (Inbound Passport Control) (queue width: 1.2m)	Staffed Immigration Desk	> 1.2	1.0 - 1.2	< 1.0	< 5	5 - 10	> 10	<1	Fast Track 1-5	>5			
	Automatic Border Control	> 1.2	1.0 - 1.2	< 1.0	<1	1 - 5	>5		n/a				
Baggage Reclaim	Narrow Body Aircraft	> 1.7	1.5 - 1.7	< 1.5	< 0	0 / 15	> 15	< 0	0 / 15	> 15	The first waiting time value relates to "first passenger to first bag". The second waiting time value relates to "last bag on belt" (counting from the first bag delivery).**		
	Wide Body Aircraft	> 1.7	1.5 - 1.7	< 1.5	< 0	0 / 25	> 25						
Customs Control		> 1.8	1.3 - 1.8	< 1.3	< 1	1 - 5	> 5	< 1	1 - 5	> 5	Waiting times refer to a procedure when 100% of the passengers are being checked by Customs		
Public Arrival Hall		> 2.3	2.0 - 2.3	< 2.0		n/a			n/a		Optimum proportion of seated occupants: 15 - 20%*		

* Lower limit to be considered only if extensive food & beverage seating is provided (within concession zones).

** The time between the first passenger arriving at the reclaim belt and the first baggage arriving on the reclaim belt should be zero minutes, in order to maximize the efficiency of checking a hold bag for the passenger. Bags delivered to the reclaim prior to passengers arriving at the reclaim belt (negative waiting times) can be considered over-design. The time to deliver all bags from a flight should be no more than last-bag delivery:
+15 minutes for narrow body aircraft flights and
+25 minutes for a wide body aircraft flights.

*** The space requirements for Gate Holdrooms have been updated incorporating the Maximum Occupancy factor in the space requirements.

Note with regard to chapter 3.4.5.2 - LoS Category UNDER-PROVIDED: For processing facilities, the LoS UNDER-PROVIDED only results when both space and waiting time parameters are sub-optimum. For the boarding gate lounge and holdrooms, the LoS UNDER-PROVIDED only results when the space parameter and seating rate is sub-optimum. For the public departure and arrivals halls, the LoS UNDER-PROVIDED only results when the space per occupant is 80% or less than the targeted optimum LoS parameter.

Source: IATA

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Figure 18: Level of Service Guidelines (IATA & ACI, 2019)

B.2 Regulation principles

In this subsection, the principles used in subsection 3.2 and section 5 are addressed. Both the annexes represent international regulations, where EU regulations and national regulations represent local regulations for the case study, Rotterdam The Hague Airport.

B.2.1 ICAO regulations

ICAO Annex 9: Facilitation

2.10 When a particular document is transmitted by or on behalf of the aircraft operator and received by the public authorities in electronic form, the Contracting State shall not require the presentation of the same document in paper form.

3.2 In developing procedures aimed at the efficient application of border controls on passengers and crew, Contracting States shall take into account the application of aviation security, border integrity, narcotics control and immigration control measures, where appropriate.

3.6 Contracting States shall not require visitors travelling by air, rightfully holding valid passports recognized by the receiving State and holding valid visas, where appropriate, to present any other document of identity.

3.11 All passports issued by Contracting States shall be machine readable in accordance with the specifications of Doc 9303, Part 4.

3.32 Contracting States shall assist aircraft operators in the evaluation of travel documents presented by passengers, in order to deter fraud and abuse.

3.34.4 Recommended Practice. Each Contracting State should consider the introduction of Automated Border Control (ABC) systems in order to facilitate and expedite the clearance of persons entering or departing by air.

3.34.6 Recommended Practice. Contracting States utilizing ABC systems should ensure that gates are adequately staffed while operational to ensure a smooth passenger flow and respond rapidly to safety and integrity concerns in the event of a system malfunction.

3.42 Except in special circumstances, Contracting States shall not require that travel documents or other identity documents be collected from passengers or crew before they arrive at the passport control points.

3.47 Except in special circumstances, Contracting States shall make arrangements whereby the identity documents of visitors need to be inspected only once at times of entry and departure.

6.21 Contracting States shall make arrangements for a sufficient number of control channels so that clearance of inbound passengers and crew may be obtained with the least possible delay. Additional channel(s) shall be available if possible to which complicated cases may be directed without delaying the main flow of passengers.

ICAO Annex 17: Security

2.4.1 Each Contracting State shall ensure that requests from other Contracting States for additional security measures in respect of a specific flight(s) by operators of such other States are met, as far as may be practicable. The requesting State shall give consideration to alternative measures of the other State that are equivalent to those requested.

2.4.2 Each Contracting State shall cooperate with other States in the development and exchange of information concerning national civil aviation security programmes, training programmes and quality control programmes, as necessary.

2.4.3 Each Contracting State shall establish and implement procedures to share with other Contracting States threat information that applies to the aviation security interests of those States, to the extent practicable.

2.4.4 Each Contracting State shall establish and implement suitable protection and handling procedures for security information shared by other Contracting States, or security information that affects the security interests of other Contracting States, in order to ensure that inappropriate use or disclosure of such information is avoided.

2.5.1 Recommendation. Each Contracting State should promote research and development of new security equipment, processes and procedures which will better achieve civil aviation security objectives and should cooperate with other Contracting States in this matter.

3.1.1 Each Contracting State shall establish and implement a written national civil aviation security programme to safeguard civil aviation operations against acts of unlawful interference, through regulations, practices and procedures which take into account the safety, regularity and efficiency of flights.

3.1.2 Each Contracting State shall designate and specify to ICAO an appropriate authority within its administration to be responsible for the development, implementation and maintenance of the national civil aviation security programme.

3.1.5 Each Contracting State shall require the appropriate authority to define and allocate tasks and coordinate activities between the departments, agencies and other organizations of the State, airport and aircraft operators, air traffic service providers and other entities concerned with or responsible for the implementation of various aspects of the national civil aviation security programme.

3.1.6 Each Contracting State shall establish a national aviation security committee or similar arrangements for the purpose of coordinating security activities between the departments, agencies and other organizations of the State, airport and aircraft operators, air traffic service providers and other entities concerned with or responsible for the implementation of various aspects of the national civil aviation security programme.

3.1.7 Each Contracting State shall require the appropriate authority to ensure the development and implementation of a national training programme for personnel of all entities involved with or responsible for the implementation of various aspects of the national civil aviation security programme. This training programme shall be designed to ensure the effectiveness of the national civil aviation security programme.

3.1.8 Each Contracting State shall ensure the development and implementation of training programmes and an instructor certification system in accordance with the national civil aviation security programme.

3.2.1 Each Contracting State shall require each airport serving civil aviation to establish, implement and maintain a written airport security programme appropriate to meet the requirements of the national civil aviation security programme.

4.1.2 Recommendation. Each Contracting State should promote the use of random and unpredictable security measures. Unpredictability could contribute to the deterrent effect of security measures. 4.1.3 Recommendation. Each Contracting State should consider integrating behaviour detection into its aviation security practices and procedures.

4.2.1 Each Contracting State shall ensure that the access to airside areas at airports serving civil aviation is controlled in order to prevent unauthorized entry.

4.2.2 Each Contracting State shall ensure that security restricted areas are established at each airport serving civil aviation designated by the State based upon a security risk assessment carried out by the relevant national authorities.

4.4.4 Each Contracting State shall ensure that passengers and their cabin baggage which have been screened are protected from unauthorized interference from the point of screening until they board their aircraft. If mixing or contact does take place, the passengers concerned and their cabin baggage shall be re-screened before boarding an aircraft.

4.4.5 Each Contracting State shall establish at an airport measures for transit operations to protect transit passengers' cabin baggage from unauthorized interference and protect the integrity of the security of the airport of transit.

4.5.2 Each Contracting State shall ensure that all hold baggage to be carried on a commercial aircraft is protected from unauthorized interference from the point it is screened or accepted into the care of the carrier, whichever is earlier, until departure of the aircraft on which it is to be carried. If the integrity of hold baggage is jeopardized, the hold baggage shall be re-screened before being placed on board an aircraft.

4.5.3 Each Contracting State shall ensure that commercial air transport operators do not transport the baggage of persons who are not on board the aircraft unless that baggage is identified as unaccompanied and subjected to appropriate screening.

4.8.2 Each Contracting State shall ensure that security measures are established for landside areas to mitigate the risk of and to prevent possible acts of unlawful interference in accordance with risk assessments carried out by the relevant authorities or entities.

4.8.3 Each Contracting State shall ensure coordination of landside security measures in accordance with Standards 3.1.6, 3.2.2 and 3.2.3 between relevant departments, agencies, other organizations of the State, and other entities, and identify appropriate responsibilities for landside security in its national civil aviation security programme.

B.2.2 European Union Regulations

Article 35
1. Taking into account the objectives and principles set out in Articles 1 and 4, and in particular the nature and risk of the activity concerned, the implementing acts referred to in Article 36 may require organisations involved in the design, production and maintenance of safety related aerodrome equipment used or intended for use at aerodromes subject to this Regulation to:
(a) declare that such equipment complies with the detailed specifications established in accordance with implementing acts referred to in Article 36; or
(b) hold a certificate in respect of that safety-related aerodrome equipment.

2. The certificate referred to in point (b) of paragraph 1 of this Article shall be issued upon application, when the applicant has demonstrated that the equipment complies with the detailed specifications established in accordance with implementing acts referred to in Article 36 adopted to ensure compliance with the essential requirements referred to in Article 33.

Article 37
1. Organisations responsible for the operation of aerodromes shall be subject to certification and shall be issued with a certificate. That certificate shall be issued upon application, when the applicant has demonstrated that it complies with the delegated acts referred to in Article 39 adopted to ensure compliance with the essential requirements referred to in Article 33. The certificate shall specify the privileges granted to the certified organisation and the scope of the certificate.

2. Organisations responsible for the provision of groundhandling services and AMS at aerodromes subject to this Regulation shall declare their capability, and the availability to them of the means, to discharge the responsibilities associated with the services provided in compliance with the essential requirements referred to in Article 33.

Article 69
1. The Agency and the national competent authorities may allocate their tasks related to certification and oversight under this Regulation to qualified entities that have been accredited in accordance with the delegated acts referred to in point (f) of Article 62(13) or the implementing acts referred to in point (e) of the first subparagraph of Article 62(14) as being compliant with the criteria set out in Annex VI. Without prejudice to paragraph 4, the Agency and the national competent authorities which make use of the qualified entities shall establish a system for that accreditation and for the assessment of the compliance of qualified entities with those criteria, both at the moment of accreditation and continuously thereafter. 22.8.2018 EN Official Journal of the European Union L 212/51 A qualified entity shall be accredited either individually by the Agency or by a national competent authority, or jointly by two or more national competent authorities or by the Agency and one or more national competent authorities.

Annex VII
1.3.2. Safety-related aerodrome equipment shall function as intended under the foreseen operating conditions. Under operating conditions or in case of failure, safety-related aerodrome equipment shall not cause an unacceptable risk to aviation safety.

B.2.3 National Regulations (the Netherlands)

Article 37b
1. De exploitant van een luchtvaartterrein wijst de delen daarvan aan: a.die door het publiek slechts betreden mogen worden, indien de betrokken personen in het bezit zijn van een geldig reisbiljet of een daartoe afgegeven persoonsgebonden kaart; b.die niet voor het publiek toegankelijk zijn; c.die slechts voor een beperkte categorie van de op het luchtvaartterrein werkzame personen toegankelijk zijn; d.die voor het publiek toegankelijk zijn.

Article 37c
1 De exploitant van een luchtvaartterrein treft de nodige voorzieningen om te voorkomen dat personen of bagage aan boord van een luchtvaartuig gaan zonder dat deze zijn onderworpen aan een controle overeenkomstig paragraaf 3.

2 De exploitant van een luchtvaartterrein is verplicht te beschikken over: a.voldoende en passende detectieapparatuur voor de uitoefening van de controle door het beveiligingspersoneel overeenkomstig paragraaf 3; b.een ruimte voor vertrekkende passagiers die zodanig is ingericht dat gecontroleerde passagiers en handbagage zijn afgeschermd en een vermenging met niet gecontroleerde personen en voorwerpen niet mogelijk is; c.een ruimte voor onderzoek van bagage en dieren bestemd voor vervoer en d.een afsluitbare en beveiligde ruimte bestemd voor het bewaren van verdachte bagage.

Artikel 37f
1 De exploitant van een luchtvaartterrein doet de personen die als passagiers aan boord gaan van een luchtvaartuig, alsmede hun handbagage, door het beveiligingspersoneel controleren op de aanwezigheid van voor bedreiging geschikte voorwerpen.

2 De exploitant van een luchtvaartterrein kan: a.voor vervoer met een passagiersvlucht aangeboden ruimbagage door het beveiligingspersoneel doen controleren op de aanwezigheid van voor bedreiging geschikte voorwerpen

Artikel 37g
1 De luchtvaartmaatschappij draagt zorg dat geen ruimbagage aan boord is die niet toebehoort aan de aan boord zijnde passagiers. Bij regeling van Onze Minister van Justitie, in overeenstemming met Onze Minister, kan hiervoor vrijstelling worden verleend. Daarbij worden voorschriften gegeven als vervangende waarborg met het oog op de beveiliging. In bijzondere gevallen kan Onze Minister van Justitie ontheffing verlenen.

Artikel 37hc
De personen die aan boord gaan van een luchtvaartuig, zijn verplicht: a.zich te onderwerpen aan een controle als bedoeld in artikel 37f, eerste lid en tweede lid, onderdeel b en b.medewerking te verlenen aan de handelingen ter uitvoering van de verplichting, bedoeld in artikel 37hb, onderdeel a tot en met c.

B.2.4 Schengen Area

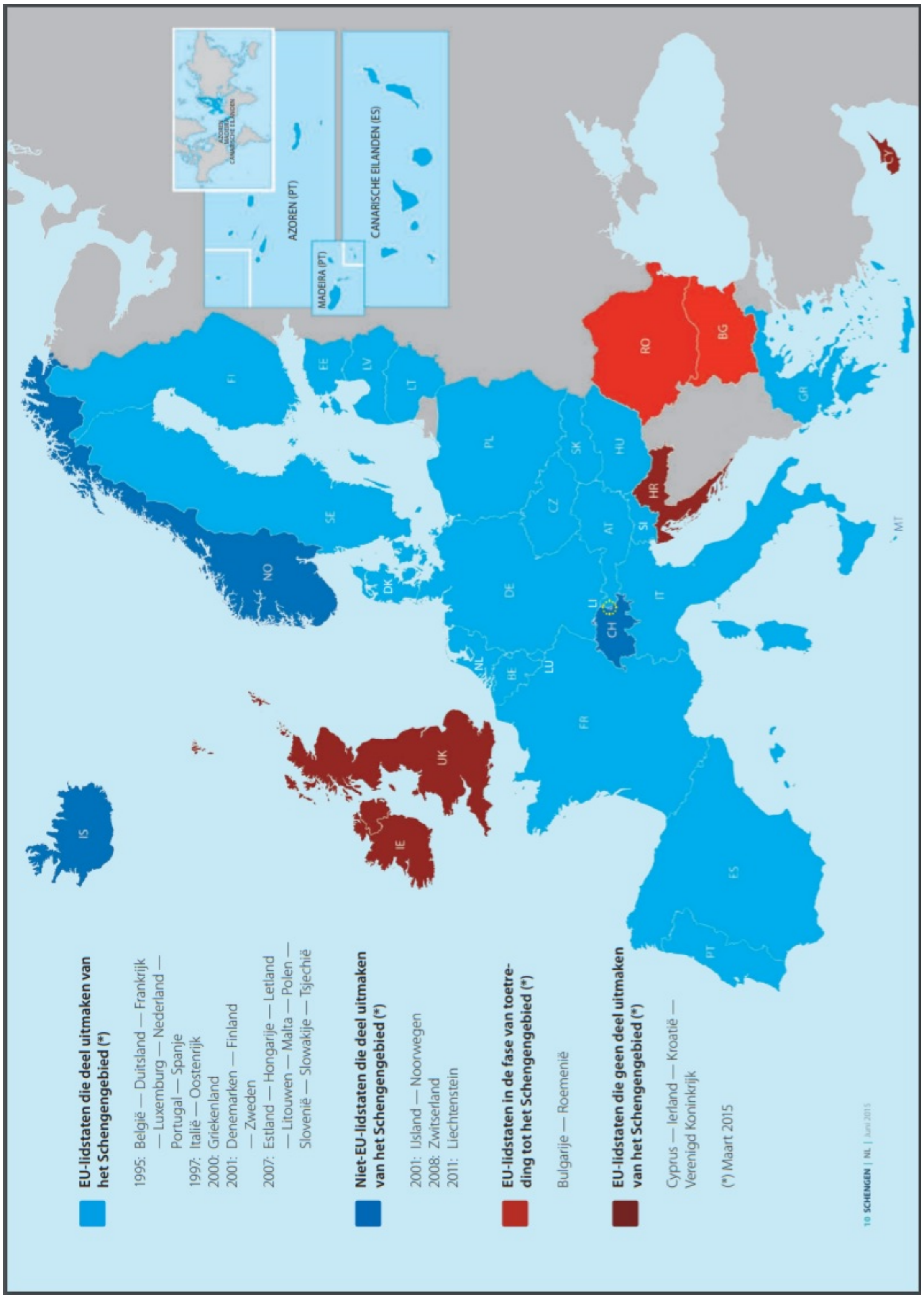


Figure 19: Schengen Area

C Rotterdam The Hague Airport

In this section, results and assumptions used in section 4 are elaborated. The information used for this analysis is gathered from Rotterdam The Hague Airport (2020b) and the capacity analysis of NACO (2020) commissioned for Rotterdam The Hague Airport.

C.1 Demand

In Figure 20, the mentioned growth in traffic demand of the last decade for RTHA is presented.

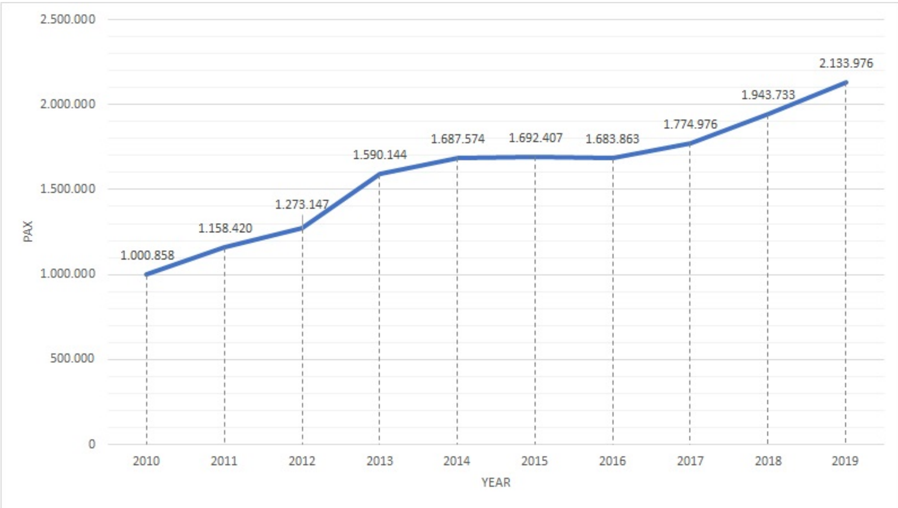


Figure 20: Annual passengers RTHA (PAX) (Rotterdam The Hague Airport, 2020b)

C.2 Peak Hour

As mentioned in subsection 4.2, the peak hour data is retrieved from recent terminal capacity analysis, executed by NACO (2020) for RTHA. In Figure 21, the used method to compute the representative day for 2021 is graphically elaborated.

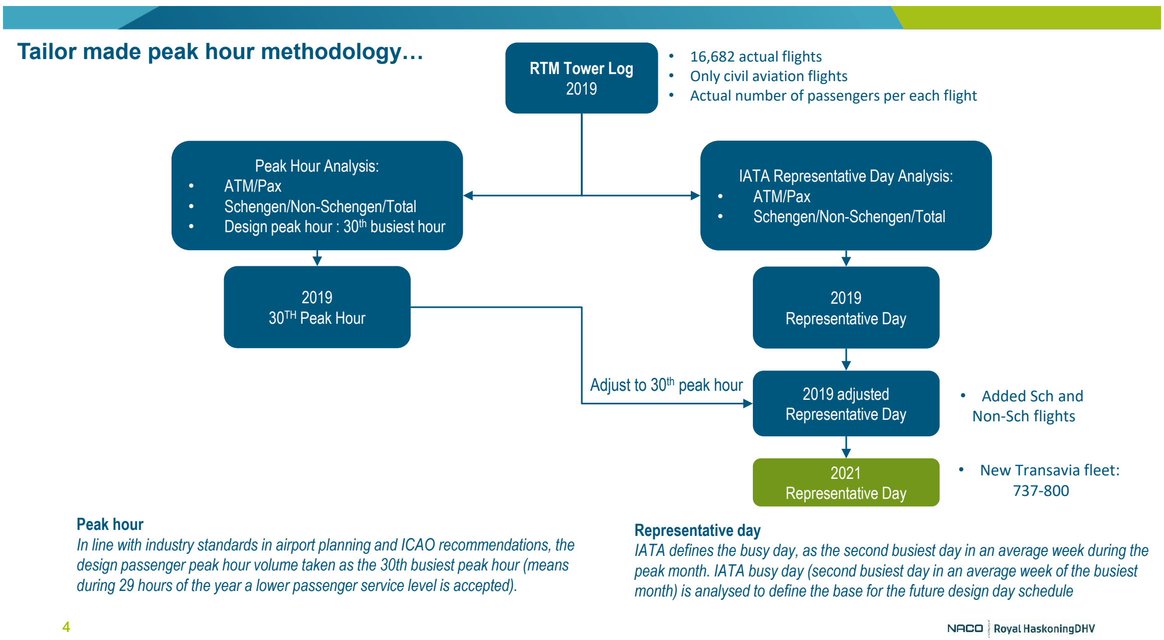
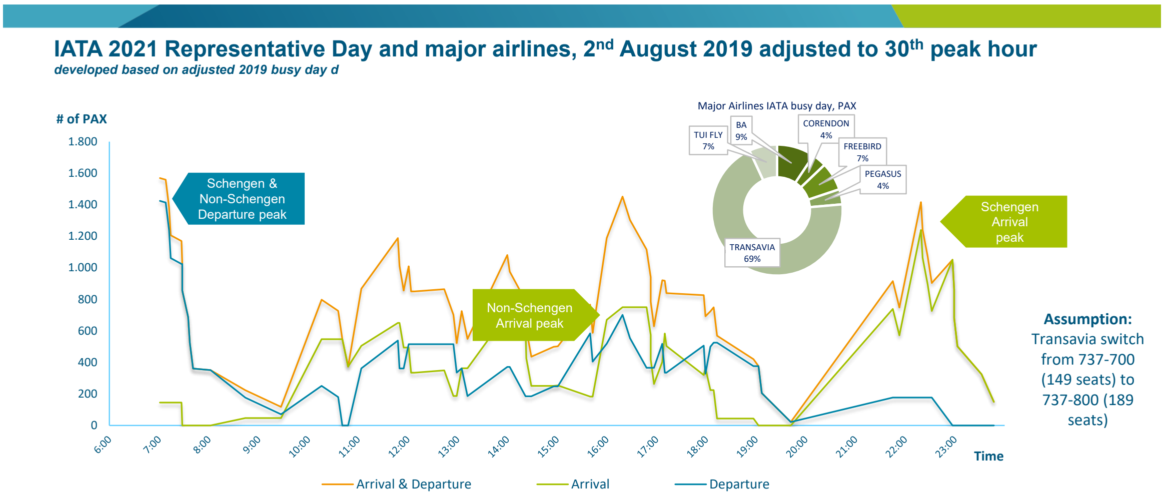


Figure 21: Method used to compute representative day in 2021 (NACO, 2020)

As can be seen in Figure 21, two different processes can be distinguished within the used method: peak hour analyses and representative day analysis. In the peak hour analysis, the design passenger peak hour volume is determined. In line with ICAO recommendations and industry standards, the 30th busiest peak hour of the year is the leading peak hour for airport design. Thereby, a lower passenger service level is accepted during 29 hours per year (NACO, 2020).
In the representative day analysis, a base for the design day schedule is defined. As stated by IATA, the representative day is the second busiest day in an average week during the peak month. As identified in subsection 4.2, the peak month of RTHA in 2019 is August.

Thereafter, the identified representative day is altered by adding the predicted number of three extra flights per day. Furthermore, the representative day is adjusted to match the design peak hour, as identified in the peak-hour analysis. Lastly, the adjusted representative day is altered by adding the extra passengers, coming forth out new, and bigger, Transavia aircraft. In the latter step, load factors statistics are taken into account to give a genuine representation of the future situation (NACO, 2020). In Figure 22, the results of this process are presented.



	Total Pax	Start Peak	End Peak	Non-Sch	Start Peak	End Peak	Sch	Start Peak	End Peak
Arrival & Departure	1,569	7:01	8:00	688	11:48	12:47	1,063	22:19	23:18
Arrival	**1,240**	22:19	23:18	**495**	16:00	16:59	**1,063**	22:19	23:18
Departure	**1,424**	7:01	8:00	**374**	7:01	8:00	**1,050**	7:01	8:00

2

Figure 22: Representative day RTHA 2021 (NACO, 2020)

C.3 Facilities

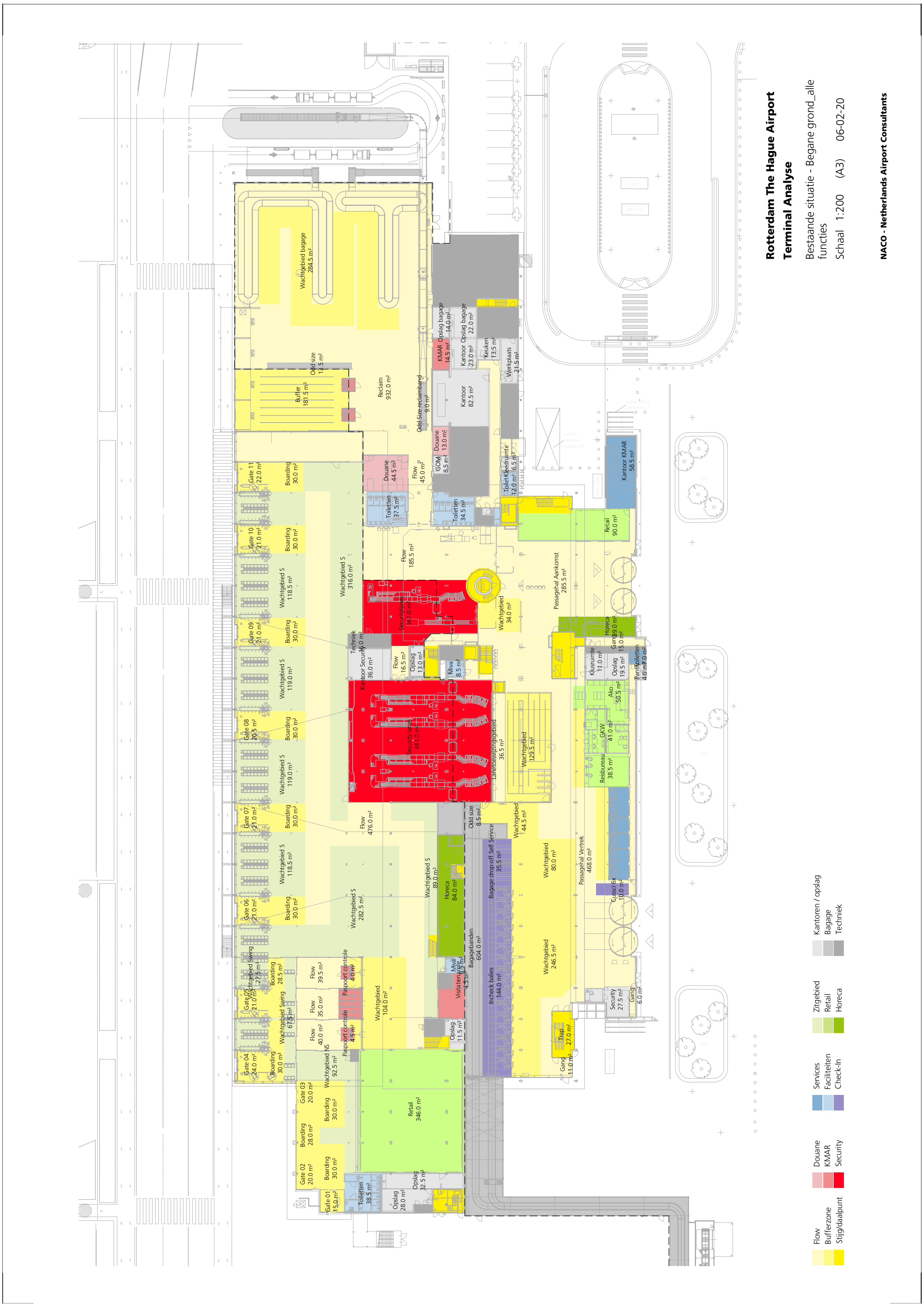


Figure 23: Layout RTHA end 2020 including functionalities (NACO, 2020)

D Seamless flow concepts

In this section, additional information on the seamless flow concepts, as introduced in section 5, is presented. First the current equipment of Rotterdam The Hague Airport will be discussed. Thereafter, details about the seamless flow equipment will be elaborated. Finally, additional information, such as assumptions and calculations, on the conceptual implementation of the concepts on RTHA are provided.

D.1 Current equipment

To determine the number of equipment in the seamless flow concepts, first the current equipment on Rotterdam The Hague Airport must be analyzed. In order to do so, the recent capacity study of NACO (2020) is used to retrieve the required information. In Table 24, the information of the current equipment of Rotterdam The Hague Airport is presented.

Table 24: RTHA equipment characteristics (NACO, 2020)

Process	**Equipment**	**Number**	**Processing time (seconds)**	**Space usage (m2 per unit)**
Check-in / Baggage drop	Kiosk	0	60	N/A
	Counter	16	90	9
	SSDOP	5	73	7.1
Access control	Gates	4	6	3
Security	Security lane	6	22.5	115
Border control	Counter	4	30	2.1
	E-gate	5	30	4
Boarding	Touchpoint	N/A	N/A	21

As earlier mentioned, the equipment characteristics are gathered from the capacity analysis by NACO (NACO, 2020). Within this analysis, different scenario's were simulated. In every scenario, the available equipment composition was altered and the performance was analyzed. The presented data in Table 24 is the equipment composition in which the best passenger experience is achieved (considering the current available equipment). Furthermore, the space usage of each type of equipment is determined by the current surface reserved for the equipment divided by the number of lanes or gates. For example the space usage of a security lane is calculated as follows:

$$Space\,per\,lane = Total\ space\ for\ security\,touchpoint/Number\ of\ security\ lanes$$

$$Space\,per\,lane = 461.0/4$$

$$Space\,per\,lane = 115.25\,m^2$$

D.2 Seamless flow equipment

In Table 25 the characteristics of the seamless flow equipment are presented. As stated by the product manager of SITA, the processing time of each touchpoint differs while the system needs to check different data. While both product manufacturing companies and airport representatives were not willing to share the performance numbers of the system, these are based on the little information found in the desk research and assumptions of NACO experts.

According to SITA (2020), their smart path solution could board up to 240 passengers in 10 minutes. This will correspond with one passenger every 2.5 seconds. While this is the situation is the optimum performance the processing time will be rounded up to 3 seconds per passenger. At the boarding touchpoint it is checked whether the passengers have a valid boarding pass by capturing their biometric and retrieving their travel documentation. While the same process is executed at the access control touchpoint, it is assumed that the processing times are equal. Furthermore, both NACO specialists and the IATA and ACI (2019) stated that the SSDOP time is 60 seconds per passenger (considering the use of passenger biometrics). The time spend at a kiosk and at a counter are retrieved from the capacity study from NACO (2020). Lastly, the border control processing time is assumptive and defined together with NACO experts. Thereby it is assumed that border control is executed at the touchpoint and not on remote as discussed in subsection 5.2.

Table 25: Seamless flow equipment

Process	Equipment	Processing time (seconds)
Check-in/Enrollment / Baggage drop	Kiosk	60
	Counter	90
	SSDOP	60
Access control	Biometric gate	3
Border control	Biometric gate	10
Boarding	Biometric gate	3

In Table 25, only the processing times of the seamless flow equipment at different touchpoints are presented. Based on statements of both SITA and the gate manufacturer, as presented in Appendix F, it is assumed that the space usage of a biometric solution is the same as that of a regular automatic gate while it is simply integrated or an add-on.

D.3 Current concept equipped with seamless flow technology

Within this study, the current airport equipment with the seamless flow equipment forms the base case. Consequently, the constructed seamless flow concepts will be compared to this terminal concept.

In this concept, the processes of the current terminal concept are equipped with seamless flow technology. The desired processing performance is determined by using the in subsection 4.3 identified KPI's and the capacity study of NACO (2020). As result, the sufficient number of equipment for each touchpoint is calculated. Underneath, each calculation is either provided or discussed. In Table 8 an overview of the equipment is presented.

Looking at the number of Self-Service baggage Drop-Off Points (SSDOP), one can notice that the required number of equipment remains the same. This is due to the minor reduction in processing time (from 73 to 60 seconds). Considering the capacity analysis of NACO (2020), the usage of 5 conventional SSDOP's delivers an waiting time advantage which enhances the passenger experience. Five SSDOP's are capable of handling approximately 62 passengers per 15 minutes. If the new equipment must comply to this performance the following calculation can be used:

$$Desired\,handling\; = handling\,per\,machine\; * Number\;of\;machines$$
$$62 = (900/60) * X$$
$$X = 62/15 = 4.13$$

Consequently, 5 SSDOP machines are required to maintain the same service level.

Besides the number of SSDOP's, one can notice a decrease in the number of access control gates. Due to the 50% reduction in processing time, the four automatic gates can be replaced by 2 biometric gates without degrading the passenger service level.

When looking at the border control section, NACO's simulation already showed that the application of four manned counters already complies to the set KPI of the maximum waiting time of 10 minutes (subsection 4.3). For automatic gates, the maximum waiting time is set to 5 minutes. While the seamless flow concept only uses automatic gates, this KPI is adopted. In order to comply, the total border control touchpoint must be able to handle approximately 150 PAX per 15 minutes NACO (2020). Now the number of equipment can be calculated as follows:

$$Desired\,handling\; = handling\,per\,machine\; * number\;of\;machines$$
$$150 = (900/10) * X$$
$$X = 150/90 = 1.67$$

Consequently, in order to comply to the set service standards, the border control touchpoint must contain two biometric gates.

Lastly, the boarding gates will be equipped with biometric gates. In order to determine the number of gates a maximum boarding time of 20 minutes is set. Within this time window, all passengers must be able to board. Considering the new Transavia aircraft (B737-800), this correspondents with 189 passengers. The number of biometric gates at the boarding gates can be determined as follows:

$$Desired\,handling\; = handling\,per\,machine\; * number\,of\,machines$$

$$X = (1200/189)/(60/3)$$

$$X = 6.35/20 = 0.32$$

Thereby, only one biometric gate is required at each gate. This corresponds to a total of 11 biometric gates.

D.4 Scenario's

	ScheduleDate	ScheduleTime	Airline	Alliance	DomesticStatus	FlightDirection	PaxCount	AircraftType	Country	AirportCode	Gate	Belt
Ochtendpiek S + NS Vertrek	2-8-2019	7:01	TRANSAVIA	LCC	Schengen	D	185	B737W8	ES	GRO	A10	
	2-8-2019	7:08	TRANSAVIA	LCC	Non-Schengen	D	175	B737W8	HR	SPU	A4	
	2-8-2019	7:12	TRANSAVIA	LCC	Schengen	D	178	B737W8	FR	MPL	A8	
	2-8-2019	7:14	BA	One World	Non-Schengen	D	37	ERJ190	GB	LCY	A3	
	2-8-2019	7:27	FREEBIRD	LCC	Turkey / Marocco	A	145,000000	A320-2	TR	ASR	NSchBus	Belt1
	2-8-2019	7:28	TRANSAVIA	LCC	Schengen	D	169	B737W8	IT	PSA	A6	
	2-8-2019	7:28	TRANSAVIA	LCC	Schengen	D	169	B737W8	IT	PSA	A9	
	2-8-2019	7:35	TRANSAVIA	LCC	Non-Schengen	D	162	B737W8	TR	AYT	A2	
	2-8-2019	7:37	TRANSAVIA	LCC	Schengen	D	164	B737W8	PT	FAO	A7	
	2-8-2019	7:41	TUI FLY	LCC	Schengen	D	186	B737W8	ES	PMI	A5	
	2-8-2019	8:02	TRANSAVIA	LCC	Schengen	D	175	B737W8	ES	AGP	A10	
	2-8-2019	8:44	TRANSAVIA	LCC	Non-Schengen	D	176	B737W8	MA	TNG	A4	
	2-8-2019	9:27	BA	One World	Non-Schengen	A	47,000000	ERJ190	GB	LCY	NSchBus	Belt2
	2-8-2019	10:16	BA	One World	Non-Schengen	D	71	ERJ190	GB	LCY	A3	
	2-8-2019	10:36	FREEBIRD	LCC	Non-Schengen	D	180	A320-2	MA	AHU	A4	
	2-8-2019	10:41	CORENDON	LCC	Non-Schengen	A	174,000000	B737W8	TR	AYT	NSchBus	Belt1
	2-8-2019	10:48	TRANSAVIA	LCC	Schengen	A	184	B737W8	FR	MPL	SchBus	Belt2
	2-8-2019	11:04	TRANSAVIA	LCC	Schengen	A	189	B737W8	ES	GRO	SchBus	Belt1
	2-8-2019	11:48	CORENDON	LCC	Non-Schengen	D	177	B737W8	TR	AYT	A3	
	2-8-2019	11:50	TRANSAVIA	LCC	Schengen	A	156	B737W8	ES	ALC	SchBus	Belt2
	2-8-2019	11:55	TRANSAVIA	LCC	Schengen	D	185	B737W8	ES	IBZ	A8	
	2-8-2019	12:01	TRANSAVIA	LCC	Schengen	A	160	B737W8	IT	PSA	SchBus	Belt1
	2-8-2019	12:04	TRANSAVIA	LCC	Non-Schengen	D	176	B737W8	HR	PUY	A4	
	2-8-2019	12:08	TRANSAVIA	LCC	Non-Schengen	A	173,000000	B737W8	HR	SPU	NSchBus	Belt2
	2-8-2019	12:44	PEGASUS	LCC	Turkey / Marocco	A	162,000000	A320N	TR	ASR	NSchBus	Belt1
	2-8-2019	12:55	TRANSAVIA	LCC	Schengen	D	180	B737W8	ES	GRO	A6	
	2-8-2019	12:59	TRANSAVIA	LCC	Non-Schengen	D	159	B737W8	HR	DBV	A3	
	2-8-2019	13:05	TRANSAVIA	LCC	Schengen	D	176	B737W8	ES	PMI	A9	
	2-8-2019	13:12	TUI FLY	LCC	Schengen	A	187	B737W8	ES	PMI	SchBus	Belt2
	2-8-2019	14:00	TRANSAVIA	LCC	Schengen	A	176	B737W8	PT	FAO	SchBus	Belt1
	2-8-2019	14:03	PEGASUS	LCC	Turkey / Marocco	D	186	A320N	TR	ASR	A4	
	2-8-2019	14:22	TRANSAVIA	LCC	Schengen	A	179	B737W8	GR	HER	SchBus	Belt2
	2-8-2019	14:23	TRANSAVIA	LCC	Schengen	A	175	B737W8	ES	AGP	SchBus	Belt1
	2-8-2019	14:29	TUI FLY	LCC	Non-Schengen	D	185	B737W8	TR	AYT	A3	
	2-8-2019	14:56	TRANSAVIA	LCC	Non-Schengen	A	180,000000	B737W8	MA	TNG	NSchBus	Belt2
	2-8-2019	15:01	BA	One World	Non-Schengen	A	71,000000	ERJ190	GB	LCY	NSchBus	Belt1
	2-8-2019	15:40	TRANSAVIA	LCC	Schengen	D	179	B737W8	GR	CFU	A7	
	2-8-2019	15:43	BA	One World	Non-Schengen	D	69	ERJ190	GB	LCY	A4	
Middagpiek NS aankomst	2-8-2019	16:00	TRANSAVIA	LCC	Non-Schengen	A	183,000000	B737W8	TR	AYT	NSchBus	Belt2
	2-8-2019	16:19	TRANSAVIA	LCC	Schengen	D	148	B737W8	PT	FAO	A5	
	2-8-2019	16:28	TRANSAVIA	LCC	Schengen	D	188	B737W8	ES	AGP	A10	
	2-8-2019	16:48	TRANSAVIA	LCC	Schengen	A	175	B737W8	ES	GRO	SchBus	Belt1
	2-8-2019	16:30	TRANSAVIA	LCC	Non-Schengen	A	156,000000	B737W8	HR	PUY	NSchBus	Belt2
	2-8-2019	16:53	TRANSAVIA	LCC	Non-Schengen	A	156,000000	B737W8	HR	PUY	NSchBus	Belt1
	2-8-2019	16:57	TRANSAVIA	LCC	Schengen	D	183	B737W8	ES	ALC	A8	
	2-8-2019	17:07	TRANSAVIA	LCC	Schengen	D	183	B737W8	GR	HER	A6	
	2-8-2019	17:10	FREEBIRD	LCC	Non-Schengen	A	79,000000	A320-2	MA	AHU	NSchBus	Belt2
	2-8-2019	17:12	TRANSAVIA	LCC	Schengen	A	184	B737W8	ES	IBZ	SchBus	Belt1
	2-8-2019	17:57	TRANSAVIA	LCC	Schengen	D	178	B737W8	IT	PMO	A9	
	2-8-2019	17:59	TRANSAVIA	LCC	Non-Schengen	A	140,000000	B737W8	HR	DBV	NSchBus	Belt2
	2-8-2019	18:05	TRANSAVIA	LCC	Schengen	D	157	B737W8	ES	BCN	A7	
	2-8-2019	18:09	TRANSAVIA	LCC	Schengen	A	180	B737W8	ES	PMI	SchBus	Belt1
	2-8-2019	18:13	TRANSAVIA	LCC	Schengen	D	171	B737W8	ES	VLC	A5	
	2-8-2019	18:57	BA	One World	Non-Schengen	A	44,000000	ERJ190	GB	LCY	NSchBus	Belt2
	2-8-2019	19:03	TRANSAVIA	LCC	Schengen	D	171	B737W8	AT	VIE	A10	
	2-8-2019	19:07	TRANSAVIA	LCC	Schengen	D	183	B737W8	ES	ALC	A8	
	2-8-2019	19:42	BA	One World	Non-Schengen	D	22	ERJ190	GB	LCY	A3	
	2-8-2019	21:45	TRANSAVIA	LCC	Schengen	A	167	B737W8	GR	CFU	SchBus	Belt1
	2-8-2019	21:53	BA	One World	Non-Schengen	A	58,000000	ERJ190	GB	LCY	NSchBus	Belt2
Avondpiek S aankomst	2-8-2019	22:19	TRANSAVIA	LCC	Schengen	A	176	B737W8	PT	FAO	SchBus	Belt1
	2-8-2019	22:21	TRANSAVIA	LCC	Schengen	A	167	B737W8	ES	AGP	SchBus	Belt2
	2-8-2019	22:27	TRANSAVIA	LCC	Schengen	A	170	B737W8	ES	ALC	SchBus	Belt1
	2-8-2019	22:32	FREEBIRD	LCC	Turkey / Marocco	D	177	A320-2	TR	KYA	A4	
	2-8-2019	22:57	TRANSAVIA	LCC	Schengen	A	189	B737W8	ES	BCN	SchBus	Belt2
	2-8-2019	22:59	TRANSAVIA	LCC	Schengen	A	180	B737W8	ES	VLC	SchBus	Belt1
	2-8-2019	22:59	TRANSAVIA	LCC	Schengen	A	180	B737W8	ES	VLC	SchBus	Belt2
	2-8-2019	23:03	TUI FLY	LCC	Non-Schengen	A	177,000000	B737W8	TR	AYT	NSchBus	Belt1
	2-8-2019	23:32	TRANSAVIA	LCC	Schengen	A	175	B737W8	IT	PMO	SchBus	Belt2
	2-8-2019	23:47	TRANSAVIA	LCC	Schengen	A	150	B737W8	AT	VIE	SchBus	Belt1

Figure 24: Flight Scheme representative day 2021 (NACO, 2020)

D.5 Merged airside concept

In Table 26, the processing times for each touchpoint in the merged airside concept are presented.

Table 26: Processing times merged airside concept

Process	**Time**
Boarding (total)	20 min
Access control	3 sec/pax
Border control	10 sec/pax
Access + passport control	10 sec/pax
SSDOP	60 sec/pax

D.5.1 Simultaneous peak hours scenario

In Table 27, an overview of the required equipment for implementing the merged airside concept on RTHA is presented. In the same table, the current concept equipped with seamless flow technology is also presented for comparison. The first noticeable difference is the number of access control gates. Although the average passenger processing time is increased at that touchpoint, no extra machines are needed. This can be explained by the fact that current number of access gates are already underused. At the security checkpoint a maximum inflow of 1060 pax/hours is assumed. Thereby, a processing capacity of approximately 18 passengers per minute is required. Each machine could on it's own already process 11.8 passengers per minute. Consequently, two gates seem to remain sufficient.

The average processing time for the access control is determined by the processing times for both Schengen and non-Schengen passengers. While the border control process will be integrated to this touchpoint, non-Schengen passengers will experience a longer processing time. Considering the fact that most of the regular access control processing time is use for recognizing the person, the processing time for simultaneous border control and access control is assumed to be 10 seconds as well. By using the passenger distribution, retrieved from NACO (2020), the average processing time is calculated as follows:

$$Processing\ time\ = \%\ Schengen\ *Processing\ time\ + \%\ non-Schengen\ *Processing\ time$$

$$Processing\ time\ = (1050/1421)*3+(374/1421)*10$$

$$Processing\ time\ = 0.74*3+0.26*10 = 4.8 seconds$$

Furthermore, one can see that the border control facilities are removed and the number of biometric gates at the boarding gates remain the same.

Table 27: Current concept equipped with seamless flow technology compared to the merged airside concept (simultaneous peak hours scenario)

Process	**Current concept equipped with seamless flow technology**			**Merged airside concept**		
	Equipment	***Processing time (seconds)***	***Number***	***Equipment***	***Processing time (seconds)***	***Number***
Check-in/Enrollment / Baggage drop	Kiosk	60	0	Kiosk	60	0
	Counter	90	16	Counter	90	16
	SSDOP	60	5	SSDOP	60	5
Access control	Biometric gate	3	2	Biometric gate	4.8	2
Security	Security lane	22.5	6	Security lane	22.5	6
Border control	Biometric gate	10	2	N/A	N/A	N/A
Boarding	Biometric gate	3	11	Biometric gate	3	11

D.5.2 Different peak hours scenario

In the different peak hours scenario ,the peak hours for Schengen and Non-schengen flights are different. Thereby, two gates can be removed and after which the spatial footprint can be used for other purposes. As result of the total number of flights within the peak hour, the number of gates can be reduced to nine. In Figure 25, a potential layout of the merged airside concept for the different peak hours scenario is presented. Note that the security lanes are not scaled accordingly. Furthermore, other possible layouts are possible.

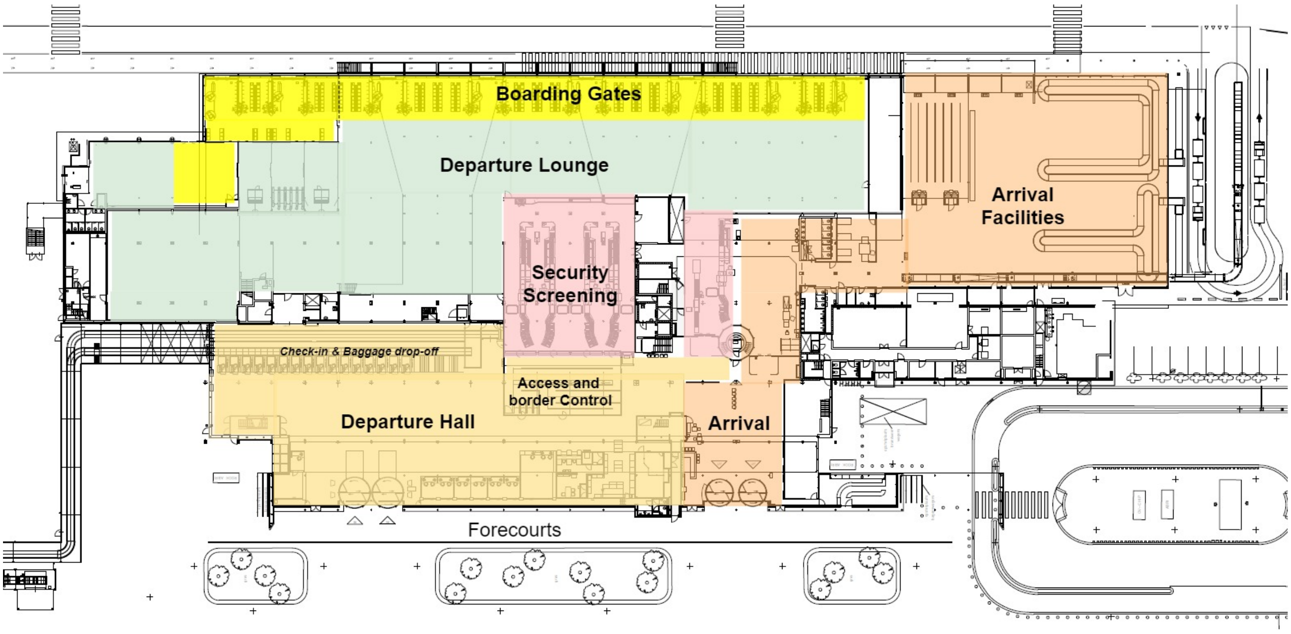


Figure 25: Conceptual layout RTHA merged airside concept different peak hours scenario

In comparison to the simultaneous peak hours scenario, the processing time of the access control point is now split up into two different numbers: one for the Schengen peak and one for the non-Schengen peak. Both are calculated likewise to the processing calculation of the simultaneous peak hours scenario. Although the processing time in the non-Schengen peak is too high to comply to the set standard of 18 passengers per minute, two biometric gates are assumed to be sufficient. The total number of non-Schengen passengers are relatively low which will result in acceptable waiting times. Furthermore, due to the lower number of gates, the number of biometric gates which are placed at each gate can also be reduced by two.

Table 28: Current concept equipped with seamless flow technology compared to the merged airside concept (different peak hours scenario)

Process	**Current concept equipped with seamless flow technology**			**Merged airside concept**		
	Equipment	***Processing time (seconds)***	***Number***	***Equipment***	***Processing time (seconds)***	***Number***
Check-in/Enrollment / Baggage drop	Kiosk	60	0	Kiosk	60	0
	Counter	90	16	Counter	90	16
	SSDOP	60	5	SSDOP	60	5
Access control	Biometric gate	3	2	Biometric gate	4.0 (Schengen peak) 7.7 (non-Schengen peak)	2
Security	Security lane	22.5	6	Security lane	22.5	6
Border control	Biometric gate	10	2	N/A	N/A	N/A
Boarding	Biometric gate	3	11	Biometric gate	3	9

D.6 Public terminal concept

In the public terminal concept, two processing times are different in comparison to concept one. These are presented in Table 29 and will be elaborated in the following sections. Note that the processing time of the other processes remain the same.

Table 29: Processing times public terminal concept

Process	**Time**
Boarding (total)	40 min
Boarding	3 sec/pax (Schengen) 10 sec/pax (non-Schengen)

D.6.1 Simultaneous peak hours scenario

In Table 30 an overview of the required equipment in the public terminal concept is presented together with the equipment of the current concept equipped with the seamless flow technology. When looking at Table 30, the significant increase in the number of security lanes stand out. In the public terminal concept, every gate contains it's own security lane. Purchasing costs of a security lane are relatively high. As a result, the airport would probably want to minimize the number of security lanes. The security specialist of NACO, mentioned the introduction of pre-boarding in order to minimize the number of security lanes. This pre-boarding includes doubling the boarding time from 20 minutes (as in the merged airside concept) to 40 minutes. Consequently, the number of security lanes can be calculated:

$$Number\ of\ machines = Desired\ handling\ /processing\ time\ per\ machine$$
$$X = 189/((60*40)/22.5)$$
$$X = 189/106.67 = 1.77$$

Consequently, two security lanes are required at each gate.

In the public terminal concept, both the access control and the border control touchpoint disappear. As a result, all passenger processes are integrated into one touchpoint at the boarding gate. The required number of equipment at the boarding gates, is determined by the processing time of each gate and the available time to handle all the passengers of one flight. This can be determined by the following calculation:

$$Number\ of\ gates = Desired\ handling\ /processing\ time\ per\ gate$$
$$X = 189/((60*40)/10)$$
$$X = 4.72/6 = 0.79$$

Thereby, only one biometric gate is required per boarding gate.

Table 30: Current concept equipped with seamless flow technology compared to the public terminal concept (simultaneous peak hours scenario)

Process	**Current concept equipped with seamless flow technology**			**Public terminal concept**		
	Equipment	***Processing time (seconds)***	***Number***	***Equipment***	***Processing time (seconds)***	***Number***
Check-in/Enrollment/ Baggage drop	Kiosk	60	0	Kiosk	60	0
	Counter	90	16	Counter	90	16
	SSDOP	30	5	SSDOP	30	5
Access control	Biometric gate	3	2	Biometric gate	N/A	0
Security	Security lane	22.5	6	Security lane	22.5	22
Border control	Biometric gate	10	2	N/A	N/A	N/A
Boarding	Biometric gate	3	11	Biometric gate	3 (Schengen) 10 (non-Schengen)	11

D.6.2 Different peak hours scenario

Similar to the merged airside concept, the public terminal concept can reduce the number of gates by two in the different peak hours scenario. A conceptual layout of the public terminal concept in the different peak hours scenario is presented in Figure 26. Once again, the size of the security lanes are not scaled accordingly.

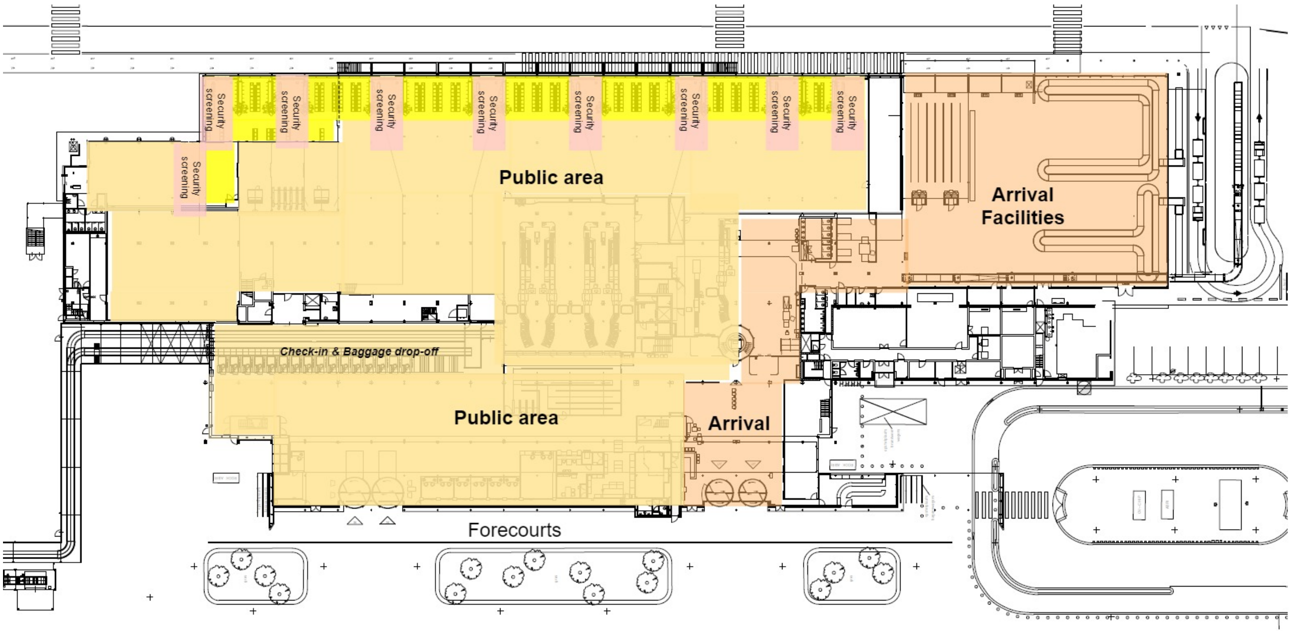


Figure 26: Conceptual layout RTHA the public terminal concept different peak hours scenario

In Table 31, the required equipment for the public terminal concept in the different peak hours scenario is presented. In comparison to the simultaneous peak hours scenario, the only difference is the number of gates and thereby the accumulated number of equipment. Due to the decrease in number of gates, the total number of security lanes decreases to 18 and the number of biometric gates to 9.

Table 31: Current concept equipped with seamless flow technology compared to the public terminal concept (different peak hours scenario)

Process	**Current concept equipped with seamless flow technology**			**Public terminal concept**		
	Equipment	***Processing time (seconds)***	***Number***	***Equipment***	***Processing time (seconds)***	***Number***
Check-in/Enrollment/ Baggage drop	Kiosk	60	0	Kiosk	60	0
	Counter	90	16	Counter	90	16
	SSDOP	30	5	SSDOP	30	5
Access control	Biometric gate	3	2	Biometric gate	N/A	0
Security	Security lane	22.5	6	Security lane	22.5	18
Border control	Biometric gate	10	2	N/A	N/A	N/A
Boarding	Biometric gate	3	11	Biometric gate	3 (Schengen) 10 (non-Schengen)	9

E Economic feasibility

In order to determine the economic feasibility, a rudimentary Cost-Benefit Analysis (CBA) is executed. In a CBA, every impact of a new alternative is expressed in monetary value. In this section, additional information to subsection 6.4 is provided.

E.1 Consequences

As introduced in subsection 6.4, two types of consequences will be distinguished: Equipment and Spatial footprint. This section provides additional graphical insights in the determination of the spatial usage of different area's and equipment on Rotterdam The Hague Airport, as presented in Table 13.

Security screening

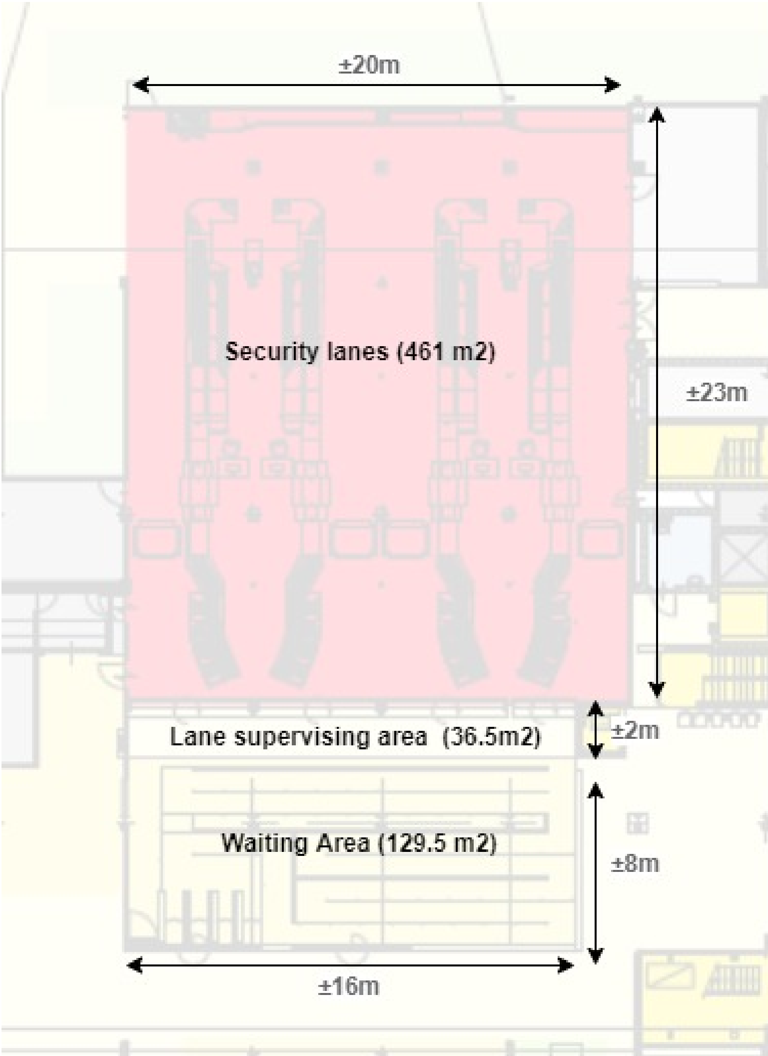


Figure 27: Spatial footprint security screening on RTHA

Border control

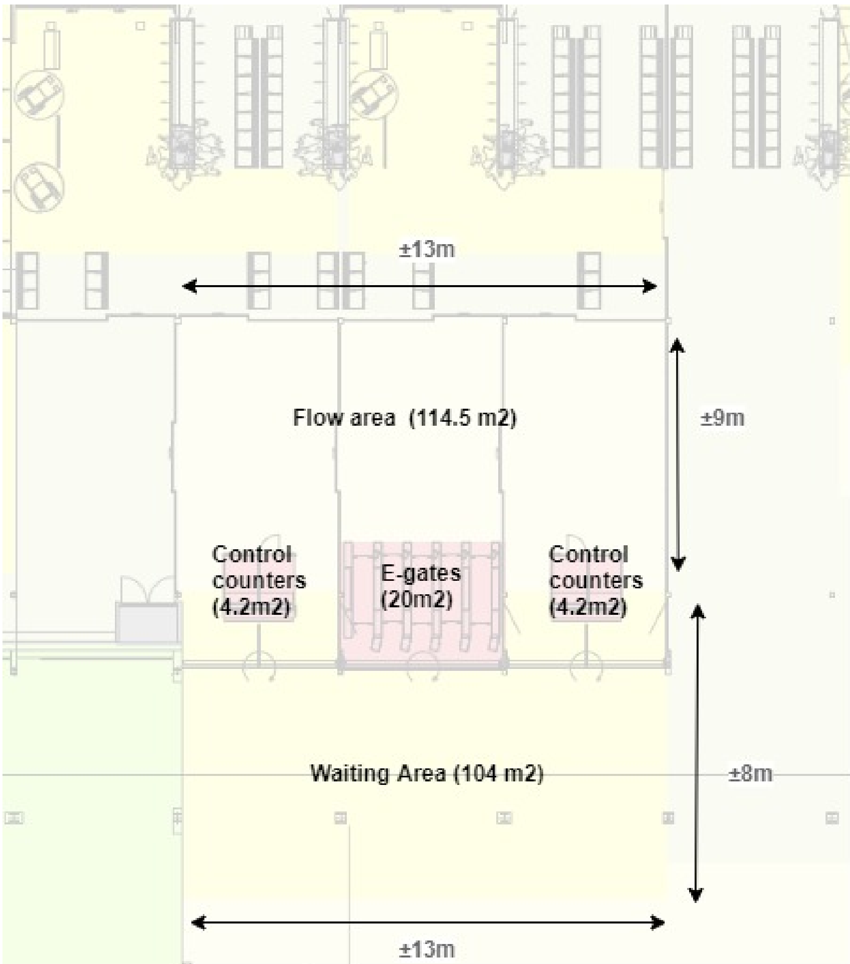


Figure 28: Spatial footprint border control on RTHA

Boarding gate

In Figure 29 the spatial footprint of a 'typical' boarding gate is presented for RTHA.

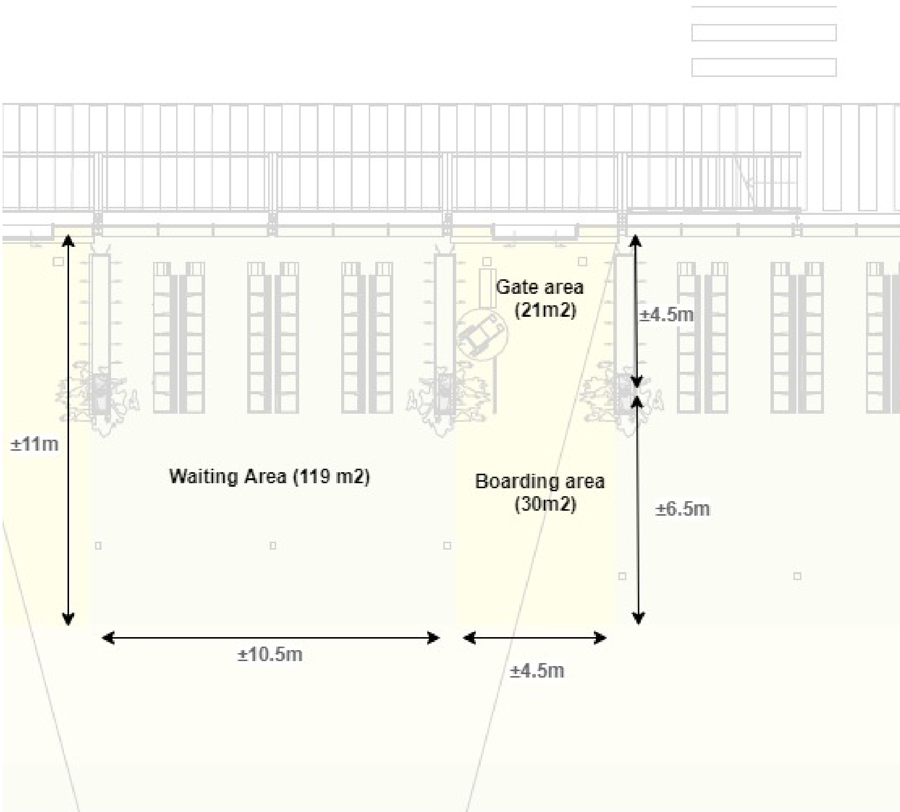


Figure 29: Spatial footprint boarding gate on RTHA

Security lanes at gate

In Figure 30, the potential lane configuration at the boarding gates of seamless flow concept two is provided. This layout is constructed together with the aviation security consultant of NACO. Based on this figure, the spatial footprint of a single security lane is determined.

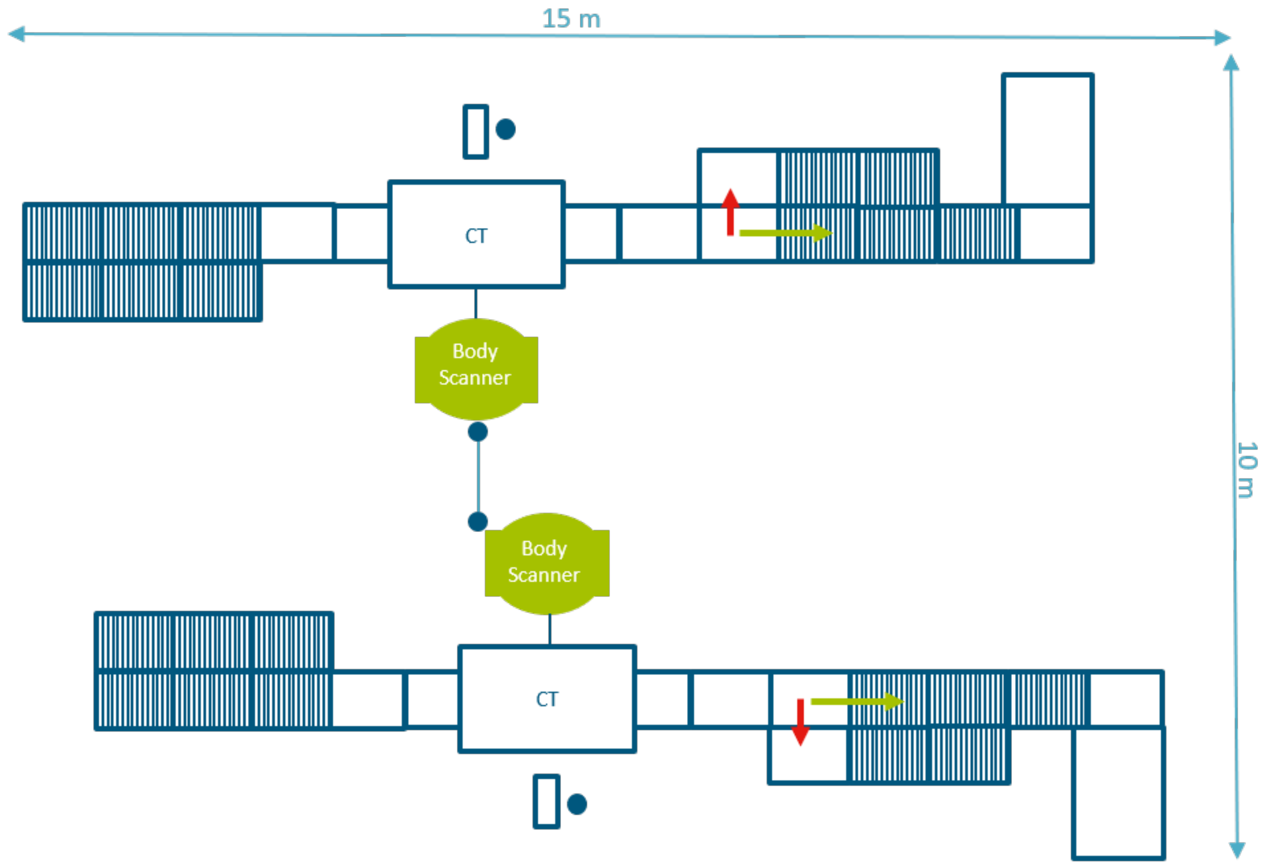


Figure 30: Potential configuration security lanes

As can be seen, two security lanes take up 150 square meter of terminal space at the gate.

E.2 Cost-Benefit Analysis

In this section additional information to the Cost-Benefit Analysis, as presented in subsection 6.4 is provided. First, the calculations for each cost or benefit item are discussed. Thereafter, a sensitivity analysis is presented.

Sensitivity Analysis

In subsection 6.4, an overview of the costs and benefits for both seamless flow concepts is presented. When looking at the results, one can notice that some items do have more influence on the end balance than others. Two noticeable items are the non-aeronautical profits in the merged airside concept and the investment in security lanes in the public terminal concept. Underneath, a sensitivity analysis of the two items is separately presented.

Table 32: Sensitivity analysis non-aeronautical profit benchmark

Merged airside Concept	**Change in non-aeronautical profit per square meter benchmark**									
	-20%		-10%		0		+10%		+20%	
	Scenario 1	***Scenario 2***	***Scenario 1***	***Scenario 2***	***Scenario 1***	***Scenario 2***	***Scenario 1***	***Scenario 2***	***Scenario 1***	***Scenario 2***
Costs	356,895	433,545	356,895	433,545	356,895	433,545	356,895	433,545	356,895	433,545
Benefits	865,208	1,287,110	965,984	1,433,248	1,066,759	1,579,386	1,167,535	1,725,524	1,268,311	1,871,662
NPV	508,313	853,565	609,089	999,703	709,865	1,145,841	810,640	1,291,979	911,416	1,438,117
B/C ratio	2.42	2.97	2.71	3.31	2.99	3.64	3.27	3.98	3.55	4.32
Scenario 1: Simultaneous peak hours										
Scenario 2: Different peak hours										

Table 33: Sensitivity analysis security lane costs

Public terminal Concept	**Change in security lane costs**									
	-20%		-10%		0		+10%		+20%	
	Scenario 1	***Scenario 2***	***Scenario 1***	***Scenario 2***	***Scenario 1***	***Scenario 2***	***Scenario 1***	***Scenario 2***	***Scenario 1***	***Scenario 2***
Costs	12,500,618	8,944,758	13,620,618	9,784,758	14,740,618	10,624,757	15,860,618	11,464,758	16,980,618	12,304,758
Benefits	80,000	120,000	80,000	120,000	80,000	120,000	80,000	120,000	80,000	120,000
NPV	-12,420,618	-8,824,758	-13,540,618	-9,664,758	-14,660,618	-10,504,758	-15,780,618	-11,344,758	-16,900,618	-12,184,758
B/C ratio	0.006	0.013	0.006	0.012	0.005	0.011	0.005	0.01	0.005	0.01
Scenario 1: Simultaneous peak hours										
Scenario 2: Different peak hours										

As can be seen in both Table 32 and Table 33, differentiations in the assumptions do have influence on the outcome. However, the conclusions about the two concepts will not change as result of the differentiation in the influential items.

External validity

In Table 34, the sensitivity analyses of the spatial footprint parameter is presented. In the external validity section, it was stated that the size of the boarding gate area's depend on the type of aircraft that operate from the concerned airport. While bigger airports would probably facilitate larger aircraft, the size of the boarding area is differentiated in this sensitivity analysis.

Table 34: Sensitivity analysis spatial footprint boarding gate

Different peak hours	**Change in boarding gate footprint**							
	RTHA		**RTHA * 2**		**RTHA * 3**		**RTHA * 4**	
	Merged Airside	***Public terminal***	***Merged airside***	***Public terminal***	***Merged airside***	***Public terminal***	***Merged airside***	***Public terminal***
Costs	433,545	10,624,757	510,195	10,402,158	586,845	10,333,908	663,495	10,468,308
Benefits	1,579,386	120,000	2,033,010	120,000	2,486,635	342,810	2,940,259	796,434
NPV	1,145,841	-10,504,758	1,522,815	-10,282,158	1,899,790	-9,991,098	2,276,764	-9,671,874
B/C ratio	3.64	0.011	3.98	0.012	4.24	0.033	4.43	0.076

As can be seen, altering the spatial footprint of the boarding gate area's will significantly influence the outcome of the CBA for airports with different peak hours for international and domestic flights (or Schengen and non-Schengen). In the merged airside concept, the benefits will increase. In the public terminal concept, it can be seen that the benefit-cost ratio of the public terminal concept will significantly increase at larger airports.

F Interviews

In this section, the interview transcripts are presented. While interviews with NACO specialists were more informal, a summary of the notes of this interviews are provided.

F.1 NACO Specialists

During my time at NACO, I talked to various co-workers whom were all specialized within different parts of the aviation industry. In the following sections, summaries of these conversations, based on notes, will be presented.

Senior airport consultant

The main goal of the conversations with the senior airport consultant was to gain more knowledge about the passenger terminal. This would help me to prepare for the interviews with both airports and the technology companies. In the conversations, we talked about the facilities and the technology that is usually used within this facilities. Consequently, we walked through the different processes within the passenger terminal. Thereby, he elaborated on the different methods of executing the processes. This could differ from manual checks to automatic checks.

Senior airport planner

In the conversation I had with the senior airport planner of NACO, we talked about her experiences with the seamless flow. In her former job, she was heavily involved in starting a seamless flow pilot on Sydney Airport. She told me about how she had to persevere in order to convince decision makers to decide to implement the system. Furthermore, she declared how much the aviation industry wanted the seamless flow concept. It would clearly benefit passengers, airlines and governments. After reviewing the system's performance, various flaws had been detected. The system was not able to recognize every passenger and a fare amount of mismatches were encountered.

Director airport strategies

During this research, various meetings were held with the airport strategies director of NACO. Initially, the main goal of these conversations was to set the scope of the Cost-Benefit Analysis. Thereby, the importance of the non-aeronautical revenues for the airport stood out. In case of the non-aeronautical revenues, he provided an estimation of the sales per square meter for shops on the airport. Furthermore, the draft CBA was discussed in order to validate the assumptions made throughout the process. Finally, the end result and my interpretations were discussed.

Consultant aviation security

With the aviation security consultant of NACO, I talked about the constructed seamless flow concepts and the number of equipment required for those concepts. In our conversations, he provided me with insights on the characteristics of screening equipment in terms of high-level cost estimations, spatial footprint and required quantities. Furthermore, the draft CBA was discussed in order to make sure the made assumptions are realistic. A noticeable new insight was the introduction of pre-boarding, which increases the boarding time. As result, less equipment is necessary to comply to the set service standards.

Architect

With the architect of NACO I discussed the capacity analysis study as referenced as (NACO, 2020). In our meeting, she elaborated on RTHA and it's key characteristics. Furthermore, the capacity study was broken down and explained. Thereby, the main goal was to get a good overview of the airport and its facilities. This would help me in the assessing the impact of the new concepts on the airport. Furthermore, this gave me additional information which helped me throughout the interviews with the operations manager of RTHA.

F.2 SITA

An interview with a product manager of SITA was held. SITA is a technology company which manufactures technology for the aviation industry. They produce a biometric system called Smart Path. This system can be used within the seamless flow concept.

Can you tell me about your smart path solution?
The smart path solution is our biometric solution for airports. We fitted that in on all the touchpoints of the airport. All touchpoints can be enabled to use biometric technology (facial recognition). It is however going to be interesting how the system is going to deal with masks by the way. Maybe we should go back to iris scans in the future.

How does the technology work in practice?
The recognition has become pretty good. I saw a demonstration at the office in which the system was shown a picture in which two pictures of people were photoshopped into one face. The system could tell that there are two faces there. The technology is hugely advanced now, the success rate of matching is pretty high. In a way it is far better than visual checking your face and your passport. I can probably get you the exact numbers of the matching.

I saw some figures online, it stated about 99%?
Yeah its pretty high. I've seen the demonstrations so I've seen what it can do. It's really surprising when they performed a test with me. I was shown pictures and I had to determine whether they are the same person or not. And it was really quite striking while I made quite some mistakes and the computer could recognize these. Because of that, biometrics solutions is pretty out there in terms of a security and safety.

How do you deal with data security?
It is secure in a sense of privacy while you have to enroll. Either by mobile or kiosks at the airport into the biometric system. These images are captured and shared only if you give permission and enroll in the system.

What are the advantages of such a system?
Once you are into the system, the advantages especially for airport and airlines is fact that you can use that ID for everything you like. You don't need a boarding pass, your identity is you, and its your face. Your face gets you on everything. Only bag tags need to be printed. Other advantages are that all processing goes away. Futhermore, that many people at check-in, or other processes, will become unnecessary. The only people need to be around are there to help people in case anything goes wrong, or people to make sure that the system is working properly.

What are the costs of such biometrics systems?
While there is an advantage in cost reductions, it is overclassed by the cost of the biometric solution itself. The nice thing about the smartpath solution is you can integrate it to the current platforms. So you can add it to kiosks and at any other part of the process. Which is great for us! This will also mitigate the costs of a complete new implementation. This technology can litteraly be added in.

So the spatial usage is not different from the current system?
Yeah, its only an add-on or a build-on. So that mitigates some of the costs. But biometrics is not a cheap option. It is a safe and secure option, certainly in the longer run the benefits would be realized. But there would be an initial investment for the airport.

What do think of the airports concept, could it change as result of the technology?
Yess, definitely.

What do you think of the concept in which domestic and international passengers are mixed in airside facilities?
What you present is definitely Schengen, here in England we do not have that extra emigration check. Apart from that it could be quite interesting!

What is the performance of the biometric systems, in terms of processing speed?
It's pretty quick, but I would have to get some numbers for that. I can look and try to get some numbers on processing. It's actually dependent on which the part of the process and thereby the type of touch point.

Check-in is about the airline host but security is about the homeland security so that could take more time.

Can you also provide me with the costs of the system?
I'm not sure if could you the costs while its commercially sensitive. I don't know what the deals are at different airports so I'm not sure if I could provide you with that information. But I'll will ask that for you.

What do you think of the feasibility?
Yeah, it's most certainly feasible. I think It's again a question of set up a structure at airports. But it depends on the country and the airport itself. The airlines do accept it, but on its own its not enough. IATA is quite slow in standardizing these technology and systems. So today, it's there but not fully adopted.

Are you as SITA working on other biometrics systems?
No, for us its just the Smart Path.

F.3 RTHA

I also interviewed the airport operations manager of Rotterdam The Hague Airport. RTHA is the case study within this research so the airport's vision on this subject is very interesting. The interview was conducted in Dutch.

Wat is jullie visie op een seamless flow systeem?
Ja uiteindelijk is wat we doen gewoon precies hetzelfde als dat ze op Schiphol doen. Dat is in beginsel het idee. Uiteindelijk kijken we naar de eindplaat en die houdt ook relatie met jouw onderzoek. Het moment dat je alles in plaats hebt, en je weet alles van elke passagier, dan is het allemaal niet meer zo moeilijk. Dan is het ook niet meer essentieel om die grenscontrole daadwerkelijk op de airport uit te voeren. Voor 99 procent van de gevallen kan je dat op een moment doen wat losstaat van het moment dat een passagier op de airport. Dan kan je je concentreren op die passagiers die afwijken en die je dus verder moet onderzoeken. Als dat het idee is en je weet alles al, dan zou je het moment van grenspassage ook later kunnen leggen, bijvoorbeeld bij boarding. Dat is een mooi moment, het laatste moment van de terminal. Maar als je dus alles al weet over een persoon en de screening al is gedaan dan is er dus geen nut meer van het scheiden van Schengen en niet Schengen passagiers in een terminal.

Wat zijn de andere voordelen van een dergelijk systeem?
Uiteindelijk krijg je dan een heel ander terminal idee. In kleine schaal is dit dan te zien op RTHA, maar bij andere airports moet je alles natuurlijk dubbel uitvoeren, bijvoorbeeld dubbele horeca etc. En je kan van alle lastige dubbel gates af, het maakt het allemaal wat eenvoudiger. Het moment van boarden is dan ook je grensmoment en dan heeft de kMar al lang zijn moment kunnen hebben.
Je zal dan veel fysieke ruimte krijgen die je allemaal op een andere manier kan gebruiken. Als je van iemand alles weet dan concentreer je je alleen op de personen die het niet van tevoren hebben aangeleverd of degene die je in zijn nekvel wil grijpen. Verder kan de kMar vanaf het moment dat jij je enrolled in het systeem in alle rust, zonder dat jij aan die balie staat, het screening process uitvoeren. Dit kan je ook remote in een kantoortje doen, dus je kan er zo veel capaciteit opzetten als dat je wil. Uiteindelijk kunnen ze dan tot en met je in het vliegtuig stapt je bij je nekvel grijpen als er wat mis is. Als ze me echt willen hebben, weten ze precies waar ik ben binnen de luchthaven.

Maar is dit toekomstbeeld wat we schetsen al op korte termijn mogelijk te maken?
Nee het is er nog lang niet.

Wat is dan het grootste knelpunt waar deze innovatie op vast loopt?
Dat zou je heel goed aan de desbetreffende persoon binnen Schiphol kunnen vragen. Wat je daar in ziet is dat we een ideale wereld schetsen waarin data verwerkt wordt en systemen altijd beschikbaar zijn etc.. En dan zie je opeens dat dat nog niet helemaal het geval is, en dat de seamless flow nog niet altijd zo seamless is als dat we denken. Technisch blijkt het allemaal nog een stuk moeilijker. We zijn een hele eind op weg wat betreft het afschermen en delen van data, maar het probleem zit het in de beschikbaarheid van systemen en IT infra.

Ziet de kMar ook potentie in een seamless flow systeem?
Ja, je hoeft maar naar Schiphol te gaan en je ziet een enorme rij bij de kMar. Uiteindelijk is dat een heel arbeidsintensief proces. En ondanks dat ze dat niet zo zullen zeggen, want heeft met banen te maken, of je concentreert je op 100 mensen of je concentreert je op 1 man waar het om gaat. Ik weet wel wat ik zou doen. Je kan het veel meer risico gebaseerd gaan doen, maar dat vinden ze heel erg lastig.

Hoe worden passagiers die niet vlekkeloos door de border control heen komen op dit moment afgehandeld?
In de huidige situatie kent Kmar grens een eerste en een tweede lijn. De eerste lijns controle vindt plaats wanneer een passagier bij vertrek of aankomst zijn paspoort overhandigd aan de Kmar beambte. Mocht er iets niet in de haak zijn dan neemt een tweede lijns collega dit over een neemt de passagier mee naar een ruimte waar de verdere afhandeling plaats vind.
Bij het gebruik van e-gates is de Kmar al lang van tevoren op de hoogte als er bij een persoon iets niet goed is. Dit door dat alle reisgegevens al bekend zijn na de enrollment Door gezichtsherkenning kan men al in een vroeg stadium bepalen of een persoon al op de luchthaven is. Dat is het moment dat men een passagier kan benaderen. Dit kan in alle stadia van het proces.

Wat vinden jullie de belangrijkste kosten en baten voor de terminal?
Ja het is echt een optelsom. De aanschafprijs van apparatuur (wat altijd voor rekening is van de luchthaven) is enorm hoog. Onderhoud is duur. Maargoed je krijgt er natuurlijk heel veel voor terug. Voornamelijk ruimte en een heel fijn proces voor de passagier. Wat de luchthaven uiteindelijk doet is het faciliteren van het passagiersproces, dat is wat de luchthaven doet, niet meer niet minder. Wij verzorgen de faciliteiten om dat zo goed mogelijk te doen. En de seamless flow is natuurlijk een heel mooi systeem om dit zo goed mogelijk te doen. Dat wordt allemaal uitgedrukt in de net promoter score, en die is voor ons heilig.

Wat verwacht je van de commerciele inkomsten?
Ja als iemand nou weet waar ik ben op de luchthaven, dan kan ik op aanbiedingen gewezen worden en op de koffiestands. Dus op dat punt valt er winst te behalen.

Hoe worden commerciele inkomsten gegenereerd?
Uiteindelijk betaalt een concessionaris huur, en hij betaalt nog een percentage over zijn omzet.

Hebben jullie nog duty free shops?
Ja maar dat concept bestaat eigenlijk niet meer. Kijk het heet allemaal wel duty free, maar het is het allang niet meer. Daar zou ik me niet te druk maken. Het belangrijkste wat je op RTHA ziet is dat wanneer Non-schengen naar de gate moet, dan moeten ze door de paspoort controle moeten en dan is daar niks meer. Hoe verder je het moment legt dat je door de grens gaat, hoe fijner het is qua inkomsten. Want dan heb je niet alles dubbel, en mensen zijn zo lang mogelijk in de horeca en retail.

Verwacht je niet dat passagiers korter voor vertrek gaan ankomen op de luchthaven?
Dat geldt misschien voor de frequent flyer, maar die gebruikt ook andere faciliteiten. Die gaat bijvoorbeeld parkeren etc. Maar de gemiddelde vakantiereiziger die gaat nog steeds twee uur voor tijd aan de gate zitten.

Waarom lopen jullie wat betreft de seamless flow achter Schiphol aan, in plaats van het zelf implementeren als proeftuin? Het lijkt me dat jullie airport een perfecte locatie is om dit concept te proberen.
Heel goed dat je dit zegt, dat vinden wij ook. Maar zo af en toe verschillen wij ook nog wel eens van mening met onze grote moeder en spelen daar ook wat persoonlijke belangen mee. Maargoed, wij hebben afgesproken dat wij ons concentreren op wat anders. Maar normaal gesproken kunnen wij als we vandaag iets bedenken het morgen doen, en dat is het leuke van Rotterdam. Maar je hebt gelijk, wij zouden dat heel graag doen maar het is af en toe ook niet erg om achter je grote moeder aan te lopen.

F.4 RTHA Validation

Besides the initial interview with the operational manager of RTHA, an additional interview was conducted in order to validate the results of this research. Again, the interview was conducted in Dutch. In this interview we discussed the results of my study. Thereby, the interviewee gave various comments which are presented underneath.

Wat vind je van de technische haalbaarheid van de concepten?
Hoe later je dat multidisciplinaire touchpoint in het systeem doet, hoe later die storing komt (als hij komt) dan heb je hem ook wel en dan zijn de consequenties op de performance van je boarding process groot. Techniek kan ook kapot. Hoe later je dingen doet, en het werkt niet lekker mee, in het tweede concept heb je dan echt een probleem. De betrouwbaarheid is echt nog een puntje van zorgen. Als je naar schiphol kijkt is er echt nog wel wat te doen om het in alle gevallen 100% te laten werken. Andere resultaten worden bevestigd.

Wat vind je van de sociale haalbaarheid van de concepten?
Ja,privacy is voor passagiers echt een puntje. Daar kan je een heel boek over schrijven. Maar daar gaat het verder niet op spaak lopen naar mijn verwachting. Andere conclusies worden bevestigd.

Wat vind je van de politieke haalbaarheid van de concepten?
Naast de punten die je hier noemt is er nog een aspect. Op het moment dat je volledig decentraal gaat, dat betekent dat je een hele grote verspreiding krijgt van personeel. Nu stop je al die kMar mannen bij elkaar in een hokje maar als je verschillende pieren hebt dan zijn die mannen dus de hele dag onderweg naar alle gates om de potentiele moeillijke gevallen eruit de halen. Dit lijkt mij totaal ondoendlijk. Bezetting wordt dan dus lastig en responsetijden zullen dan ook omlaag gaan, die dingen zijn wel belangrijk.

Wat betreft de well-wishers toestaan in de terminal zie je juist meer dat er vanuit de security meer wordt gestuurd naar de verschuiving van de scheiding naar de voordeur. Uiteindelijk hebben we door alle maatregelen die er zijn het achter de security redelijk op orde. Dat zie je aan de aanslagen, er wordt tegen de terminal aangereden, in Brussel gaan ze aan de voorkant van de terminal dingen doen. Dus hoe verder je ze weer de terminal in laat, hoe ongunstiger het van security opzicht is. Het allerliefste zou je het scheiden van wegbrengen ophalers bij de voordeur. En dan meteen door de security. Vanuit security opzicht is dat public terminal concept gewoon niet gewenst.

Wat vind je van de economische haalbaarheid van de concepten?
Wat betreft die ruimtebesparing zie je dat het grootste punt is dat je op dit moment op veel airports alles dubbel hebt. En dat is natuurlijk doodzonde. Nu geef je gewoon heel veel geld uit om alles dubbel uit te voeren. Daarnaast zijn de security lanes enorm kostbaar. Kosten zo over de duim, all-in all ongeveer een miljoen per stuk. Het uitrusten van elke gate met aparte security lanes is gewoon duur, en daarnaast moet je nog een terminal bij gaan bouwen voor de ruimte. Dat gaat hem dus zeker niet worden.

F.5 Schiphol

In order to gain more information about the current state of the seamless flow concept, the interviewee of RTHA advised to talk to the aviation security advisor from Schiphol Airport. This advisor is responsible for various security innovations, and in particular the concept development of the seamless flow system. Although the intention was to conduct two separate interviews, the second interview was canceled and, due to the covid-19 circumstances, never rescheduled. Underneath, the main results are provided (other answers were declared as confidential).

Wat vind je van het idee van het mixen van Schengen non-Schengen in airside faciliteiten?
Zeker een interessant concept!

Hoe is jullie ervaring met stakeholders op gebied van seamless flow systemen?
In principe is seamless flow een intitiatief van Schiphol en alle partners. Dat geeft in principe al het antwoord. Het is een publiek-private samenwerking tot op board niveau. Het is dus echt een publiek-private samenwerking met de kMar als uitvoeringsinstantie, justitie als bevoegd gezag, douane als betrokken partij, ministerie van defensie als dataverwerker. Het is dus echt een publiek-private samenwerking waarbij het wet echt met elkaar proberen neer te zetten. Alle partijen zijn er buitengewoon positief over en willen dit heel graag neerzetten. Innovaties op de grens zijn denk ik heel belangrijk.

Wat houd het nu nog tegen dan?
In principe zijn we druk bezig met een voorbereiding tot een uitrol. Maar in principe voordat je een dergelijk besluit neemt moet je met elkaar wel ook zeker weten dat het concept is wat je van tevoren met elkaar hebt bedacht. We zitten nu in een fase waarbij we aan het beproeven en toetsen zijn of de initiele dienst die er aan ten grondslag lag of die ook realiseerbaar is. En als dat zo is dan kunnen we uitrollen. We zijn tot nu druk bezig geweest met het ontwikkeling van het concept. Deze fase is nu ongeveer klaar. Daarom kijken we nu of het echt aan de eisen voldoet, en als dat zo is en dat hopen we later dit jaar te kunnen besluiten. Dan kunnen we het uitrollen.

De techniek die werkt dus mee?
Ja in principe wel. Maar dat is natuurlijk ook wel af van welke eisen je er aan stelt. In principe zie ik dat de techniek dit wel kan leveren op het moment. Maar dat hangt ook af van hoe we die business case insteken of dat daadwerkelijk uitkomt. We hebben wat aannames gedaan en die moeten natuurlijk gevalideerd worden. Dat is op dit moment lastig maar we hopen dat later dit jaar te kunnen doen.

Ik hoor je veel business cases noemen, heb je eventueel data die ik kan gebruiken?
Dat is heel lastig, die heb ik wel maar ik mag die niet met je delen. Er zitten echt enorme commerciele gesprekken achter. Dat wordt momenteel allemaal besproken dus ik kan je die informatie echt niet geven. Ook omdat het informatie is van de personeelsbezetting van de kMar.

F.6 Renowned Access products manufacturer

In order to gain more information about the biometric systems and its characteristics, an interview was held with a renowned gate manufacturer. As requested by this party, both the company and interviewee, which is a consultant for the company, will remain anonymous. Thereby, detailed interview manuscripts are also not presented while it could contain restricted information.
The goal of the interview was to gain more information about the purchase and maintenance costs of an access gate/lane equipped with a facial identification system. While this information is commercially sensitive, the interviewee was only willing to provide me with an indication price range. The purchase costs of one single gate is between 15000 and 20000 euro's. Furthermore, the annual maintenance costs of such a product will be between 2000 and 2700 euro's for the full package. The latter contains the ultimate service level which means that the shortest response time is arranged. Moreover, the interviewee stated that the true costs of a biometric airport system will mostly be determined by the costs of the integral system.
Besides the costs, the interviewee confirmed that the addition of a facial recognition system would not per definition change the spatial footprint in comparison to the available automated gates. This was also stated by SITA.