# Master's degree thesis

**LOG950**

Finding and Eliminating Bottlenecks: A Case Study of the Security Checkpoint at Oslo Lufthavn Terminal 2

Martin Vikse and Robin Fjørtoft

Number of pages including this page: 128

Molde, 24.05.2019

Molde University College
Specialized University in Logistics

# Mandatory statement

Each student is responsible for complying with rules and regulations that relate to examinations and to academic work in general. The purpose of the mandatory statement is to make students aware of their responsibility and the consequences of cheating. Failure to complete the statement does not excuse students from their responsibility.

<table>
<tr><td colspan="3">Please complete the mandatory statement by placing a mark <u>in each box</u> for statements 1-6 below.</td></tr>
<tr><td>1.</td><td>I/we hereby declare that my/our paper/assignment is my/our own work, and that I/we have not used other sources or received other help than mentioned in the paper/assignment.</td><td>☒</td></tr>
<tr><td>2.</td><td>I/we hereby declare that this paper<br>1. Has not been used in any other exam at another department/university/university college<br>2. Is not referring to the work of others without acknowledgement<br>3. Is not referring to my/our previous work without acknowledgement<br>4. Has acknowledged all sources of literature in the text and in the list of references<br>5. Is not a copy, duplicate or transcript of other work</td><td>Mark each box:<br>1. ☒<br>2. ☒<br>3. ☒<br>4. ☒<br>5. ☒</td></tr>
<tr><td>3.</td><td>I am/we are aware that any breach of the above will be considered as cheating, and may result in annulment of the examination and exclusion from all universities and university colleges in Norway for up to one year, according to the <u>Act relating to Norwegian Universities and University Colleges, section 4-7 and 4-8</u> and <u>Examination regulations</u> section 14 and 15.</td><td>☒</td></tr>
<tr><td>4.</td><td>I am/we are aware that all papers/assignments may be checked for plagiarism by a software assisted plagiarism check</td><td>☒</td></tr>
<tr><td>5.</td><td>I am/we are aware that Molde University College will handle all cases of suspected cheating according to prevailing guidelines.</td><td>☒</td></tr>
<tr><td>6.</td><td>I/we are aware of the University College's <u>rules and regulation for using sources</u></td><td>☒</td></tr>
</table>

# Personal protection

## Personal Data Act

Research projects that processes personal data according to Personal Data Act, should be notified to Data Protection Services (NSD) for consideration.

Have the research project been considered by NSD? ☐ yes ☒ no

- If yes:

Reference number:

- If no:

I/we hereby declare that the thesis does not contain personal data according to Personal Data Act.: ☒

## Act on Medical and Health Research

If the research project is effected by the regulations decided in Act on Medical and Health Research (the Health Research Act), it must be approved in advance by the Regional Committee for Medical and Health Research Ethic (REK) in your region.

Has the research project been considered by REK? ☐ yes ☒ no

- If yes:

Reference number:

# Publication agreement

**ECTS credits: 30**

**Supervisor: Svein Bråthen**

## Agreement on electronic publication of master thesis

Author(s) have copyright to the thesis, including the exclusive right to publish the document (The Copyright Act §2).
All theses fulfilling the requirements will be registered and published in Brage HiM, with the approval of the author(s).
Theses with a confidentiality agreement will not be published.

**I/we hereby give Molde University College the right to, free of charge, make the thesis available for electronic publication:** ☒yes ☐no

**Is there an agreement of confidentiality?** ☐yes ☒no

(A supplementary confidentiality agreement must be filled in)

- If yes: **Can the thesis be online published when the period of confidentiality is expired?** ☐yes ☒no

**Date:** 24.05.2019

# Preface

This thesis marks the end for the Master of Sciences in Logistics program at Molde University College. The motivation behind the research topic and thesis is related to our interest for finding unexploited opportunities of improvement and the implementation of these.

A special thanks to our supervising Dean for the Faculty of Logistics Svein Bråthen at Molde University College and Nigel Halpern, Associate Professor in Air transport and Tourism at Kristiania University College, for valuable feedback and insight.

Working with Avinor has given us valuable information and real-life experiences of highly interest. In that regards we would like to express our gratitude and appreciation to our Avinor representative, Ole Folkestad for providing us with valuable insight, clearances and arrangement of field trips related to this thesis. We would also like to thank all Avinor representatives that we have met during our field trips.

Furthermore, a special thanks is given to Molde University College for the necessary theoretical foundation and support at this Master program.

May 2019

Martin Vikse and Robin Fjørtoft

# Summary

The main objective for this thesis has been to identify bottlenecks at the security checkpoint at OSL Terminal 2 with the goal of making the security checkpoint more efficient, both in terms of investing in new technology and by studying the security checkpoint processes.
The purpose is to list a number of suggestions that Avinor could benefit from in order to reduce costs, increase customer satisfaction and improving the time passenger spends at the divest area and the reclaim area.

The main method of data collections has been through observation at both Oslo Lufthavn and Stavanger Lufthavn. The passengers have been observed and analysed without any interactions. They were also divided into several categories to identify any specific findings within the specific group of passengers. The categories were divided into age groups, genders, fast track and regular lane passengers and if they were subjected to any inspection or not. The passengers were observed both in the divest area, and in the reclaim area, and were noted when both the passengers and their trays were subjected to a recheck. The observations took place on a typical weekday, around the times when peaks are high for both airports.

The results from the observation conducted at Oslo Lufthavn gave the necessary data foundation in which a comparison could be possible. The findings from Stavanger Lufthavn indicates that the size of the trays does play an important role in terms of divest and reclaim time for the passengers. The trays used at Oslo Lufthavn har smaller in size and the time spent for passengers at both divest and reclaim area are higher compared to Stavanger Lufthavn. A new type of X-ray machine has also been studied with the purpose of increasing customer satisfaction and increasing efficiency of passenger luggage being x-rayed.

Based on the findings and analysis of the observations a list of recommendations has been presented to Avinor. The change in the design of the trays could potentially increase efficiency and reduce both the divest and reclaim time. New investment in a more technologically advanced x-ray machine is also recommended. Further, focusing on the reclaim area in which the passengers spend approximately 2/3 of the total time should be studied closer.

## List of abbreviations

ATRS: Automatic Tray Return System

CIP: Centralized Image Processing

EU: European Union

FT: Fast Track

GVA: Geneva International Airport

LAG: Liquids, Aerosols and Gels

NOK: Norwegian Krone

OPT: Optimised Production Technology

OSL: Oslo Lufthavn

PAX: Airline passengers

RL: Regular Lane

SAS: Scandinavian Airlines System

SVG: Stavanger Lufthavn

TOC: Theory of constraints

TSA: Transportation Security Administration

T2: Terminal 2 at OSL

# Contents

## List of figures

# List of tables

# 1.0 Introduction

This chapter will consist of an introduction of the research background, presentation of Avinor, the problem statement, the purpose, research questions and the structure of the thesis.

## 1.1 Research background

The airline industry has undergone several rises and falls, but from the middle of the 1990's up until the beginning of the 2000's, it has achieved one of its greatest rises yet. This was due to the increased GDP, when mixed with the increased globalization world-wide, where a greater demand for airline travel occurred, allowing the larger airlines to grow 4-6% annually (Cento 2009). However, after the year 2000, growth stagnated and was quickly diminished by the effects of the September 11$^{th}$ attacks in New York, along with the SARS outbreak in the Far East (WHO 2003).

Following this economic decline, the rise of low-cost carriers became apparent. Their ability to generate profits and growth came from a strategy of generating a cost advantage, often offering "no frills", a term which means elimination of the passengers' needs for extra services and comforts for their flights, typically being point-to-point rather than a hub-and-spoke system (Cento 2009). These services can include extra, or any, luggage, seat choice, lounge access, foods and drinks on boards and priority boarding. This new passenger demand was taken advantage of by several airlines, for example Ryanair, easyJet and Norwegian. This advantage is referred to as the "Southwest effect", honouring the foundation of the low cost carrier, done by Southwest Airlines (ICAO n.d.).

This change of setting for airlines also meant that a new passenger type will flow into the marked, the leisure passengers. Naturally, there have been charter flights to destinations as long as there have been commercial flights, but aviation was long associated with business travel, and priced accordingly. These leisure passengers do not travel every week and is more likely to carry contraband items through a security checkpoint at the airport due to unfamiliarity of protocols and illegal items allowed (Alards-Tomalin et al. 2014).

In the United States, the Transport Security Administration, TSA, was created to handle security protocols for public air transportation, both domestically and internationally. It was created as a direct response to the 9/11 attacks and includes not only screening procedures at airports, but also federal air marshals on planes, canine units and explosive specialists (Grinberg 2009), (Crocker et al. 2008). Yet even as the amount of passengers has increased with 15% between 2013 and 2016, the amount of screening agents has decreased with 10% (Vasel 2016).

What became known as the 2006 transatlantic aircraft plot, a potential high-stake terrorist attack, aimed on several flights to the United States and Canada from the United Kingdom was averted by the authorities. The terrorists were disguising liquid explosives as soft drinks and other non-threatening items. Mixed together, they would have been sensitive to heat, shock and friction, which could be connected with a detonator, potentially causing up to 10,000 deaths (Gardham 2009).

As an immediate follow-up, passengers were not allowed to carry any liquids what so ever, apart from baby formulas, between flights in the UK and US. After some time, it was allowed for passengers to carry liquids up to 100ml if presented in a plastic bag. This enforcement is still active in 2019, even as new technologies are being researched (Gardham 2009).

Furthermore, with the increased baggage fees coming with the amount of leisure travellers for low cost carriers, which causes passengers to bring more luggage as a carry on, especially on holiday travels. More carry-on luggage means that there is more luggage that needs screening, which in turn can create longer queues. To add insult to injury, several larger traditional airlines are offering cheaper tickets on their “light” section, which mimics a low cost carrier style of not offering complimentary luggage and seat choosing (KLM n.d.), which again increases the amount of hand luggage in need of screening.

With more security measures being necessary for passengers and airlines to be safe for air travel, combined with a steady increase of passenger flow, as well as passengers are more than ever carrying their luggage with them rather than check it in, there is a huge challenge for airport security to smoothly and swiftly process them. Furthermore, with technologies attempting to make one process faster, it could potentially simply move a bottleneck to another part of the process.

## 1.2 Worldwide air passenger forecast

Statistically, the number of passengers carried with air transportation has increased every year from the 1970s until today. The graph represents the increased number of passengers carried from approximately 310 million in the 1970s to 3,9 billion in 2017. It is based on both domestic and international passengers worldwide (The World Bank Group 2017).

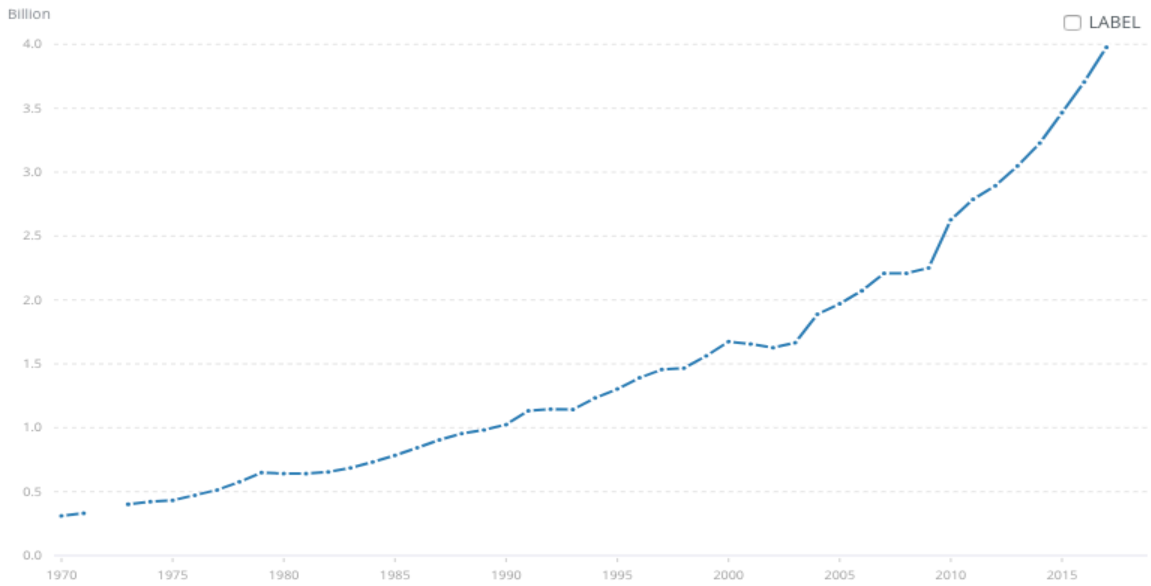



*Figure 1: Growth of domestic and international passengers from 1970-2017. Source:* ("Air Transport, Passengers Carried | Data" 2017)

IATA 20-year air passenger forecast predicts that the number of passengers will nearly double from 3,8 billion passengers in 2016 to 7,2 billion by 2035. Contributing factors for the predicted factors are referred to the emerging middle class in the developing countries such as India and China, low-cost airlines which reduce the cost of travel and further liberalization of aviation markets (IATA 2019).

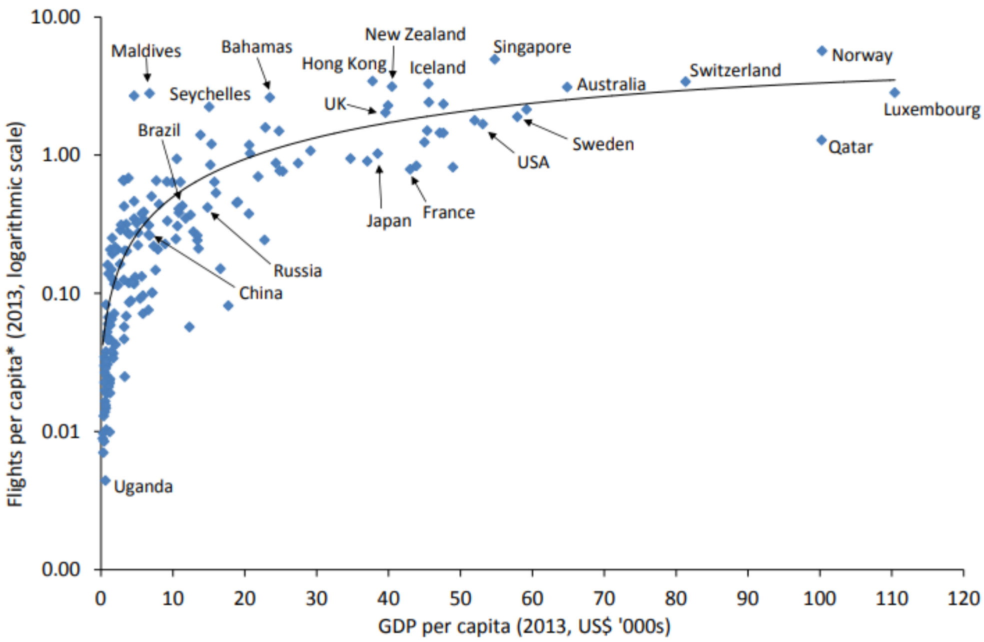



*Figure 2: Relationship between GDP and flights per capita. Source:* (Pearce n.d.)

Another assumption is that there is a correlation between the number of flights per capita and GDP per capita. The figure above supports this argument as low income countries, such as Uganda and middle – income countries, such as China, Brazil and India tend to fly far less than high – income countries such as Norway and Luxembourg on average. Predictions indicate that both China and India will by the year of 2050 have a massive increase in GDP. China could become the largest economy in the world, followed by India (PWC 2017). With the growth of GDP, specifically in the Asian region, the indications are that this would lead to an increased number of passengers traveling in the future. This will naturally increase the number of passengers that has to go through the airport security checkpoint.

## 1.3 Norwegian flying culture

In terms of population size, Norway is reasonably a small country.

However, numbers from Eurostat, states that Norwegian tend to make three domestic travels per person, a year. In 2015, the number of domestic travels per Norwegian was 2.4, indicating that Norwegian tends to fly more frequently today than before (Thune-Larsen and Farstad 2016).

In addition, domestic air travel in Norway due to private purposes was approximately 52 percent while 48 percent was related to work/business (Thune-Larsen and Farstad 2016).

However, other sources have claimed similar, yet slightly different numbers for the average Norwegians travels, both domestically and internationally. Where Thune-Larsen and Farstad (2016) claimed there to be 2,4 annual flights domestically for a Norwegian, Kristiansen (2017) has claimed there to be 2,9 in the same year, 2015. Regardless, the point remains the same. Having 2,4 or 2,9 still makes Norway the dominant nation within domestic travel, whereas Norway's' neighbouring country Sweden, with similar cultural values, stands at 0,8 domestic flights.

Norway has a high number of combined domestic and internationally flights, passed in Europe only by island nations, namely Iceland, Malta and Cyprus (Kristiansen 2017). The number of Norwegians travelling both domestically and internationally stands in 2015 at 7,9 flights per year. They have all share the similarity of having not more than one major city, so air travel to other cities usually means flights abroad. For Norway, this means that they are on the top when compared with continental European countries. Furthermore, being located so far north means that Norwegians appreciate going to Southern Europe on holiday, which likely affects the number of international trips further.

In 2015, two of Europe's busiest passenger air routes was in fact domestic routes in Norway. The air routes it depicted in the figure below, where Oslo Airport Gardermoen to Værnes in Trondheim is 6$^{th}$ on the list, carrying 1,95 million passengers in 2015. Ranking 8$^{th}$ is the route between Oslo Airport Gardermoen and Flesland, Bergen, carrying 1.81 million passengers (Findlay 2015).

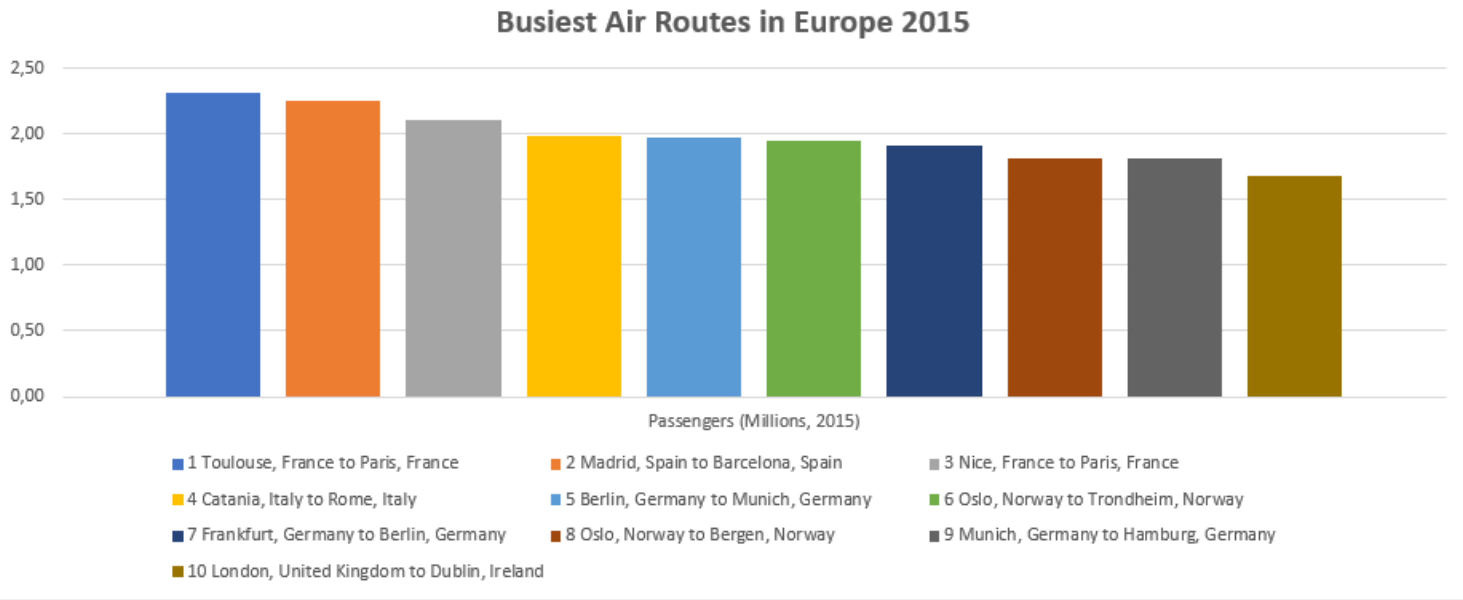



*Figure 3: Busiest Air routes in Europe 2015. Source: Own work, based on* (Findlay 2015)

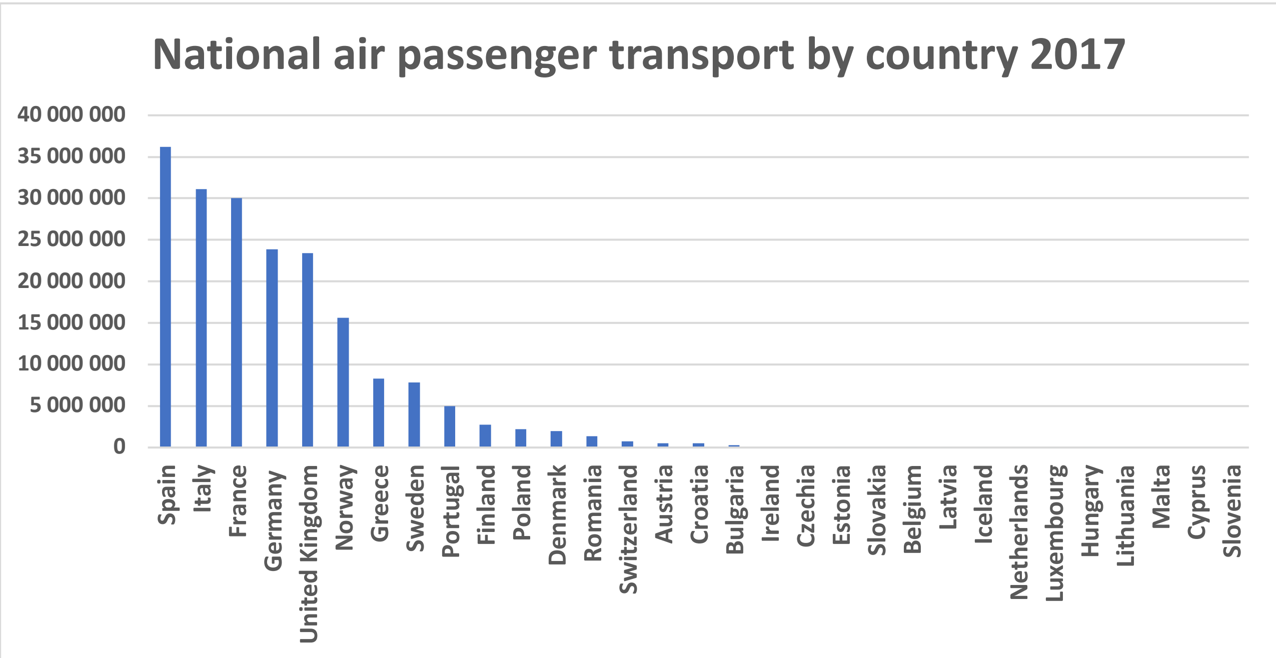



*Figure 4: National air passenger transport by country 2017. Source:* (Eurostat 2017)

The figure above represents national air passenger transported by country in 2017. There is perhaps no surprize that nations with large populations such as Spain, Italy, France, Germany and UK are topping this statistic. More surprisingly is the fact that Norway is ranked 5$^{th}$, bearing in mind that the Norwegian population in 2018 was approximately 5,3 million (SSB n.d.). The reasons why Norwegians fly frequently could first be associated with the geography of the Norwegian country. The country length in Norway vertically is quite long, even if the majority of the Norwegian population is centred in the southern half of the country. In addition, it is dominated by mountains, which make public transportation lines such as trains and roads challenging to build. The long distances with the combination of transport methods that can compete on speed, makes flying more attractive. Furthermore, Norway also have an excellent network of airports located across the country. Avinor has a hyper-connected aviation network consisting of 45 Norwegian airports located across the country (Avinor n.d.[f]). The well-established network of airports offers passengers several travel solutions to cope with the long distances and otherwise difficult geography.

Another argument is that there are various number of direct airline routes from Norway to multiple destinations both across Europe and elsewhere in the world. Oslo Airport is currently offering 17 intercontinental, 33 domestic and 104 European destinations (Avinor n.d.[d]). This means that a Norwegian living in a town in central Norway can visit a number of cities in Europe with only two flights, an offer many uses to reach warmer destinations during the holiday season. It also enables business opportunities that would otherwise have been unheard of in smaller Norwegian communities. The fact that Norwegians have a high income and standard of living could also be a contributing factor for the high number of flights per citizen.

## 1.4 Introduction of Avinor

Avinor AS is a fully state-owned limited company that operates 44 state owned airports across Norway. Avinor was formally known as Luftfartsverket, which was established in 1947 before the name was changed to Avinor in 2003. This was due to the reorganization of the company which turned Avinor into a wholly owned by the Norwegian state company. In total, there are over 3000 employees whom are responsible for the development and planning and operating efficient airport but also air navigation services. Avinor headquarter is located in Oslo, Norway. Avinor is responsible for approximately 50 million passengers annually, in which 25 million travels to and from Oslo Airport, the largest airport in Norway. In terms of financing, Avinor is self-financing mainly through their main activities such as airport charges and other commercial activities.

## 1.5 Case description

Avinor states that the airport traffic and the distribution of peak and arrival times for traveling passengers has a significant effect on passenger throughput at the airport security checkpoint. At Oslo Lufthavn, the Airport Express train and Vy delivers a high number of passengers at specific times upon arrival. This makes passenger flow forecasting challenging, which again affects the number of security agents at the airport security checkpoint difficult due to this type of variation.

Furthermore, the area that the airport security checkpoint is operating on is also challenging. The length of the security checkpoint sets the limitation of how many passengers that can be handled and are allowed through. Bottlenecks are likely to appear when the passengers are putting their belongings into the trays and/or after when they are at the reclaim area. The main challenge for Avinor in which this thesis will be based upon, will be to look for potential bottlenecks and areas of improvements. In addition, the implementation of new technologies and infrastructure such as centralized image processing and new types of X-ray machines will also be taking into consideration in terms of improved efficiency and capacity.

### 1.5.1 Purpose

The purpose for this research is to identify bottlenecks by studying the airport security checkpoint from when the passengers start to put their belongings onto the trays until, passed through the metal detector and reclaimed their belongings. The research will narrow the field of observation to observe passengers at Oslo Airport Terminal 2 and at Sola Lufthavn Stavanger. From the observations, data will be collected and studied in order to find potential areas of improvements and bottlenecks. Overall, this research will be presenting relevant statistics of passenger throughput time and based on this a theoretical approach to identify bottlenecks and improvements will be followed. The main goal of this thesis will be to identify bottlenecks in a real-life case and apply theory and knowledge to create recommendations to increase efficiency.

## 1.6 Research questions

It will be necessary to create research questions to answer and find possible solutions and recommendations for the challenges mentioned in the problem statement. Therefore, this research main objective is to answer the following research questions:

I. *What are the main bottlenecks and areas of improvement for the security checkpoint at OSL and would it be possible to improve them?*
II. *Where are the bottlenecks located and what are the contributing factors of their existent?*
III. *Are there factors other than the techniques used in the airport security that affects its efficiency?*
IV. *Would it be feasible and worth investing in new technology and x-ray machines to improve the overall efficiency for the airport security checkpoint at OSL?*

Answering these research questions could provide Avinor with valuable insight and a list of recommendation that can be taken into consideration. To be able to answer these questions an observation of the security checkpoint will be conducted in combination with field trips to other relevant airports. In addition, speaking and obtaining feedback from relevant personnel will be important. From a management decision perspective, the research will provide manager with an analysis of the current problem issue and possible measurement/actions to implement to improve and increase the total operational effectiveness at OSL.

## 1.7 Thesis outline

The outline represents an overview of the different parts of the thesis, structured as follows:
Chapter 1: Introduction and the research background, travelling habits, introduction of Avinor, case description, purpose of the research and research questions.
Chapter 2: A presentation of Oslo Airport and Stavanger Lufthavn
Chapter 3: Details about the airport security and costs at Oslo Airport
Chapter 4: A review of literature that is relevant for the research topic obtained from articles, scientific papers and case studies. Relevant concepts and theories that forms the theoretical framework for this research paper.
Chapter 5: Research methodology and design. A more detailed description concerning the observation, selection criteria, segmentation and hypothesis for both OSL and SVG.
Chapter 6: Presentation of data collected from the observations at OSL, SVG and GVA.
Chapter 7: Discussion and analysis based on the observations conducted.
Chapter 8: Findings and identifications of bottlenecks at OSL.
Chapter 9: Conclusion and recommendations based on the findings.
Chapter 10: List of limitations for our research, description of future research and a summary of the research paper.

# 2.0 Presentation of airports for observation

## 2.1 Oslo Airport

As the largest airport in Norway, OSL serves as one of three major hubs for SAS, the others being Stockholm Arlanda and Copenhagen Kastrup, as well as being the main hub for the airline Norwegian. As a major hub, it connects the mountainous country of Norway with smaller, domestic flights to and from OSL, for other destinations, both domestic and international. Furthermore, OSL is the starting airport for several passengers coming in from most parts of eastern Norway. With a large capacity increase in 2017, Oslo Airport claims to be able to handle 32 million annual passengers, widely increasing the limit of 23 and 17 million annual passengers in 2013 and 1998, respectively. The new terminal space roams 117 000 square metres, with eleven new bridge-connected aprons and ten new remote aprons (Avinor n.d.[a])

OSL has also increased their number of runways from two to three as a response to the capacity limit of handling 85-90 activities on these runways per hour. Traffic estimations state that this will be exceeded by the year 2030, making it absolutely vital to implement a third runway at the airport (Avinor n.d.[c]).

In terms of income on OSL, having satisfied passengers is of paramount importance. This is due to passengers shopping their duty-free items and parking their vehicles, while waiting for their flights. In 2017, OSL counted that more than 50% of its income came from sales and rent (Avinor 2018).

The researchers observed what airline was accepting check-ins at the two locations, where the "Norwegian" side includes the following airlines, in addition to Norwegian:

- Air Baltic
- British Airways
- Finnair
- Brussels Airlines
- Ryanair
- EasyJet

The “SAS” side includes the following airlines, in addition to SAS and Widerøe:

- Aeroflot
- Air France
- KLM
- BMI
- Icelandair
- Qatar Airways
- Thomas Cook
- TUI
- Lufthansa
- Swiss Airlines
- LOT
- Austrian Airways
- TAP
- DAT
- Emirates

It is worth mentioning that these airlines are not necessarily the only airlines having check-in at this area, but were the ones observed at the time of research in OSL.

## 2.2 Oslo Airport terminal 2

With the increase of passenger flow in the mid 2000’s, the project idea of expanding into a second terminal, known as the Central Building 2, came in 2007, and opened a decade later, in April 2017. It is built west of the older terminal area, covers 117,000m$^2$ and includes twelve new security checkpoints. The estimated investment costs for the terminal stands at € 900 million (Airport Technology n.d.). The terminal now has a capacity of annually 32 million passengers. The new security access is located with close proximity to both the domestic and international sections, both which are used thoroughly.

## 2.3 Sola Lufthavn Stavanger

Sola is the oldest civilian airport in Norway, opening in 1937. During the German occupation in World War 2, the runway was extended to more than double size, from 920m and 850m to 2000m and 1800m, respectively (Avinor n.d.[b]). Since Norway discovered its oil potentials, Stavanger has become the very centre of its activity. This has opened several flights between the outside world and Stavanger, amongst them a direct flight between Stavanger and Houston. However, this route was cancelled in 2015 due to low amounts of passengers, likely due to the declining oil price (Waage 2015). Yet there remain daily international flights to Amsterdam, Copenhagen, London and Stockholm, as well as multiple flights to Oslo, Bergen and Trondheim.

# 3.0 Airport Security

The purpose of airport security and screening can be referred to as methods to ensure that passengers, aircraft, staff and airport infrastructure are protected against threats, harm and crime. The screening of passengers has been in use in Europe and North America since the 1960s and 70s. To maintain the level of security that is required, airport should implement and maintain a system security plan. The airport security plan needs to describe what actions that must be taken to protect the airport, passenger, staff aircraft and property against threats, harm and crime. The main goal is to ensure the safety of the passenger while maintaining a good flow, from when the passengers arrive at the terminal until they are safely seated at the aircraft (Ghobrial and Fleming 1994).

## 3.1 OSL Passenger and Luggage Process

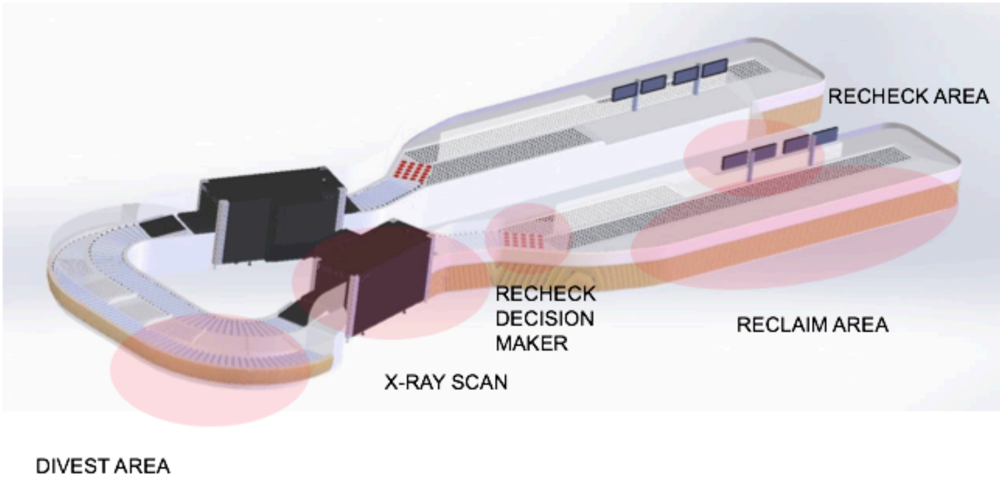



*Figure 5 - Different steps of the OSL Security Checkpoint for luggage. Source: Own work, based on (Avinor confidential report 2019 with permission to publish illustration of the OSL security Checkpoint)*

The figure above is a representation of the layout and design of the security checkpoint at OSL in which a detailed explanation is provided below.

Luggage divest area: The luggage divest area is the first station after passing through the security line. This is where the passengers prepare for the portal x-ray scan, where it is necessary to deposit any electronic equipment, outerwear, and eventually any shoes. Some airports have preparation sections prior to this section to best allow passengers to prepare for this section. In OSL, there are up to four of these divest areas for each x-ray machine. They are connected with a belt that allows the trays to be sent to the x-ray machine.

Portal: After the passenger has put their luggage and personal items onto the trays, they are ready to proceed through the portal of the security checkpoint. Here, the portal main objective is to identify and scan passenger for any additional items or objects that are prohibited to bring through the security checkpoint.

X-ray scan: The passenger's luggage is scanned using a dual view x-ray with remote screening. Any findings of prohibited items will result in an additional inspection conducted at the recheck area. The luggage can also be randomly selected for an additional inspection. The process of identifying and clearing trays takes a few seconds for the agent to do, so the trays continue to move to a certain section called the decision maker, where the tray is either cleared and sent back to the passenger, or to a recheck area. The trays are marked with an RFID tag, making it possible for both the decision maker and the machine afterwards to identify the tray that is sent to one or the other side.

Reclaim Area: The reclaim area is the final section of the x-ray security process. From here, the trays are either automatically sent to the passenger, either directly from the decision maker after the x-ray scan, or from the recheck area, if the trays are subjected to a recheck by a security agent. The latter is often located behind the belt and provides the passengers with the trays after the recheck.  After this section, the passenger is cleared and free to enter the terminal.

Recheck area: This recheck can either envelop a random check, often done with the help of a sniffer machine to locate narcotics or illegal powders, or if the decision maker has sent it due to a potential discovery of illegal items, such as liquids. If the latter is suspected, the agent will check the contents of the trays to find the potential hazard or illegal substance. The trays can be scanned and identified with the RFID tag, which allows the agent to quickly find the image taken by the x-ray machine and find the suspected goods. The reclaim area often provides benches and seats for re-equipment of shoes and clothing.

## 3.2 Nokas

Nokas is the leading security group in Norway and they are also in charge of the security at OSL. At OSL, Nokas security agents conducts all necessary safety control, both inside and outside of the airport. In addition, Nokas operates in Sweden, Denmark and Finland providing different security guard services (Nokas n.d.). As of last year, Avinor has awarded Nokas Aviation Security AS with a new contract that is valid from the 1st of March 2019 with a duration of five years with an option of additional three years. One part of the contract is concerning the security check of passengers, hand luggage and check in bags while the other part is the security check of other personnel, items, inspection of vehicles and other deliveries to OSL  (Aktuellsikkerhet n.d.).

According to the Avinor representative, the waiting time for the security check should never exceed more than 15 minutes and should in most cases handle passenger in less than five minutes, from passengers arriving in the queue, until reclaiming their belongings from their trays. Avinor seeks the same results, where one of their goals is to seek to improve their safety management system. Examples of these goals are by implementing new technologies, such as Centralized Image Processing and new types of X-ray machines.

## 3.3 Airport security timeline

The age of globalization has mainly been based on increased trade, technology and economic growth. As a result, nations have become even more interconnected and the civil aviation industry has evolved to become a more global industry where airports are competing for airport passengers (Gillen and Morrison 2015[a]). It can be easy for passengers to feel displeased due to the security measurements faced at an airport. This is due to long queues, putting their laptop in a separate tray, restriction of liquids, x-ray of shoes, belts and jackets to mention a few examples.

The civil aviation history proves that airports and aircrafts is an attractive location for violence and terrorism. It can be hard to keep up with all the rules and regulations as attacks calls for additional implementations of new rules and regulations. However, the airport security with its regulations has changed drastically if we take a closer look upon the history.
Meltzer (2015) highlights some of the most relevant security measures and when they were implemented in the section below.

In July 1970, the first implementation with the use of metal detectors was introduced. New Orleans International was the first airport to implement this to increase airport safety for passengers.
In November 1972, the requirement of screening all passengers with their carry-on bags was implemented. The main reasons behind the implementation was due to a threat from hijackers to fly an airplane into a nuclear reactor.
In December 1988, a bomb killing all passengers onboard a Pan Am flight resulted in the requirement to X-ray all checked bags for passengers.
In September 2001, items and objectives with a blade is banned as a result from the hijackings on September 11$^{th}$. In December airport security agents was also starting to search passengers' shoes due to an earlier attempt, were a passenger tried to ignite explosive hidden inside his shoe.

In September 2004, passengers were required to remove their jackets and coats, to be x-rayed through the security checkpoint. In addition, passengers who did not have a valid boarding pass were not given permission to go through the security checkpoint.
In 2006, the main rule was to ban all liquids, gels and aerosols from carry-on baggage. This was due to a planned terrorist attempt on an airplane from London. However, it is still allowed to carry small amount of liquids, specifically 100 ml. All liquids containing more than 100 ml are prohibited, save baby formula.
In December 2009, the introduction of a full-body scanner was implemented. This is currently being used at OSL and other airports across the world.

All of the mentioned security measurements from the 1970s until today has been implemented both at OSL and at most other airports around the world. Furthermore, as technology and different improvements in screening infrastructures continues to develop, new implemented regulations may be expected in the near future as well. This can affect the way the airport security agents operate. It is therefore important to be able to adapt to new regulations and implementations to still maintain an optimal flow of passengers through the airport security checkpoints.

### 3.3.1 Aviation security policy

In the field of civil aviation security, the need of well-established common rules for protecting both passengers and goods are necessary. The European Commission has since 2002 established a common set of rules which include screening of passengers, cargo, supplies and staff recruitment with training to mention a few examples. These common rules within the field of civil aviation security also applies for Norway (European Commision Mobility and Transport n.d.).

Avinor are following a strict set of both national and international safety regulations. Further, the Civil Aviation Authority also known as "Luftfartstilsynet" has the responsibility to govern and ensure that these regulations are being up to date within the civil aviation in Norway (Avinor n.d.[e]). Since 2004, Norway has adapted and implemented the international rules and regulation's set by the EU. This has been of high importance for Norway because by following these regulations, Norway would not be treated as a "third-country". In general, the result would be that all passengers, luggage etc, arriving from Norwegian airports to airports located within

EU would have to be re-checked before they could be mixed with other passengers (Regjeringen 2006). Had this been the case, it would put more pressure on the airport security agents and efficiency related to flow of passengers through the airport security checkpoint.

### 3.3.2 Airport security challenges

"*The complexity of security systems at airports within the United states, indeed, worldwide, has grown significantly over the years in response to increasing threats and regulatory developments*" (Wilkinson and Kosatka 2017).

Each airport is designed differently, each with its own security system. Both Oslo, Bergen and Stavanger have their own take on airport security design and setup, while still following the standard regulations. Furthermore, the design and setup for the security checkpoint needs to be flexible and able to anticipate and adapt to future demands of passengers. This can be in terms of implementing new technology such as CIP, a system that is now in use at OSL. New X-ray machines is another investment worth mentioning as this can affect both the passenger satisfaction and efficiency through the security checkpoint. It is worth mentioning that OSL are considering looking into the option to purchase and upgrade their x–ray machines. The challenge would see if these upgrades would really adapt and increase the efficiency at the specific airport. There must also be enough space to fit new machines and technologies, as space is something that is limited at an airport.

However, as stated previously, and also stated by Nowacki and Paszukow (2018), the aviation market will have a solid growth due to rise of emerging nations such as China and India and economic growth. As the security is becoming stricter, the pressure of ensuring the steady flow of passengers is rising. In addition, cost is also something that needs to be kept as low as possible. The security process would have to be more streamlined and collaborative in order to become even more efficient (Nowacki and Paszukow 2018).
Further, the rise in technology and implementation of new technological infrastructure that can be implemented at the airport security checkpoint would also indicate that the aviation industry will become a more data driven process. Automated systems would perhaps enable management of different situations in which airport security agents only needs to interfere in special circumstances (Nowacki and Paszukow 2018).

## 3.4 Traffic statistics Oslo Airport

There are several traffic statistics from 2017 available for analysis to make arguments and developing hypothesis for this research, regarding the improvement of the airport security flow at OSL. These statistics include passengers' numbers, domestic and international, their movements, the number of passengers per weekday and passengers per hour. Studying these statistics will play an important role, defining how and what we want to observe at the airport security checkpoint at Oslo Airport.

| **Weekday** | **Average number of passengers 2017** |
|---|---:|
| **Monday** | **78 044** |
| Tuesday | 73 070 |
| Wednesday | 76 056 |
| **Thursday** | **81 687** |
| **Friday** | **86 545** |
| Saturday | 49 214 |
| **Sunday** | **81 842** |

*Table 1: Average PAX per weekday. Source:*(Avinor 2017)

The table depicts the number of passengers for each weekday, making a flight from Oslo Airport. The number tells us that most of the passengers tends to fly on a Monday, Thursday, Friday or Sunday. An assumption is that there are several business passengers travelling on Monday, Thursday and Fridays. Commuting passenger typically travel on Mondays and return on either Thursdays or Fridays. In addition, there will also be a high number of passengers traveling on leisure for a weekend trip to destinations across Europe or domestic ones on Friday. Furthermore, statistics depicting passengers per hour both for arrival and departure tells us at what time passengers tends to fly. The airport security agents must therefore plan accordingly in terms of security agents and preparations to make sure that the flow of passengers is as high as possible.

| HOUR FROM | Arrival | Departure | Total |
|---|---|---|---|
| 00 | 565 | 35 | 600 |
| 01 | 181 | 8 | 189 |
| 02 | 83 | 5 | 88 |
| 03 | 94 | 1 | 95 |
| 04 | 51 | 3 | 54 |
| 05 | 75 | 92 | 167 |
| 06 | 427 | 1 212 | 1 639 |
| **07** | **1 760** | **2 381** | **4 142** |
| **08** | **2 449** | **2 414** | **4 863** |
| **09** | **1 409** | **2 643** | **4 052** |
| 10 | 1 910 | 1 874 | 3 784 |
| 11 | 1 611 | 2 117 | 3 728 |
| 12 | 2 661 | 1 425 | 4 086 |
| 13 | 1 872 | 2 568 | 4 440 |
| 14 | 2 266 | 2 295 | 4 561 |
| **15** | **2 845** | **2 312** | **5 158** |
| **16** | **3 168** | **2 561** | **5 729** |
| **17** | **2 518** | **3 641** | **6 159** |
| **18** | **2 633** | **2 858** | **5 491** |
| 19 | 2 623 | 2 519 | 5 142 |
| 20 | 2 015 | 2 323 | 4 338 |
| 21 | 1 892 | 1 423 | 3 315 |
| 22 | 1 405 | 722 | 2 128 |
| 23 | 1 137 | 145 | 1 282 |

*Table 2: PAX per hour at OSL. Source:* (Avinor 2017)

There is no even flow of passengers flying from Oslo and other Norwegian airports throughout the day. Passengers tends to travel on specific days and different times during the day. During work days the time between 07.00 – 09.00 in the morning and 15:00 – 18:00 in the afternoon are the most popular timeslots. The airport security agents will plan accordingly but passengers will naturally still experience queues to a certain degree. One of the main goals for Avinor is to have a maximum queue time of 15 minutes, regardless on time of day. A previous study from 2018 depicted a list of proportion of airports experiencing congestion. The top five area where the check-in area, taxi rank, access points, arrivals and passenger screening (Marsh and Calder 2018).

## 3.5 Airport security costs

Airports can be complex and relatively expensive to manage. Dealing with millions of traveling passenger each year, handling business, leisure, domestic and international travellers with baggage is challenging. In addition, rules and regulations must be followed to ensure a safe and secure travel for each and every one of the passengers. This is, however, very expensive and day to day operations such as airport security agents come with a high cost related to it. If both airports and airliners wish to stay profitable in the future, addressing ways for potential cost savings related to the airport security checkpoint process could be a smart idea.

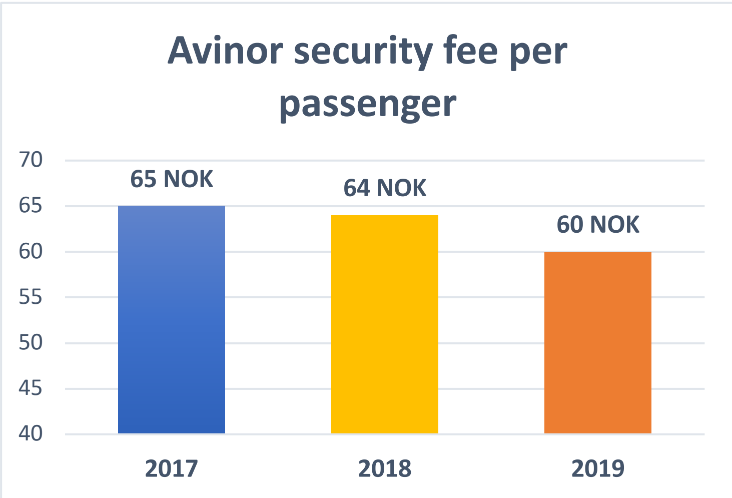



*Figure 6 - Avinor security fee per passenger 2017-2019. Source: (Own work, 2019)*

The graph represents the average security fee per passenger across all Avinor airports in Norway from 2017 – 2019 provided by the Avinor representative. The security costs are not expected to further decrease due to increased security investments which will likely increase the costs for 2020. The numbers prior to 2017 is not comparable. In 2016, the EU commissioned a regulation that made a part of the passenger fee to be included in the security fee. This means that there was an increase in the security, with an equivalent reduction in the passenger fee.

The costs are financed by a security fee that is added to the tickets of the passengers. This fee is there to help finance costs for the security and ensure to maintain a safe and efficient flow of passengers. The same system is also in use across the world like in the US. The Transportation Security Administration (TSA) oversees the security of travelling passengers in the US. TSA conducts screening for explosive and passenger at the security checkpoint, patrolling and inspection to mention a few examples (Transportation Security Administration 2017). According to TSA, the current fee is set at $5,60 per one-way trip in air transportation for passengers originating from the U.S. Roughly estimated at NOK 50 per passenger. It's also collected from air carriers from the passenger itself to cover the costs.

The representatives of Avinor set an emphasis on costs, where the expenses directly associated with the security protocol was doubled between 2003 and 2006, from NOK 90 million to NOK 180 million. Even as the curve has smoothed out since then, there has still been a considerable increase from 2006 until 2018, being doubled again to approximately NOK 330 million in annual expenses. With the increase of passenger flow both in Norway and abroad, along with future investments in technology possibly on the way, this number could increase further.

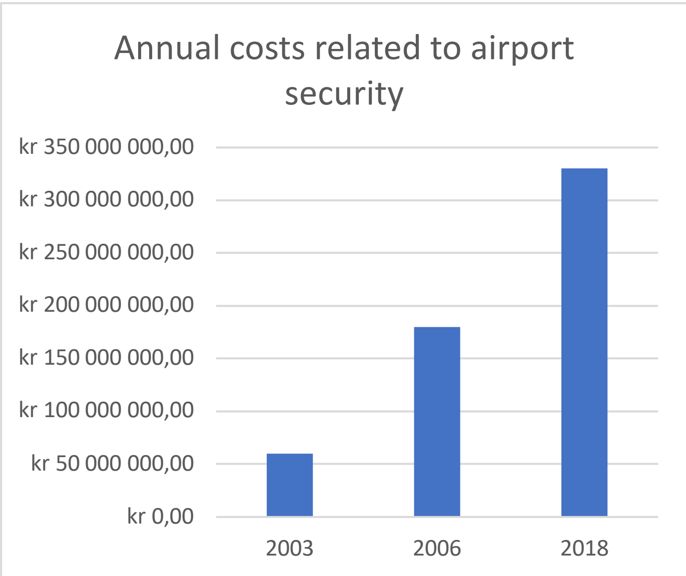



*Figure 7 - OSL annual expenses from 2006-2018. Source: (Own work, 2019)*

## 3.6 Technology and future

Centralized imaging processing is something that is currently in use at OSL.
CIP refers to a network of luggage pictures that are taken by the x-ray machine. Its potential is to loosen up the 1:1 ration between the x-ray machine itself and the x-ray screener.
This means that the security screeners do not need to sit next to the x-ray machine in order to evaluate images (Aviation Security International 2017[a]). This technology is currently being used at the research focus area, OSL, and reportedly has its respective advantages and disadvantages.

The advantages include flexibility, allowing agents to be off location, which could help contain anonymity at an optimal level. However, one of the better advantages is the fact that it allows efficient screeners to handle more than one security machine at a time. This means that the potential efficiency capacity can be reached for all screeners. This would also assist processes containing unexperienced or underqualified screeners to keep up at an optimal level. As it increases the security agent's efficiency, it allows high activity lanes to flow better, reducing the need for opening other lanes at sub-optimal capacity. This will in turn lead to better cost efficiency. In fact, research has shown that the implementation of CIP was inspired by this cost efficiency, and not as much by the increased level of security this adds (Baur-Ahrens et al. 2015).

A disadvantage could occur if the screeners are located off the location of the checkpoint. Screeners on the checkpoint location in OSL are limited to approximately 20 minutes of screening time before rotation, due to reduction of sharpness and concentration after this time (Avinor Representative, 2019). However, research has shown that if the screening room is located within an acceptable, short, walking distance of the checkpoint, the rotation between screening and checkpoint personnel is possible. It is however argued that this solution could reduce or restrict a flexibility of setting radio communication between screeners and the x-ray machines (Aviation Security International 2017[a]).

More than a decade since the ban on passing through liquids on aviation travel, the passengers are still subject to this ban, save for medicinal liquids and liquid food for infants. However, security scanning manufacturers are at the time allowed to submit technologies to airports that can be categorized into three operational scenarios, C1, C2 and C3 (Aviation Security International 2017[b]). The latter of these categorizations can indeed allow liquids to pass through the security check.

To represent electronic devices with a battery, a laptop is used as example. The first machine, C1 follows the one protocol that hassled passengers are most familiar with, where both laptops and liquids are removed from bags. These liquids are limited to containers of 100ml. The C2 machine allows laptops to remain in the bag, but liquids are removed. The final, C3, allows both laptops and liquids to remain, albeit inside the limited container and fitting inside a plastic bag. For the passengers' convenience and their reduced stress level, it is important for technologies to be set at C2 and C3 standards, as removal of these electronics, liquids in containers and potentially removing footwear, combined with potential loss of items and secondary searches increase the amount of stress on the average passenger (Aviation Security International 2017[b]).

The potential for the C3 type machines and their succeeding replacements are to not require passengers to set anything aside on the trays or a carry-on bag. The bags can potentially go through the x-ray as they are presented. Research has shown that this technology could be presented in a few years (Biesecker 2018).

The head of IATA, Giovanni Bisignani, expressed his thoughts on how the subjects of the throughput rate, the passengers, should be able to feel when flying. He said:
'*We spend 7.4 billion Dollars a year to keep aviation secure. But our passengers only see hassle. Passengers should be able to get from curb to boarding gate with dignity. That means without stopping, stripping or unpacking, and certainly not groping'* (Baur-Ahrens et al. 2015).

While there are ideas on how to manage the airport security issues with the technology and hardware available with today's methods, there are other ideas on how to find solutions with technology that either is in a prototype alpha stage, or non-existent at all yet. These methods could speed up the process of passenger lines significantly. The methods have two preferences, improvements for the passengers themselves, and the passengers' carry-on luggage.

One idea is an idea of using a machine names ***Shoe Scanner*** from Scanna, which uses a grid of sensing electrodes to do an analysis of shoes and its potential content. This is done without actually having to take the shoes off. The idea is to potentially integrate it with a full body scanner, making it work alongside the x-ray scanner for the rest of the body (Scanna 2019). If this proves difficult to implement, there is also an opportunity to use it on passengers *while they are waiting* in the security queue (BBC 2019). Scanna is currently processing a trial version for the end of 2019.

Another major hassle for passengers is to remove jackets and coats, as well as cell phones or other electronic devices from pockets. A scanner that was originally designed for observing different heat temperatures in outer space, can be used for effectively detecting contraband objects on the person. Likewise, it can also detect non-harmful objects, such as cell phones and headphones, clearing them with a green light after being detected. The entire process takes a few seconds and could potentially eliminate one of the top issues that needs improvement, as per IATA's passenger survey (Phys Org 2018).

The machine is known as a Millimetre Wave Camera and uses an extremely cooled sensor, down to -273 degrees Celsius, which allows passengers to be screened effectively from a distance up to nine meters. With this extreme sensitivity, any items, clarified or not, will appear as a clear shadow on the person's body. This cooling will have a certain cost, but it is claimed that many airports could find the cost worth it in order to reduce queue time (BBC 2019). This machine was tested at Cardiff Airport as a collaboration between Cardiff University and Sequestim (Cardiff University 2018).

Where terrorists are after attention and causing the most amount of havoc, a cramped screening area does not limit terrorist attacks, in fact it can be a target in itself. An aviation science professor from the Metropolitan State of Denver has suggested an implementation of terahertz scanners by the entrance of public areas. He claims that passengers entering the terminal building would not, in the majority of cases, notice anything as they are passively scanned. If there is not threat detection, they can enter the terminal without stop. This system has been introduced in the Los Angeles subway system for testing and is currently ongoing (Pring-Mill 2018).

# 4.0 Literature review

Literature that will be relevant for our research subject will be obtained from articles, scientific papers, book, case studies and previous research. Furthermore, the literature will be critically evaluated to find relevant information that can be used to solve our specific research topic. The literature review will be used to get an overview of the current problem and to demonstrate how we use the findings for the literature to our research problem. In this case, we have used different sources to get an in depth understanding of the research problem. The articles we have used are related to different areas within optimization, airport crowd research etc.

In an article by (Hainen et al. 2013), by creating a hazard based analysis on time spent in airport security, they concluded that there were an abundant amount of factors that affects the transit times. They include factors from the number of seats available on average per flight that day, weather conditions, what day of week it is, with the more obvious factors, such as amount of open security lanes and actual number of passengers. They also concluded that the security system in Cincinnati in the US, a relatively large airport, is reactive rather than proactive. This means that they have a tendency on responding to events after they have happened. This includes opening more security machines and making a general effort to increase the throughput rate after the queue is increasing, even though there is clear evidence that there is a surge in passenger flow in the early morning and in the middle of the afternoon.

This article shows that implementing a model to optimize passenger flow is necessary, in order to make the airport security system more proactive rather than reactive.

In another article about optimization in airport security, it was determined by (Xu et al. 2018) that the main bottleneck in this process is when passengers wait in line to remove shoes, belts, jackets and items sentenced to individual inspection. The article takes the Monte Carlo method into action. This method is used to perform several simulations in order to find key bottlenecks in the security process, maybe even to limit waiting time variance. The high variance makes one of two inconvenient factors for the passengers. The passengers are unnecessarily early or will miss their flight if the variance is too high. (Xu et al. 2018) continues with several ideas for optimization, such as opening special security lanes for passengers without luggage, family lanes and adding a pre-check lane for low-risk travellers and a part of an elite membership in a partner airline, a system more common in the United States (*LoungeBuddy*, 2018).

The article by Chen, Xu and Wu (2017) examines the passenger throughput at an airport security checkpoint and how it can be optimized. The article key challenge is "How to balance the trade-off between maximizing security and minimizing the expected amount of waiting times and variance to improve passenger throughput" (Chen, Xu, and Wu 2017). Furthermore, the article mentions different types of queuing service systems, which are individually modified to find the best possible system. In addition, the use of computer simulation is also mentioned as a tool of evaluating performance of the different queue systems. The article is of high relevance as it addresses and analyses different types of queue systems, finding the most optimal one, in order to increase passenger throughput. This is what our study aims to achieve and get an in-depth understanding of the current problem and find an optimal solution.

Wei (2017) article discuss optimization of airport security lanes, especially how the security system can be maximized in order to minimize the inconvenience for the passengers. The articles discuss four main problems related to development of models, adjustment to current security system, how to accommodate cultural differences and suggestions that can be implemented based on the model. These are all problems that are relevant for our main topic, as we will most likely address some of the same problems during our research.

Furthermore, the Petri net model is used as a tool to analyse the security-screening layout and process. It is described as "*an effective tool which can describe and analyse concurrent systems and models the discrete events systemically*". (Wei, 2017). Main bottlenecks that are affecting the queue time is also identified and different means of improvement is implemented. The implemented optimization measures mentioned in the article indicates that it has a positive effect, increasing both the passenger throughput and a more effective security screening process (Wei, 2017).

In another article by de Lange, Samoilovich and van der Rhee (2013), there is an attempt to optimise one the main factors, customer satisfaction, while still attempting to minimize costs. They do this by offering the passengers a priority lane if they show up during a limited time window. The point of it was to smooth out distribution of arriving passengers, making them arrive at a more designated time, for better comfort for both the security team and the passengers themselves. With this method, de Lange, Samoilovich and van der Rhee claims that it could reduce the number of security agents by 6,4-17,5%, with no consequences to average passenger waiting time.

The article written by Gillen and Morrison (2015[a]) focuses on the economic issues such as pricing and financing related to aviation security and performance. The article addresses relevant topics related to benefit-cost analysis, information flow and human factors to mention a few. From an economic perspective, it addresses questions such as to what extent an airport best can allocates their resources to achieve the highest level of performance. Furthermore, the rising cost of aviation security based on the prediction that the number of passengers will continue to grow will have an impact. According to the article, the average growth rate is estimated between 4.2 and 4.7 percent until 2033. (Gillen and Morrison 2015[b]). Relevant figure such as the one illustrating the security cost per passenger is very interesting, specially from an economic perspective. In addition, it raises awareness of the evolution to risk-based aviation security. The assumption is that every passenger is a potential terrorist, therefore, all passengers receive the same level of security checks. This results in queue and delays, decreasing the passenger satisfaction. Overall, the article addresses some very interesting perspective related to airport security and performance, which can be fruitful for our research.

## 4.1 Theoretical framework

The purpose of the theoretical framework would be to get an overview over relevant theories, concepts and definitions. It would be important to understand these theories as these can be linked and connected to this case and research paper, ultimately finding possible solutions and implementation based on the theories and concepts. Further, it will also give the research purpose and direction.

### 4.1.1 Bottlenecks

"A bottleneck is defined as any resources whose capacity is less than the demand placed upon it. A bottleneck, in other words, is a process that limits throughput (Lawrence and Buss 1995) The authors further mention several other definitions of what a bottleneck can be described as such as:

- Any operation that limits outputs
- A function, department or machinery that impedes production
- Congestion points occurring within the production

Further, Wang, Zhao, and Zheng (2006) defines bottlenecks as resources or utilities that limits the performance of a production system. A solid statement is that the bottlenecks are not only caused by physical constraints, such as machine capacity, physical objects, the facility or the different resources needed to produce a specific product. It is also affected by non-physical constraints such as the operators of the machinery, corporate procedures and training or the approach an employee has to a problem. In addition, a bottleneck is not necessarily something that is static, it could also be something that`s appear temporarily.

If the bottleneck is causing problems the decision will have to be focused on the different options available. Would it be possible to remove the bottleneck completely or can it be reduced by adding more capacity and resources?

### 4.1.2 Bottleneck management and the theory of constraints

The throughput time of the system is determined by the existing bottleneck. To be able to optimize the logistic processes, the focus must be on the total throughput time, from start to finish. Focusing only on optimizing individual logistic processes within a supply chain, would not be the optimal solution as this can cause bottlenecks or constraints at other parts and areas of the logistics activities (Martin 2011).

Eliyahu Goldratt made a significant contribution on how to view the logistics processes with the introduction of what is known as the theory of constraints (TOC). This can also be known as optimised production technology (OPT). All the different logistic activities can be categorised as a bottleneck or non-bottlenecks. The bottleneck has a critical impact on the throughput time for the whole system. If the goal would be to speed up the throughput time of the whole system, the area of focus would be on the bottlenecks. This can be done by either adding more capacity or resources where it is needed, to reduce the total throughput and set-up times (Goldratt and Cox 1984).

Further, Goldratt has also created the five focusing steps which is defines the process of on-going improvement.

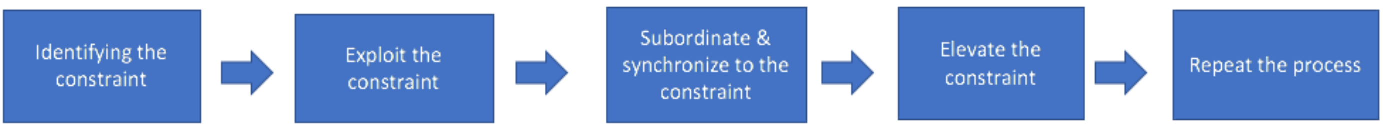



*Figure 8 - The Five Focusing Steps. Source: Own Work, based on (Goldratt and Cox 1984)*

Identifying the constraint: Step one would be to identify the constraint or bottleneck within the supply chain and network of activities. Identifying the cause of why the constraint exist and why the entire system is affected by it.

Exploit the constraint: Step two would be to the maximize the productivity at the identified constraint. This would imply that the constraint should be utilized at 100 %. The pace of the system can then be adjusted and aligned with the pace of the bottleneck, resulting in a higher throughput rate and utilization.

Subordinate & synchronize to the constraint: Step three, the non-constraint would have more capacity than the identified constraint. Therefore, it is crucial that for the non-constraint to not produce as such capacity that the constraint can`t handle it. It is necessary to ensure that the rest of the non-constraint supports the work of the constraint, for example by giving it inputs.

Elevate the constraint: Step four, if the constraint still remains, step four is to consider any further actions that needs to be done in order to eliminate it. This usually means that step four is continued until the constraint is reasonably broken or removed entirely. Alternatively, spending capital investments may be necessary to process further.

Repeat the process: Step five, once the constraint has been identified and improved, the result is a positive effect. It is therefore important to go back to the beginning, trying to identify new bottlenecks within the system by following the four previous steps described. Eventually, the process will benefit from this concept, reducing the number of bottlenecks while increasing throughput time and efficiency.

### 4.1.3 Queuing Theory

Queuing theory addresses an aspect that is present in most endeavours, both in life and in the business. This aspect, waiting, causes people and their processes to be halted or limited while someone else in front are being handled. Queuing theory is a mathematical study usually done in order to make business decisions on how to optimise a queue, or to give a clear indication on what resources are required to provide a service (Sztrik 2012).

The theory is based on the works of Danish mathematician Agner Krarup Erlang (1878-2929), on how he solved a problem on determining how many circuits were required to provide an acceptable telephone service, by finding out how many operators were needed for handling a set of incoming calls. In his work from 1909, he proved that the Poisson distribution theory is applicable for random telephone line traffic (Erlang 1920). The Poisson distribution theory can be shortly explained as the probability of a given number of events if the events occur at a set constant rate and independent from the previous event (Haight 1967).

To explain the queuing system, it is important to understand what factors it involves. The most important one is the queue itself, containing jobs or customers. These containments usually has to wait for a time, as well as being processed, then departing the queue (Sztrik 2012).  A typical example would be at a supermarket. The employee at the cash register can handle one customer at a time, gets processed, then depart the area. It is possible for there to be more than one cashier, to handle several customers. In this case, there are three employees, one available, one in process of another customer and one just finished with a customer and is immediately available for another customer. Therefore, if there are more jobs at the node then there are servers, the jobs will initiate a queue and wait for their turn.

There are also several ways to process these customers/jobs, meaning here that there are different chronological orders to handle them. These are known as scheduling policies and can be used for these queues. The most commonly used are "First in first out" and "Last is first out". The former, FIFO, is a principle that says that customers are served at the chronological order of which they came in, meaning that the customer waiting the longest is served first (Laguna and Marklund 2011).. The latter, LIFO, also handles customers one at a time, but the last arriving job is handled first. This is also known as stacking (Jain et al. 2014)

### 4.1.4 Customer Satisfaction

Customer satisfaction is defined as the degree to which a product, service or experience meets a customer's expectations. However, achieving expectations is not necessarily sufficient for satisfaction (Morpace International. et al. 1999).

There are several benefits of achieving a high customer satisfaction. Hill, Roche, and Allen (2007) explains that a high customer satisfaction can lead to higher profitability, better return for shareholders and is a key indicator on customers' willingness to spend. Furthermore, they argue that today's customers are placing more emphasis on the experiences they are going through, rather than the possessions themselves. They refer to several studies that concludes that experiential purchases, meaning here '*doing'*, is better linked to happiness and long-term satisfaction than material purchasing, meaning here '*having'* (Hill, Roche, and Allen 2007).

#### 4.1.4.1 Airport Customer Satisfaction

In terms of customer satisfaction in an airport setting, (Kramer et al. 2013) argues that an airport is one of many front lines that needs to handle customer satisfaction in order to thrive economically. Airport managers were interviewed to reveal several reasons why maintaining a good customer satisfaction is of importance. First, by measuring the customer experiences unveils what improvements are necessary from the customers' eyes. Second, making the customers feel calm, relaxed and at ease makes it more likely for them to return to the experience, spending more at the shops and services around them. For an airport, this would mean, among others, parking services, duty free shopping and restaurant establishments. The final reason for maintaining customer satisfaction is the fact that if it is high enough, it will give a competitive advantage for the airport compared with other airports.

Customers are in this context often referred to as passengers, but there are several other airport customers. These customers can be the “Meet-and-greet” people, visitors whom are in the proximity for business, tenants of the airport, which may include the airlines, aircraft owners, security agents, rental car companies and other economic business endeavours, and the employees of the airport (Kramer et al. 2013).

There are several major factors that determines the airport customer satisfaction, as written by Senguttuvan (2007). Some of them are:

- Airport accessibility
- The security checks
- Terminal facilities
- Food and beverages
- Retail services
- Baggage claim
- Immigration and customs

Furthermore, Senguttuvan continues to illustrate the quality service performance on the areas listed below.

- Navigating the airport, with the level of flight information systems, signs and illustrated walking distance indicators.
- Airport services and facilities, such as restaurants, facilities and lavatories.

- Security and immigration services, most importantly the helpfulness of agents and waiting time for security inspections.
- Environment of the airport, meaning the character and atmosphere of the airport. It also includes cleanliness.
- Airport services, such as efficiency of check-in and waiting times for queues.

Edwards and Edwards (2005) writes that thriving airports often faces a difficult challenge, whether to focus more on airport growth or customer satisfaction. The passengers him/herself experiencing overcrowding is one of the most damning effects of undermining customer satisfaction, as uncontrolled growth can result in delayed trips, overcrowding in terminal buildings and longer queues.

Regarding the security check of an airport, there is a clear link between customer satisfaction, the waiting time and its observable quality (J. K. C. Chen, Batchuluun, and Batnasan 2015). There are naturally several other factors that determine the customer satisfaction, all which are important to understand in order to do any refinements in airport screening procedures (Gkritza, Niemeier, and Mannering 2006).

### 4.1.5 Material flow

The main goal for a supply chain is to keep materials flowing from start to the end customer. There is a time dimension within the supply chain which aims to move the material, parts or items as fast as possible through the chain. In order to achieve this, the different parts needs to be coordinated efficiently to avoid congestions within the different steps of the chain (Harrison, Hoek, and Skipworth 2014). According to Knill (1992) the main goal is to achieve a continuous, synchronous flow. The term continuous refers to the fact that there is no interruptions or unnecessary accumulations of inventory. Synchronous refers to materials, items or parts being delivered when they are needed, on time, in the right order and exactly to the point needed.

### 4.1.6 Information flow

Multiple types of information flow exist within the supply chain such as forecast and demand, inventory levels, financial, product data and descriptions to mention a few examples. The information technology enables sharing of both demand and supply data of high details and accuracy (Harrison, Hoek, and Skipworth 2014). The main goal would be to integrate both the supply and demand data, to create a more accurate picture of the market and end customers. If companies and organizations manage to achieve this, such integration can provide a competitive advantage. Further, Harrison, Hoek, and Skipworth (2014) states that "*the greatest opportunities for meeting demand in the marketplace with a maximum of dependability and a minimum of inventory come from implementing such integration across the supply chain"*.

# 5.0 Research Methodology

It is important to decide what research design is most suitable for this research.
The decision needs to be well-considered and the chosen research design must be able to evaluate and create data to a phenomenon in the correct context.

## 5.1 Research design

A research design can be seen as an action plan which include different steps, getting from here to there. "Here" can be defined as the different questions that you would want the research to answer and "there" can be the different steps in order to answer them such as collection data for analysis and interpretation (Yin 1984). Furthermore, Yin (1984) states that a research design deals with at least four problems which are;

1. *What questions to study*
2. *What data are relevant*
3. *What data to collect*
4. *How to analyse the results*

The research design is however much more than an action plan. The purpose would be to avoid a situation in which the evidence from the research does not address the research questions. The importance of developing an appropriate research design in the beginning is crucial. If this is not properly done, it would be difficult to draw any accurate conclusions for the research (Yin 1984).

## 5.2 Qualitative research design

Briefly explained, a qualitative research design attempts to explain the studied behaviour. The data can be collected through conversational communication such as in-depth interviews. The qualitative method can help to understand certain behaviour or perception of a specific group related to a specific topic (Lowhorn 2007).

Yin (2016) mentions five features of a qualitative research.

1. Studying the meaning of people's lives, under real – world conditions.
   The people being studied will perform and express themselves independent of the research that's is conducted. People would be expressing their own thoughts and opinions without being limited to a preestablished questionnaire as an example.

2. A representation of different views and perspectives of the people. To capture someone's perspective, view or opinion could be one of the major reasons of conducting a qualitative study.

3. Covering the contextual conditions within which people live
   Contextual conditions might influence the way people behave, depending on the circumstances or environmental conditions.

4. Getting insight into different concepts that can help to explain human behaviour.
   A qualitative research design wants to explain events and why people behave in a certain way, explaining this through existing concepts.
5. Using multiple sources of evidence and not rely on a single source alone.
   A qualitative research strives to collect and present data from multiple sources. However, the variety in sources would come from the fact that you have to study a real-world setting with multiple participants.

## 5.3 Quantitative research design

A quantitative method can be described that studies and tries to explain a specific phenomenon. The explanation can be based on numerical data, arriving for observations, that are later analysed and put into statistics (Yilmaz 2013).

Furthermore, a quantitative method can also be the results of data collected through questionnaires, polls or analysing existing data studies through a computer program. Its main characteristics are based on larger sample sizes that represent the population, and its results being presented in the form of statistics and data. Such a study can often be repeated or redone in a similar fashion, as it presents data not likely to change over time unless a modifying factor is set in (Labaree 2009).

Quantitative research designs are divided into two objective categories, descriptive and experimental. The former addresses issues and subjects by researching them only once, finding differences or associations between variables. The latter, however, researches both before and after a given treatment, establishing causality (Labaree 2009).

For this research, the primary objective would be to undergo a descriptive, quantitative study. It will be conducted to quantify the current problem, generating data that can later be transformed into statistics or number. The main form of quantitative data collection method will be to use observation. During the observation of the airport security checkpoint, we will examine passengers in a natural setting and under normal circumstances, recording passenger's behaviour to gain a better understanding and behavioural patterns of interests. Furthermore, the observation can provide us with valuable information that later will lay the foundation of theory and proposition development.

It is also important to mention that interviews might be conducted where we find this relevant to gather more information. For example, if we want to get a better understanding of how the airport security company operate, in – depth interviews with security agents might be relevant. All within reason regarding the confidentiality for the airport security system.

In terms of approaches, there is the option of using either a deductive or an inductive approach. The deductive is when there is an already formulated hypothesis from existing theory, moving from a general research to a specific one. The researcher in this approach will study what others have already researched and then test hypotheses from their theories (Halliday 2016).

An inductive research however, is about collecting fresh data on a specific topic of interest. After enough data is collected, the researcher will step back to better understand the data, finding patterns and logical algorithms to both better explain the data and develop a theory (Halliday 2016).

For this case, these two approaches collide. On the one hand, it is necessary to look at previous research to test other theories on optimizing airport security efficiency, finding specialized methods that can be implemented to the OSL stations. On the other hand, there is a need for actual observation in for example trends, deviations and variables. Looking for patterns to develop a specialized theory for the specific airport can be vital. We can therefore say that one of the tasks will be to use both inductive and deductive methods to find an optimized model.

Another task for this assignment would be to create a model that considers several aspects, including airport size, average passenger flow, actual passenger flow, seasonal variations etc. If the tasks respond to a quantitative research, the research tasks are concrete, focused and ensures one single way to do the task successfully. This means that there is only one-way to do the task, their ambiguity is limited. This also opens for having a single success criterion, making a clear end conclusion to see if the research was successful or not (Jost 2016). For this to be achieved there is need for observation. For this case, some research tasks need completing. Completing research and analysing records can give us a clear answer on how to formulate recommendations to improve the airport security checkpoint at OSL.

As the researchers will approach the observational area, there will almost certainly be a collision between the assumptions of the theoretical background, and the actual empirical evidence that the observations will uncover. There is, almost without exception, at least a small difference between theoretical assumptions and what is actually uncovered.
This means that the theory has to be used deductively for structure purposes, but it can also be important to remain inductive, that the researchers needs to be open for conclusions not thought of before. Following this example, it doesn’t only become possible to prove a theory, but also to expand it.

By following Johannessen, Tufte, and Christoffersen's (2016) methods, observation and analysis needs to be performed separately. In order to comprehend the information behind the raw data, a thorough analysis needs to be done at its own time. This could mean that the research will start out very wide but will be narrowed into more specific observations as time goes. By narrowing down, priorities must be made, discarding uninteresting information and gives a clearer focus on the bottlenecks or other problem settings. Again, this can also develop new, undiscovered issues and maybe even a way to approach them.

(Johannessen, Tufte, and Christoffersen 2016) illustrates this by showing a spiral starting from a very wide focus to a more tapered focus after new conditions are introduced:

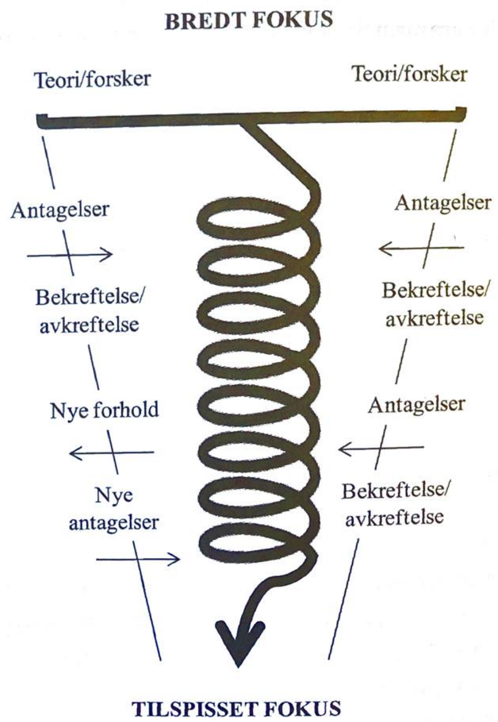



*Figure 9 - Spiral illustration on how to narrow down observational methods. Source:* (Johannessen, Tufte, and Christoffersen 2016)

## 5.4 Mixed methods

Combining both quantitative and qualitative methodological research makes a mixed method, a phrase being ever more used. In fact, Newman and Benz (1998) writes in their article that today's research is less about quantitative and qualitative being opposed to each other, but rather that researchers place themselves on a middle ground between them, if not simply *tending* to be more leaned towards one of the two.

The concept of the mixed method is to collect and analyse both forms of data in a single study. The first official recording of this type of method was used in 1959, as Campbell and Fisk used both methods to better understand the validity of physiological traits (Campbell and Fiske 1959). The method allows both open- and closed ended questions, and their suggestive answers, clear or not. The main idea is to allow several viewing points on a single perspective, allowing potential opportunities wherever possible. In other words, it can allow closed ended measurements and calculations, yet leave open ended observations (Creswell 2003).

## 5.5 Observations

When we are observing people, we are studying their behaviour. Conducting an observation is well suited if the observer wants to get a direct insight and better understanding of why people behave in a specific way. Sometimes, the only way of collecting the necessary data is to conduct an direct observation (Johannessen, Tufte, and Christoffersen 2016). An observation can be used to test hypothesis and give answers to the approach to the observer's problem. Data collected from the first observation will be a detailed description of human activity, in this case the passenger's behaviour and actions. According to Johannessen, Tufte and Christoffersen (2016), there are six central point's related to an observation.

1. The observer(s) will be the scientist, trying to understand and interpret a detailed description of the actions and events as thorough as possible.
2. The observation needs to be systematic and detailed. It is therefore important to define what or who is going to be observed, specifying the situation and at what time it would be most reasonable to conduct the observation.
3. The field of the observation will be the specific area in which the observers will observe from.

4. Fieldwork, the collection of raw data material in the specific area. The observers will try to create a close up of the situation they are studying.
5. The setting of the situation is where the observation specifically is carried out/conducted. The setting of the observation could be natural or arranged. The observers can be observing from different locations to study how people behave in different situations. In this case, at different points and locations where the passengers go through the different stages at the airport security checkpoint at OSL.
6. The unit of analysis is related to the unit or elements that is directly being observed. There are different analysis units, for example individuals such as passengers, their actions, events and their correlations with different stages as they go through the security checkpoint.

The following tables below contains different selection criteria that has been created to specify and go into greater detail for the observations at OSL and SVG. The main goal is to define the setting, unit of analysis, occurrences and time slots for both observation field. This would in general contribute to a better structure and plan and also what to expect in terms of unit of analysis and occurrences when the observations are being conducted.

## 5.6 Selection criteria for OSL

| **Selection criteria for Oslo Lufthavn** | **Options of passengers going through the airport security checkpoint at OSL Terminal 2** |
|---|---|
| Setting | The setting will be the airport security checkpoint area at OSL. Observing passengers from when they start to put their personal belongings on to the trays and collect them at the other side of the security checkpoint. |
| Units of analysis | Airport passenger`s, how they behave, number of trays, male/female categorization, time spent. |

| | |
|---|---|
| Units of analysis (cont.) | Security personnel, their capability to ensure a smooth flow of passengers, observer if each of the personnel have a common practise in which they conduct their security check on passengers. |
| Occurrences | Passengers interaction with different stages through the airport security checkpoint<br>- Encounters of passenger and airport security personnel<br>- Passengers putting their personal belongings on to the trays<br>- Passengers going through the portal<br>- Passenger being re-checked by a security personnel<br>- Passenger luggage being rejected and re-checked<br>- Passenger collecting their luggage |
| Time-slot | Measuring at specific times:<br>- During the morning rush between 07:00 and 09:00, when the number of passengers is travelling to and from work or catch an early morning flight for leisure purposes.<br>- During the afternoon between 15:00 and 18:00, when passengers are traveling home. |

*Table 3: Overview of selected criteria and options for observation of passengers through the airport security checkpoint at OSL. Source:* (Ryen 2002)

## 5.7 Selection criteria for SVG

| **Selection criteria for Stavanger Lufthavn** | **Options of passengers going through the airport security checkpoint at Stavanger Lufthavn** |
|---|---|
| Setting | The setting will be at the airport security checkpoint area at Stavanger Lufthavn. This will be an observation in which a comparison can me drafted towards the observation from Oslo Lufthavn. |
| Units of analysis | The main goal will be to observe the same as in Oslo. Measuring the divest and reclaim time, and the number of trays per passengers. Furthermore, the larger trays at Stavanger will be given extra attention in relationship with the number of trays on average, reclaim and divest time. |
| Occurrences | Passengers interaction with different stages through the airport security checkpoint<br>- First point of contact between the passenger and airport security personnel<br>- Passengers putting their personal belongings on to the trays<br>- Passengers going through the portal<br>- Passenger being re-checked by a security personnel<br>- Passenger luggage being rejected and re-checked<br>- Passenger collecting their luggage in the reclaim area. |

| | |
|---|---|
| Time-slot | Measuring at specific times:<br>Both the specified time underneath will try to be synchronised with the ones from the observation at OSL.<br>- During the morning rush, starting the observation from approximately 09:00.<br>- During the afternoon, starting at approximately 15:00. |

*Table 4: Overview of selected criteria and options for observation of passengers through the airport security checkpoint at SVG. Source: Own work, based on* (Ryen 2002)

There are two types of roles in which the observers can choose from, a participating and non-participating role. It will be important to define and specify what type of role the observers should choose. This can be crucial because it will be important to choose a role that is relevant for the phenomena the observers are about to study (Johannessen, Tufte, and Christoffersen 2016). In a non-participating role, the observers will not interact with the environment, or in this case any of the passengers going through the airport security checkpoint.

The observers will study the passengers from a distance and write down what they see and observe. One of the advantages is that the observers does not interact between the passenger they observe. This results in an observation that is conducted where passenger behave in a way that the normally would do, without any influence from the observers. However, the challenge of when observing from a distance is that it can be difficult to understand the real meaning of what`s being said, how and why passengers behave in a certain way. This is because the observers will not interview each and every passenger but interpret based on their own assumptions and on the formulated hypothesis.

The first observation will take place at OSL, where it is planned to make an observation of the airline passenger`s going through the airport security checkpoint at OSL Terminal 2.
This means that there will not interactions with any of the passengers during the study. It will be necessary for our study to make observations to predict, test our hypothesis and to draw assumptions and conclusion based on the findings.

In the time following the primary observation, a report will be formulated, stating details on what was shown, statements from agent conversations will be reviewed and estimated assumptions will be made to formulate different hypothesises in order to prepare for the main observation studies in the future.

After the report, the observers will look into details of these hypothesises, and try to formulate them into a well remedied preparation. To do this, usage of theoretical work for observational methods will be utilized. In this case, the book on social sciences by Johannessen, Tufte, and Christoffersen (2016) will be used. This preparation will give guidance on whom to pay attention to while the researchers observe, at what specific time is most relevant and where to be positioned in order to maintain discretion.

## 5.8 Segmentation

Segmentation is known as a strategy of dividing the market into homogenous group (Goyat 2011). It is perhaps mostly related to marketing; however, it is fairly common to separate between two types of passengers, business or economy passengers. Dividing the airline passengers into different segmentation groups is important for understanding their behaviour and develop new approaches (Teichert, Shehu, and von Wartburg 2008).

However, in our study, we do not believe that segmenting airline passenger into only two groups will be sufficient enough to measure and capture what is intended. Therefore, we will add and identify other segments as well, with a combination of passenger’s characteristics. The main objective is to divide the passenger`s into groups where they share the same behaviour or characteristics. This would make it easier to predict how the different passenger`s categories respond and behave through the airport security checkpoint.

The segmentation of airline passengers in our study will be divided into the following groups:

- Gender, male and female
- Three different age groups
- If the passenger is subjected to an extra inspection or not

## 5.9 Hypothesises – Oslo Lufthavn

Following this productive meeting, it was possible to sit down and develop several hypothesises for the observations. The following hypothesises were developed after the initial meeting in January at OSL.

| **Hypothesis** | ***Detailed description*** |
|---|---|
| Hypothesis 1 | *The number one security personnel have a critical impact on how the rest of the process flows* |
| Hypothesis 2 | *The oval structure in which the passengers put their belongings on the trays will ensure that passengers take much more responsibility on their own.* |
| Hypothesis 3 | *The screening process conducted using the X-ray machine is being 100 % utilized due to the implementation of Centralized Image Processing* |
| Hypothesis 4 | *Reduction of dial back could potentially increase flow and efficiency of the security check* |

*Table 5: Hypothesises for OSL. Source: (Own work, 2019)*

The first hypothesis is that the Number One security personnel, the one standing behind the counter where the passengers are to set their electronics and belongings has a critical impact on how the rest of the process with flow. The general thought is that if Number One can effectively communicate to the continuously flow of passengers about what needs to get out of backpacks, such as devices with batteries, toiletries and other items that would otherwise trigger the system, it will decrease the amount of time spent on average for passengers for the entire security process. This thesis' observation rounds will inspect Number One and study the effects he/she is having on the rest of the process.

This can be partially observed by comparing the Number One at Terminal 1 and Terminal 2. The recently built Terminal 2 has a newly developed system where the oncoming passengers are distributed to booths in an oval state, as seen from Number One. This means that Number One can have direct contact with all passengers without moving. It could be useful to see the impact this is having on the passenger's ability to get through the check without needs to stop.

The next hypothesis builds on what happens with the oval structure of the passengers, and the consequences it has. The main idea is that passengers needs to take more responsibility, for example by acquiring their own trays for their items. The hypothesis is that the passengers will take more responsibilities on their own, which means that there may be more variations, but perhaps a better flow on average, both in terms of time spent and number of trays per passenger.

It is already mentioned that Avinor claims that the television screens have an impact on the preparation levels of the passengers, especially during longer queue times. This is partially why there are not advertisements for airport located, or any other types for that matter, brands. This leads to a hypothesis that the screens and notices that advert how to function before the security process is directly linked with the effectiveness on how the average passenger, not only is processed, but also how they themselves process the security check. This assumes that the screens show efficient and easy-to-understand processes that if everyone paid attention to it, there would be an approximately 100% understanding rate.

The x-ray machine is hypothesised to be working at a 100% optimal level when compared with the entire screening agent level, due to their ability to interchange between pictures. This means that the efficient screeners are always using their capacity when needed so there is no "dead-time" for them while less experienced and efficient are operating at full capacity. It is also worth to mention the regular change of guard for the screening check is something that needs research, so a hypothesis on that subject is that the flow of three changes per hour is the same as, for example, two changes per hour.

Another hypothesis is that a reduction of dial back could potentially increase the flow, and therefore the efficiency of the security check. A dial back is done when the security scanner is not sure on what is seen, so the basket needs to be physically removed and set back into the x-ray queue for further inspection. This would obviously drag out both the time spent for the passenger personally, but the average time would also be dragged out, as the time spent for that particular basket would be doubled, it would require manpower that could be spent elsewhere and, most essentially, it would make the baskets behind the one in question wait even further. By researching this hypothesis, we can see if there is potential truth in this, how often it occurs, and if the other improvements, such as an improvement on Number One's stage have any effect on it.

It was mentioned during the first meeting that the passenger flow is not the major bottleneck, it is the handling of their luggage that causes delays, queues and stress. This means that the passengers going through are going at a much higher speed than their luggage, needing to be x-rayed and decided to be sent to inspection or not. This luggage usually travels at a slow, but hopefully steady pace. If the number of passengers is processed faster, it can be assumed that the bottlenecks doesn't necessarily lie with them, but rather what they leave in baskets. It is important to understand this claim, as improvements for the passengers' x-ray would leave them waiting even longer before acquiring their luggage, which again could cause even longer bottlenecks.

## 5.10 Hypothesises – Stavanger Lufthavn

The following hypothesises are structured as a direct comparison with the OSL security system, as they have protocols that with fundamental similarities, such as random checks and security agents at the same locations. However, comparing with another Norwegian airport that has a different structure, not only physically, but in terms of flights per day, passengers per given hour and public transportation arrivals makes the hypothesises slightly different due to these circumstances. They are as follows:

| **Hypothesis** | ***Detailed description*** |
|---|---|
| Hypothesis 1 | *The number of boxes per passenger will on average be lower compared to the findings from OSL.* |
| Hypothesis 2 | *The divest time will be higher than in OSL as a whole due to older design without oval shape.* |
| Hypothesis 3 | *The passenger's total throughput rate would in general be higher at Stavanger Lufthavn due to a considerably lower number of available airport security checkpoints at a daily basis, when compared with OSL.* |

*Table 6: Hypothesises for SVG. Source: (Own work, 2019)*

The first hypothesis is one of the main aspects on why Stavanger Lufthavn is worth observing. The trays, or rather, their dimensions, are larger in height, width and length, when compared with the OSL equivalent, both on the new and the older section. This makes it logical to assume that the number of trays used in both the fast track and regular lanes will be lower at Sola. This assumption is made due to suspicion of taking another tray for coats and outerwear, which might not be necessary if the trays were larger.

This hypothesis is made, even though the agents at OSL has warned about the usage of these trays can have unforeseen consequences, such as if the trays are larger, more passenger luggage will be stacked, making it more difficult for the screeners to analyse the luggage, eventually causing more trays to be sent for recheck.

The second hypothesis focuses on the divest time and how it can be considered different form its OSL equivalent. First of all, OSL has a fairly new method of dividing their passengers into different stations, where they can operate without having the entire queue behind them being dependent on his/her individual divest time. Stavanger Airport does not possess this technique at this time, so the passenger taking off his/her outerwear and electronic equipment needs to finish before anyone behind can move forward. With this in mind, it is suspected that this will create a pressure point, where passengers are forced to be more efficient. By this, the second hypothesis makes an estimated guess that the passengers will be more efficient during the divest time, but since there is only room for one passenger at the time, there will be less efficiency in if the timer would start as the queue formed.

The third hypothesis for the Stavanger observations is that the throughput rate in Stavanger Airport will be higher than in Oslo Airport. This is not due to the number of passengers passing through in total, but rather the throughput rate through each x-ray machine. In Sola, there must be an extraordinary amount of passenger coming through for them to consider to open another x-ray machine, meaning that they will have a higher pressure on the one that is shared with the fast track lane. In OSL however, when the pressure builds up, the threshold for opening another lane is lower, as they have the appropriate number of agents available for a spike in passenger flow at a given time. This is likely due to their number of available security agents at OSL is higher than at SVG. Furthermore, security agents in SVG even expressed that there would need to be an excessive number of passengers waiting in line for them to call on more agents and open another x-ray machine.

## 5.11 Representative selection of passengers

For the planned observation, it will be nearly impossible to observe every single passenger that passes through the airport security checkpoint. Therefore, a limited, selected number of passengers will represent the population. The observed passengers will in this observation be used further to generalize the findings. The observation will therefore be conducted as a sample study in which random passengers are selected. These passengers will represent a miniature world which represents the population in general. Furthermore, it is important to make sure that there is a diverse representative selection based on the groups/segmentations we want to measure. For example, we need to make sure that there is an equal number of men and women to be observed.

Furthermore, how large the sample with the included subpopulation, could be difficult to define and it must be adapted depending on the setting and type of observation. According to Johannessen, Tufte, and Christoffersen (2016), the subpopulation should be represented by 100 passengers, minimum 30. As the observation will be conducted between 07:00 – 09:00 and 15:00 – 18:00, we have a limited amount of time to observe the number of passengers within this specific timeframe. An assumption is that each passenger will on average spend 2-3 minutes from where they start to put their belongings on to the trays until they have passed the portal and collected their belonging on the other side. This would in general mean that the researchers should be able to observe 40 passengers between 07:00 – 09:00 and 60 passengers between 15:00 – 18:00, a total of 100 passengers.

## 5.12 Preparations for the observation at OSL

The primary intention is to arrive a day in advance to settle in and make preparation for the observation. An Excel sheet has been created, defining what needs to be measured.
In addition, sketches, illustrating the airport security checkpoint at OSL has been studied in detail. This has been done to make sure that everything will run smoothly and to test the Excel observation sheet which will be used to register all the raw-data collected from the observation. In collaboration with the Avinor representatives, a location for the best possible spots to conduct the observation will be decided. It will be crucial to determine the spots location and what is observable from here to get the raw-data that is required for the research.

The observations will be conducted over the course of two days, where the main goal is to observe passengers where the capacity of the security agents is tested to the limit. In general, this means that the observation will be conducted at the start of the day, during the morning rush from 07:00 – 09:00 and during the afternoon at 15:00 – 18:00. The reasons for the specified observation times is to see if there are any parts of the different stages of the security checkpoint which is stacked up more than usual during high passenger throughput. See appendix 1 for a more detailed description of the different part of the security checkpoint that needs observing and measurements.

For the primary observation days, there are several factors that is considered important for research. The first one will be the number of trays is used per passenger. This is done even though there are historical numbers available, as having empirical data on the actual number can prove useful. Furthermore, the number of trays will also be divided into gender specifications, as there might be a quantity difference between men and women. Also, this number will be compared with an equivalent observation from the fast track section.

The next observation will check how many times the recheck area will grind to a stop due to full capacity in this section. If enough trays are sent to this area without them being cleared faster than they arrive, sooner or later there will be a stop in the system that the decider machine separated cleared and not-cleared. This is a direct clog in an already presumed bottleneck that would make the throughput rate stop completely until the recheck area has open slots again. If this happens, another simultaneous observation will take place, where a timer will be started for an oncoming passenger, observing how long it would take for the entire process will take for him/her.

Another observation that needs to be done is the one where the time of reclaim is recorded. To do this, it is important to know whether or not the passenger is taken into a personal recheck. This will add time spent for the passenger, so the question is whether the timer will start after the passenger is cleared or before. After some discussions, it falls into the observers' best interest to start afterwards, as the time spent with the recheck could alter the average time spent from the x-ray scanning until leaving the area. Similarly, this means that there is a question on when to stop timing. The decision is that the timing of the passenger will stop when they have collected all their items from the trays and starts to move away from the reclaim area.
A limitation here would be the passengers who do *not* set the trays back are not being recorded in any way, even though they may give more work for the passengers coming behind.

After the observations has been conducted, the raw-data needs to be transformed into representative statistics that is easy to interpret. The statistics will serve as figures in which patterns and habits can be identified to illustrate passenger's behaviour and actions. Furthermore, the statistics will hopefully contribute and indication of potential bottlenecks and areas of improvements. In addition, transforming the time spent on each of the different stages through the airport security checkpoint will be converted into percentages. It will then be easier to spot and identify what process which the passenger or the security agents spend the most time on.

## 5.13 Oslo Lufthavn field trip and observations

Arriving a day in advance to prepare and familiarise with the checkpoint area at OSL to ensure that the observations would be conducted as planned without any delays. Again, it is vital to locate the best possible spots in which the observations could be conducted without interfering with the passengers themselves. The numbers and statistics collected from the observation at Oslo Lufthavn was gathered on Monday 25.02.19 and Tuesday 26.02.19. Furthermore, the necessary permission and clearance needed to be arranged. The Avinor representative, Ole Folkestad ensured that all the necessary permission and clearance was in order before entering the security checkpoint early on Monday morning.

OSL are using smaller trays compared to the ones at SVG, it was therefore very interesting to see what affect this has on passenger flow, divest and reclaim time. Furthermore, the oval design in which the passengers put their belongings into was highly interesting. The first spot for when we conducted the observation, enabled us to see how the airport security agents were operating behind the conveyor belt as well as observing the passengers.

In addition to the presented statistics in the next section, other findings of importance where noted that might affect the flow of passenger throughput at OSL. In terms of public transportation, it became very apparent when the train known as Flytoget arrived, which is a very popular mode of public transportation to OSL. Arrival on fixed schedules, passengers would arrive in large batches, which was very easy to spot during the observation. The arrival of Flytoget, NSB/Vy is also located so that passenger can walk straight towards the new terminal security checkpoint. This is something that the airport security agents need to be aware of to handle this type of phenomena in an efficient way.

# 6.0 Presentation of data and results

## 6.1 First field trip to OSL

The first field trip was done at the 10$^{th}$ of January, with the aim of familiarizing the security process and conversing with Avinor and Nokas representatives. The day started with an introduction of our representative, Ole Folkestad and his colleague, Bjørn Erik Larsen, whom has more than enough experience on airport security protocols and improvement specifications. They provided us with valuable information on an absolute optimized passenger flow, with a similar showcase for optimized security trays per hour.

The statements below are empirical experiences and assumptions from the Avinor representatives, which we will use as hypothesis foundations and, if nothing else, the general understanding of the Avinors agents has on the protocols and what they do to optimize.

The numbers were theoretically set at 720 passengers per hour on Terminal 2, if the flow is a consistent 100%. Combined with the average two trays per passenger, this means that there can be processed, in theory, 360 passengers per hour on average.

There has been reported historical numbers as high as 360 passengers per hour, but usually the amount meant that there were less than two trays per average passenger at the time. This was partially achieved due to high levels of tactical coordination for the security agents, whereas "Number One", being the agent standing behind the luggage loading area, is arguably the most important one. The better coordination and communication Number One distributes to the ongoing passengers, the less liquids, aerosols and gases (LAG) follows, causing frustration for both passengers and agents. If enough LAG's are sent for further inspection, it will cause a full stop in the security process flow, as the oncoming trays that also needs inspection cannot be sent back to the passenger and will need to wait. This complete halt can spiral back and cause large queues and further frustration for oncoming passengers.

Furthermore, with the implementation of allowing the passengers on Terminal 2 to acquire their own security trays causes the passengers to take more responsibilities on their own. Whether this has an impact or not on the optimization time could possibly be compared with Terminal 1's approach, that which involves Number One's assistance.

Another assumption made by the representatives of Avinor is that the screens and notices in the security lines affects the passengers in a way that makes them more productive, especially when the lines are long. They argue that with longer lines, a higher percentage of passengers will avert their attention towards the screens telling them to follow protocols, taking out toiletries, liquids and laptops. Avinor have strict policies on having a limited-to-none advertisement for brands or services within the security area, as this might interfere with the attention the passengers need to focus on effectively going through the security process. Avinor have strict policies on having a limited-to-none advertisement for brands or services within the security area, as this might interfere with the attention the passengers need to focus on effectively going through the security process.

Another experience the Avinor personnel has noticed is the fact that separating passengers does not provide enough reward for the trouble. The effort of 'segregating' people has been tried in the past, often causing confusion, frustration and annoyance from the passengers.

It was also noticed during the tour of the area that several of the agents were not entirely familiar with the protocols of what should be sent through the x-ray machine and not. However, this is not in the dramatic and perilous way, allowing items such as allowing liquids or contraband items through the area, but rather protocols for scanning and inspecting items longer or larger than the basket allows. An example we saw multiple times were crutches made out of plastic. We witnessed, up to several times, that these crutches were sent through the x-ray machine, causing not only a delay in the decision-making process, but also disrupts the decision makers' marking system. This system is designed to have the baskets at a set distance from each other and disruption of this balance could cause difficulties for the machine that is sending the basket for further inspection or clearing it.

Finally, one of the major issues Avinor has, and what they identify as one of their most difficult bottlenecks, is the very limited space between the x-ray machine and the decision maker that determines whether luggage is cleared or requires further inspection. This is a difficult process as the entire machines is actually three machines working together, made from three different companies. The three companies distribute the x-ray machine, the decision-making machine and the "conveyor belt".

The decision maker is a very limited time window after the x-ray has been seen, where a screener needs to either approve or deny the contents. From the x-ray picture is taken, the screener has approximately *7-8 seconds* to analyse the content and make a decision. This can cause large variations as not all screeners are equal in observational and decisional skill. Furthermore, the amount of time a screener is allowed to actively be on his/her station is approximately 20 minutes due to requirements of high levels of concentration. This means that there are three rotations per hour, which will naturally have variations. Fortunately, the position of screening is popular amongst the security agents, so there is no shortage of screening volunteers.

In order to eliminate the quality variation of the screening process, effective and eligible screeners have the opportunity to handle other screening images. This means that the security screener at Station 1, who is 1,5 times more efficient than the screener at Station 2, can handle the remaining screens as soon as he/she is available to. This can make both security stations operate at optimal efficiency, assuming that they have identical effectiveness on decision making.

As previously stated, the main objective was to observe passenger during high peak and when the airport security checkpoint was close to working at high capacity. Therefore, the first observation started at approximately 08:30, 30 minutes behind the planned scheduled. This was mainly due to the security agents working at the checkpoint area needed to be informed about the purpose of the observation. In addition, the location in which the observation where to be conduct from needed to be adjusted in order to get a better view of the passengers. The location did not interfere with the flow of passengers nor did it affect the necessary tasks that was conducted by the security agents.

### 6.1.1 Oslo Lufthavn: First observation – Fast track lane

From 08:30 – 09:30 the main focus was to observe passengers using the fast track lane. The observations of passengers were divided into two focus areas in which the one of the observers had the responsibility to measure type of gender, age group, number of trays and divest time. Furthermore, the second observer responsibility was to measure type of gender, age group, reclaim time and passenger category for when the passengers had passed the x-ray machine. The data from the observation was transferred directly to the excel template which was created in advance. Based on the data from the observation the following graphs where created, illustrating the average number of trays, divest time and reclaim time for both genders.

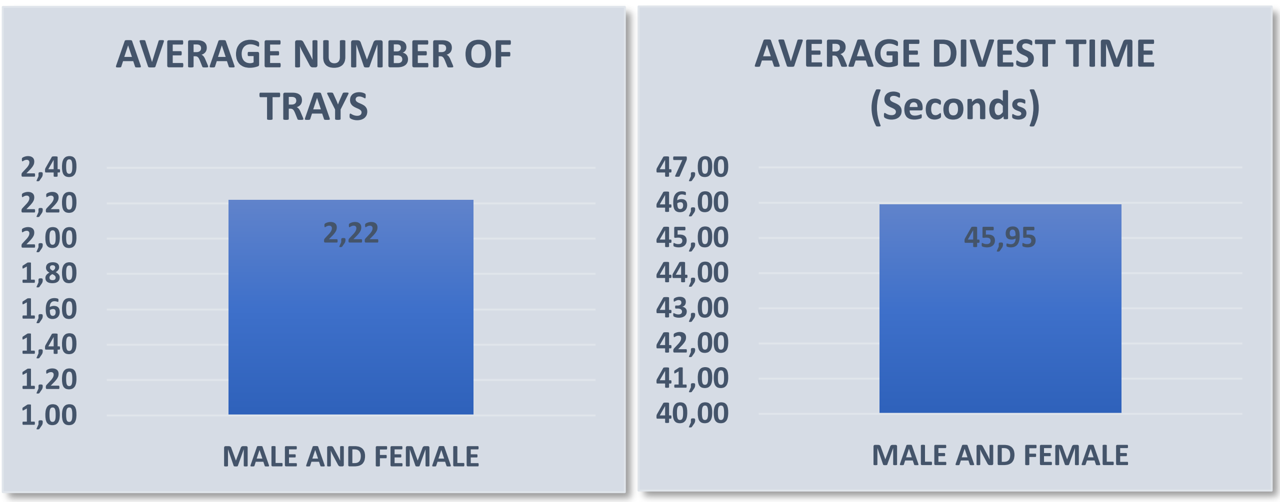



*Figure 10: Average number of trays and divest time for the fast track lane at OSL. Source: (Own work, 2019)*

N of cases = 96, representing the number of observed male and females for the average number of trays and divest time. As represented from the graph, the average number of trays for fast track passengers is respectively 2,22 for both genders.
The divest time illustrated that each passenger spends 45,95 seconds on average, putting their personal belongings on to the trays. The timer started when the passengers was walking towards the available spot and started to reach for the trays underneath the table. Furthermore, the timer was stopped when the passenger pushed the last tray onto the conveyor belt before the X-ray machine.

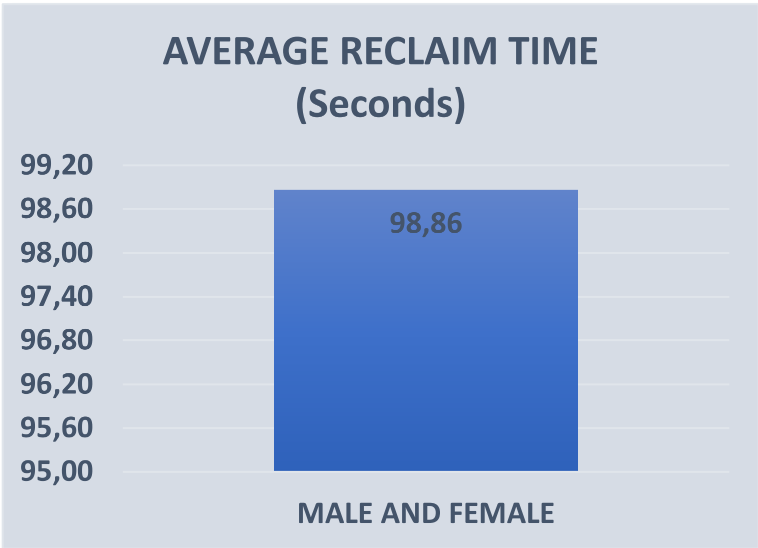



*Figure 11: Average reclaim time for the fast track lane at OSL. Source: (Own work, 2019)*

N of cases = 51, representing the number of observed male and females for the average reclaim time. For the reclaim time, the timer started when the passenger had passed the portal, the timer stopped when the passenger had collected all their personal belongings, in which he or she started to walk away from the reclaim area.
The reclaim time represents the average time for each passenger, regardless of being subjected to inspection or rechecks. On average, the graph indicated that each passenger spends 98,86 seconds for reclaim time for both male and female.

The reclaim time can be affected by several additional factors such as the passenger and/or luggage being subjected to an additional control after the portal. This will naturally affect the reclaim time and it has therefore been natural to divide the reclaim time for passengers into four different categories.

| PASSENGER CATEGORY | | |
|---|---|---|
| TYPE | RECHECK PAX | RECHECK LUGGAGE |
| P1B1 | NO | NO |
| P1B2 | NO | YES |
| P2B1 | YES | NO |
| P2B2 | YES | YES |

*Table 7: Passenger category explanation. Source: (Own work, 2019)*

P1B1 represents that the passenger is in a category where he or she is not subjected to any recheck after the portal neither is the luggage. This means that the passenger can move towards the reclaim area as soon as he/she passes the portal without any interference.

P1B2 represents that the passenger is not subjected to any recheck after the portal. However, the passenger's luggage is subjected to an internal control, which in most cases increases the total reclaim time as depicted in the statistics below.

P2B1 represents that the passenger itself is subjected to an internal control, either by the security agents or the body scanner. The passenger luggage is not being subjected to any additional control.

P2B2 represents that both the passenger and the luggage is being subjected to an additional control. The total reclaim time for passengers that falls into this category are the highest of all four categories. However, it should be noted that there were a minimal number of passengers that fell into this category; therefore, the result is very difficult to generalize due to lack of observations of passengers for this specific category. In total, the number of observed P2B2 passengers, both male and female was 5 with an average reclaim time of 142,16 sec.

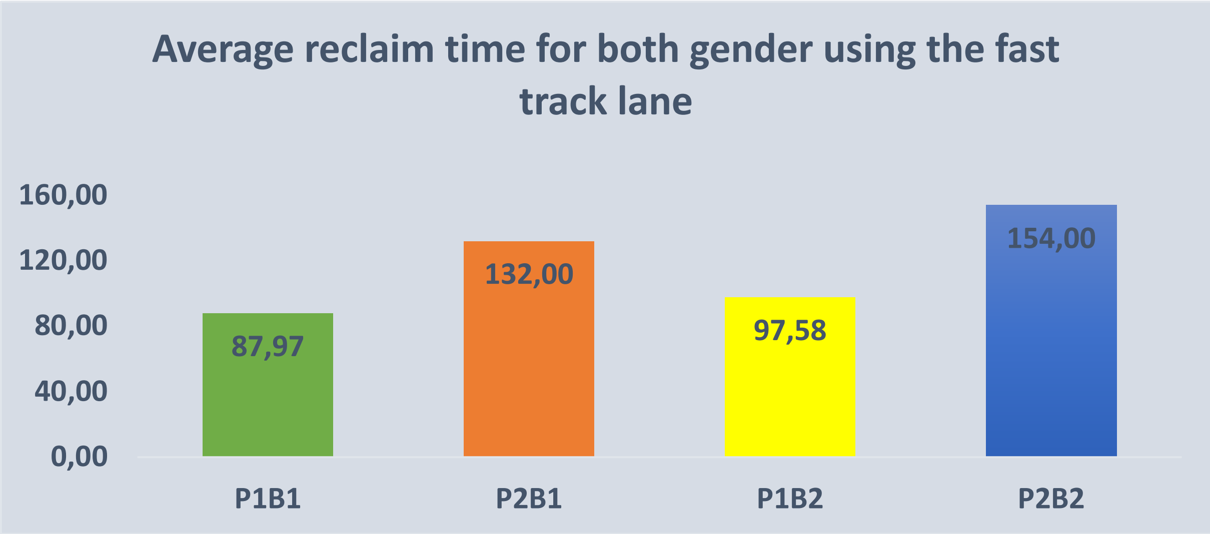



*Figure 12. Average reclaim time for the fast track lane divided into passenger category. Source: (Own work, 2019)*

The statistics represents the average reclaim time for both genders using the fast track lane. The time stated in all graphs are in seconds.

N of cases = 30 for P1B1.

N of cases = 12 for P1B2.

N of cases = 7 for P2B1.

N of cases = 2 for P2B2.

Both the P1B2 and P2B1 has a low number of observed passenger and should therefore be used as a small estimate.

N of cases = 2 for P2B2, it should be noted that this number is not representative enough based on the low number of observed passengers in this specific category.

Total N of cases = 51.

The average reclaim time for the four categories matches the average reclaim time regardless of category.

## 6.2 Fast track: Gender split

The observation of fast track passengers was split, dividing the passengers into males and females. In order to generalize the findings, the goal was to observe an even number of both males and females. However, it should be noted that the majority of the passengers using the fast track lane at the specific time and date were males. Therefore, N of cases = 55 for males and N of cases = 41 for females. To clarify, the graphs underneath is based on the same dataset as the ones represented in the beginning, the only difference is the split/segmentation from the same dataset into male and female. The process of measuring the time for each passenger are the same as described in the graphs above.

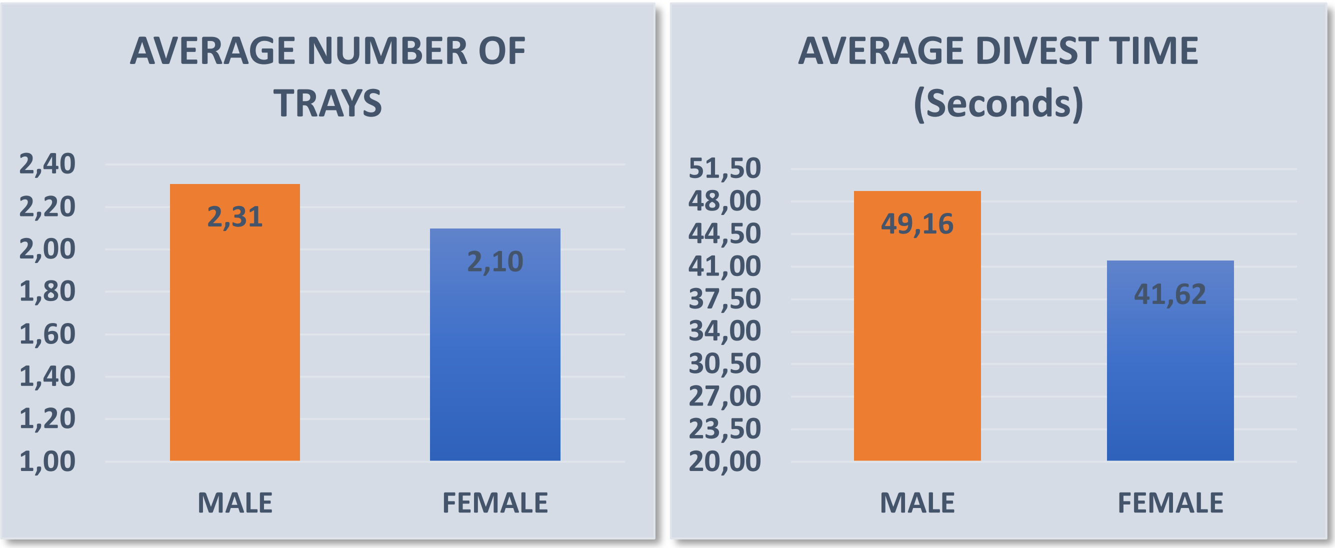



*Figure 13: Average number of trays and divest time for male and female using the fast track lane at OSL. Source:(Own work, 2019)*

As represented from the graph, the average number of trays for fast track passengers is 2,31 for males and 2,10 for females.

The divest time illustrated that males spend 49,16 seconds on average compared to 41,62 seconds for females.

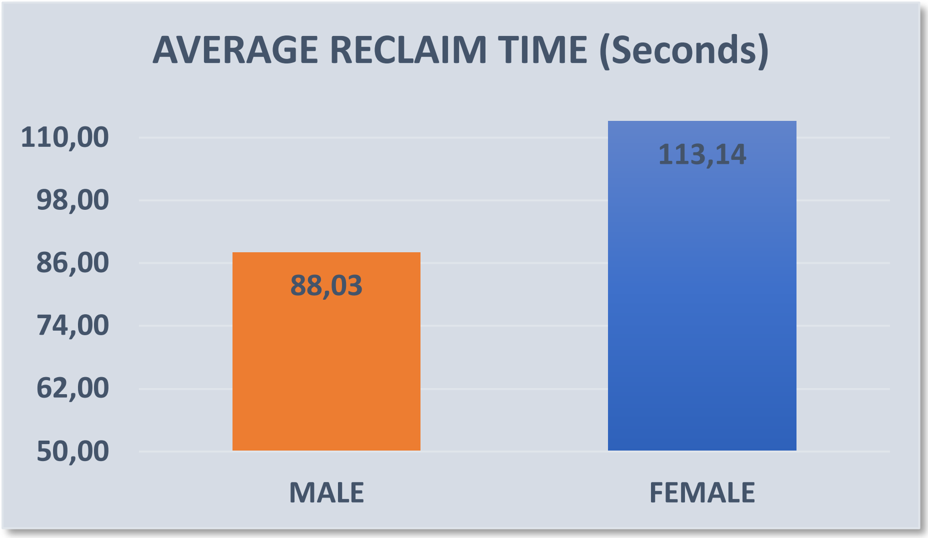



*Figure 14: Average reclaim time for male and female using the fast track lane at OSL. Source: (Own work, 2019)*

N of cases = 29 for males and N of cases = 22 for females using the fast track lane.

On average, the graph illustrates that males spends 88,03 seconds and females 113,13 seconds during the reclaim of personal belongings. As mentioned, the reclaim time represents the average time of all the four types of categories.

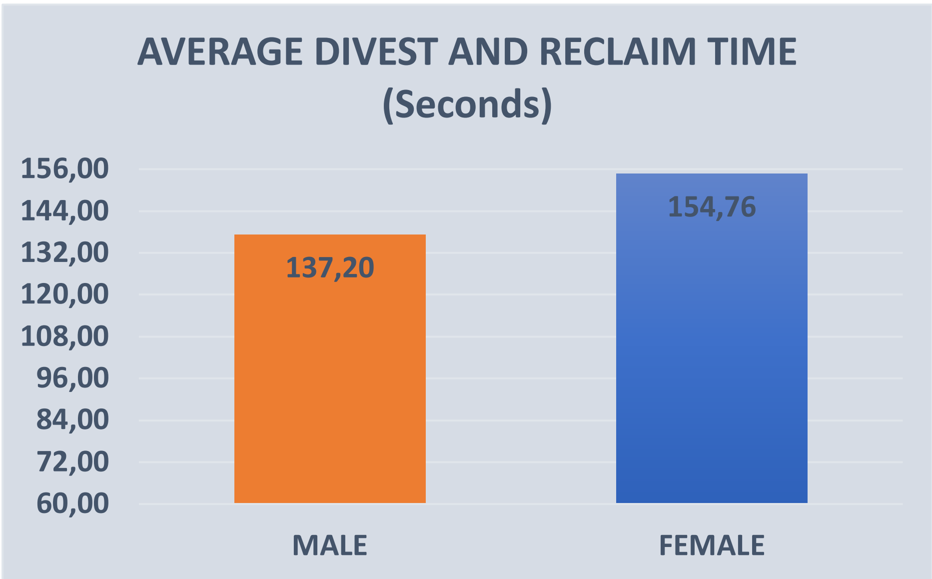



*Figure 15: Average divest and reclaim time for male and female using the fast track lane at OSL. Source: (Own work, 2019)*

This graph illustrates the addition of divest and reclaim time for males and females using the fast track lane. Males spend 137,20 seconds compared to 154,76 seconds for females.

The total N of cases = 84 for males, a combination of 55 males at divest and 29 for reclaim.

The total N of cases = 63 for females, a combination of 41 females at divest and 22 for reclaim.

## 6.3 Presentation of data: Regular Lane

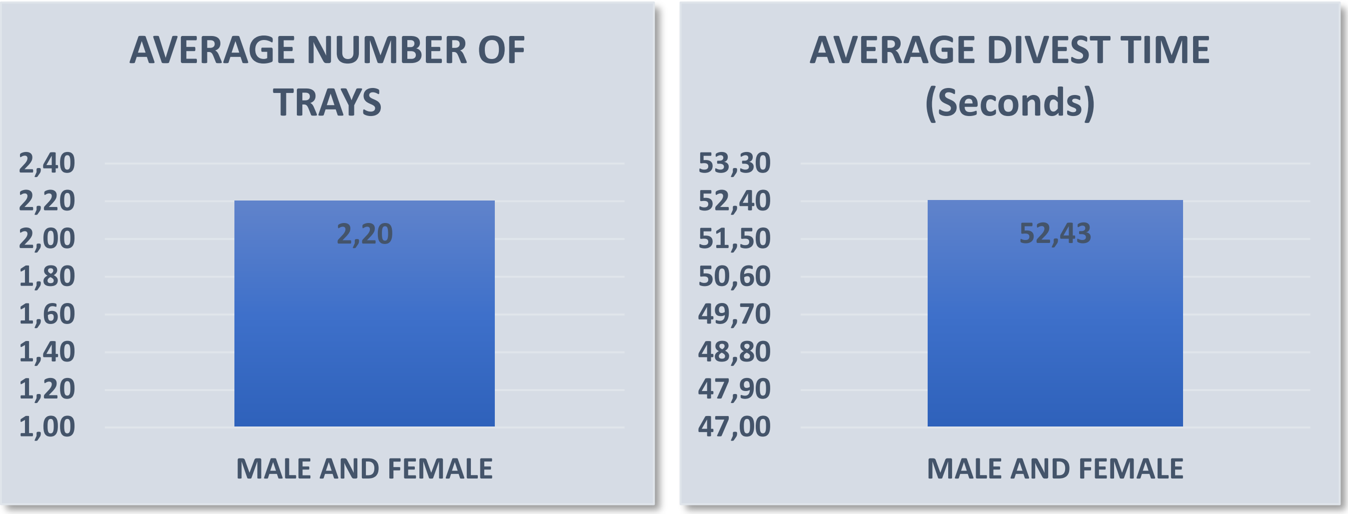



*Figure 16: Average number of trays and divest time for regular lane at OSL. Source: (Own work, 2019)*

The figure shows the average number of trays, again, regardless of any passenger category for the regular lane. The average number of trays is 2,20, which is almost identical to the average number from the fast track lane. The divest time is slightly higher, with 52,43 on average compared to 45,95 seconds for the fast track lane.

N of cases = 94, representing the number of observed male and females for the average number of trays and divest time

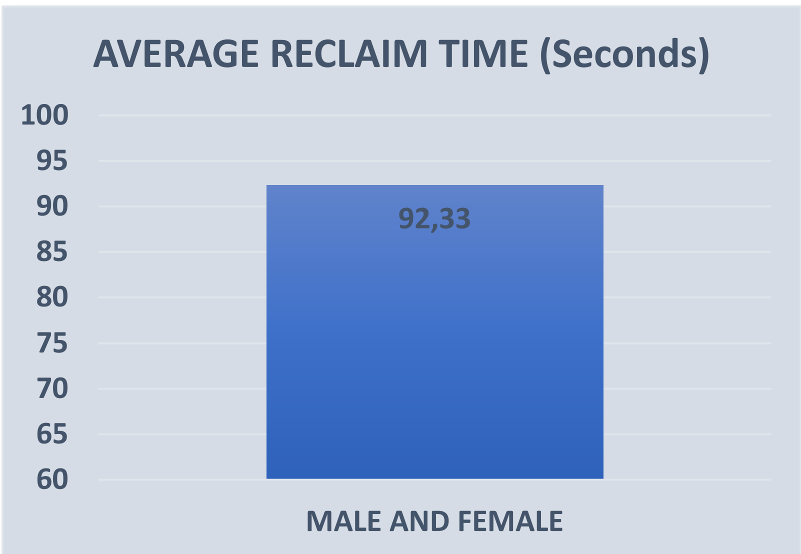



*Figure 17: Average reclaim time for regular lane at OSL. Source: (Own work, 2019)*

N of cases = 72, including both males and females for the average reclaim time.

It should be noted that the number of observed passengers in the reclaim area using the regular lane is more than double compared to the 51 observed passengers for the fast track lane. There are several reasons for this, firstly there was a higher number of passengers using the regular lane at the specified time during the observations. Secondly, the time spent observing passengers at the reclaim area was 30 minutes longer compared to the observed passengers for fast track. In general, the main focus was on the regular lane while also observing passengers using the fast track lane as a comparison to see if the results deviate from each other. Furthermore, the graph indicated that each passenger spends 94,18 seconds for reclaim time for both genders. The time is almost identical for the passengers using the fast track lane where the average time was 98,86 seconds, a difference of approximately 4 seconds.

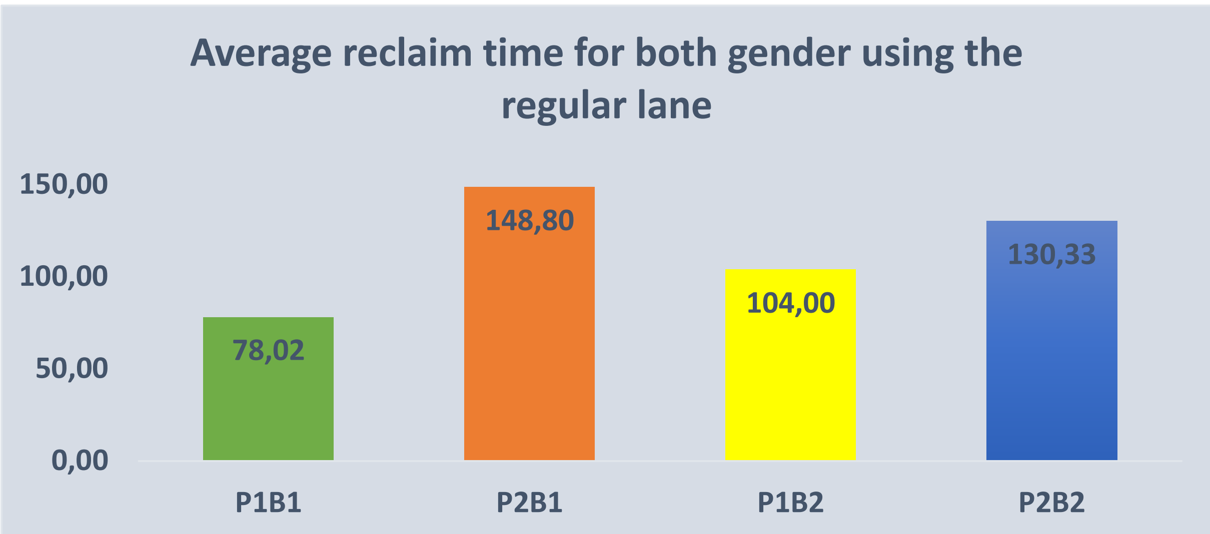



*Figure 18: Average reclaim time for the regular lane divided into passenger category. Source: (Own work, 2019)*

The statistics represents the average reclaim time for both genders using the regular lane. The number stated in all graphs are in seconds.

N of cases = 44 for P1B1

N of cases = 20 for P1B2

N of cases = 5 for P1B2

N of cases = 3 for P2B2

Both the P1B2 and P2B2 has a low number of observed passenger and should therefore be used as a small estimate.

Total number of N of cases = 72.

The average reclaim time for the four categories matches the average reclaim time regardless of category.

Comparing the result from the fast track and regular lane indicates that for P1B1 passengers, the reclaim time is lower for those using the regular lane. 155,78 seconds for regular lane passengers and 180,81 for fast track passengers. Further, for P2B1 for regular lane passengers the times are 209,78 and 304,55 for P1B2 passengers. For fast track passengers the times are 201,40 for P1B2 and 267,25 for P1B2. This indicates that passengers defined P2B1 and P1B2 using the fast track lane has a lower reclaim time in comparison with passengers using the regular lane.

### 6.3.1 Regular lane: Gender split

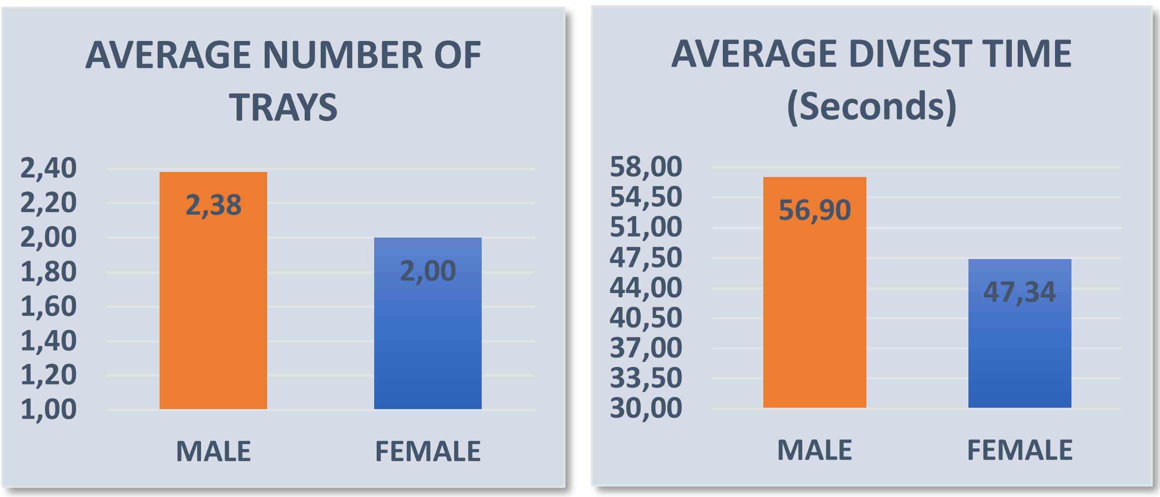



*Figure 19: Average number of trays and divest time for male and female using the regular lane at OSL. Source:(Own work, 2019)*

N of cases = 50 for males and N of cases = 44 for females.

As represented from the graph above, the average number of trays for passengers using the regular lane are 2,38 for males and 2,00 for females respectively.

In comparison with the graph from the fast track lane, there is a small difference in which the number for both male and female using the regular lane. However, they are almost identical with 2,31 for males and 2,10 for females using the fast track lane.

The divest time illustrates that males spend 56,90 seconds on average compared to 47,34 seconds for females. For the fast track lane, the number was 49,16 for males and 41,62 for females. For both lanes, males tend to spend the most time when putting their belongings into the trays.

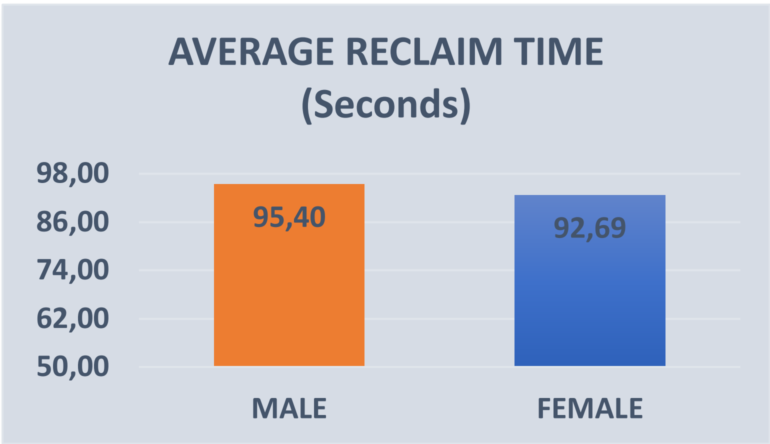



*Figure 20: Average reclaim time for male and female using the regular lane at OSL. Source: (Own work, 2019)*

N of cases = 63 for males and N of cases = 51 for females.

On average, the graph illustrates that males spends 95,43 seconds and females 92,69 seconds during the reclaim of personal belongings. In comparison with the graph from the fast track lane, males using the regular lane are slower. However, females are faster using the regular lane compared to the ones using the fast track lane. The numbers from the fast track lane are 88,03 seconds for males and 113,14 seconds for females.

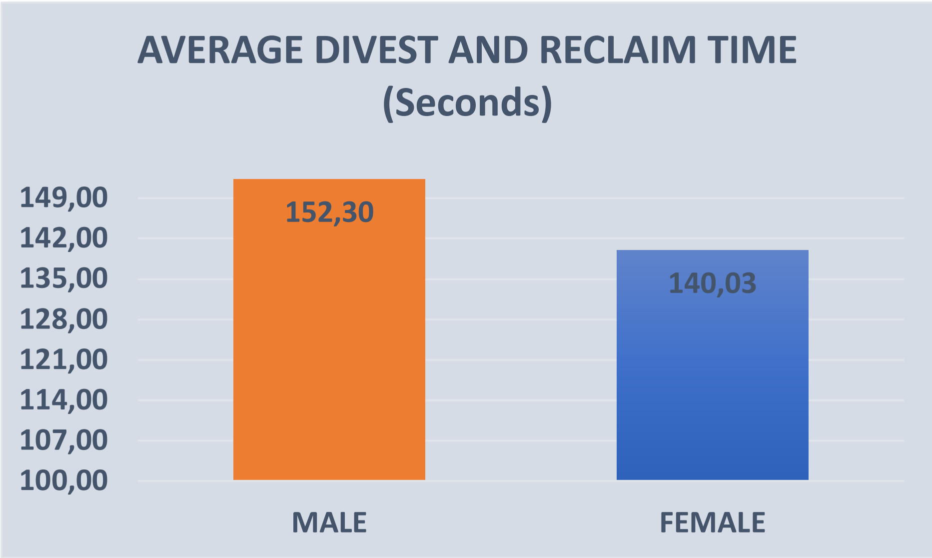



*Figure 21: Average divest and reclaim time for male and female using the regular lane at OSL. Source: (Own work, 2019)*

This graph illustrates the combination of divest and reclaim time for males and females using the fast track lane. Males spend 152,30 seconds compared to 140,03 seconds for females.

The total N of cases = 113 for males, a combination of 50 males at divest and 63 for reclaim. The total N of cases = 95 for females, a combination of 44 females at divest and 51 for reclaim. In this case, males tend to spend more time when combining divest and reclaim time compared to females using the regular lane. However, the picture is quite the opposite for passenger using the fast track lane where females are the slowest with 154,76 seconds compared to males using 137,20 seconds on average.

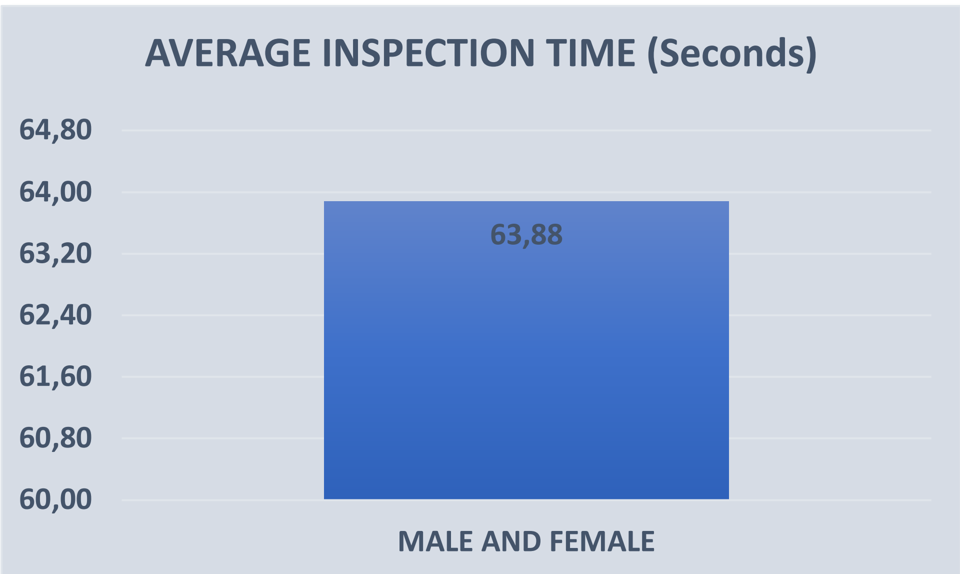



*Figure 22: Average inspection time for both genders using the regular lane at OSL. Source: (Own work, 2019)*

N of cases = 57, the total number of both males and females.

The inspection time starts when the security agent begins their process by asking whose luggage the tray belongs to and ends when the tray is delivered back to the passenger. As there is little the passenger can do at this phase, other than eventually assisting the agent with the inspection if needed, and whereas several of the inspections are random, the average inspection time is here added as both male and female.

## 6.4 Stavanger Airport field trip

With raw results gathered from OSL, it would be wise to compare it with another field study with similar research methods. The decision was to do similar observational research at Sola Airport SVG, located in Stavanger. With both researchers familiar and with close proximity to Sola, this suggestion from the Avinor representative became a clear choice. Furthermore, SVG has been using their larger trays for some time, so the average number for these trays could potentially be a key factor for improving the passenger flow, divest and reclaim time.
It would, however, also be of interest to research activities behind the x-ray as well, especially reclaim time and luggage inspection time, due to its shorter infrastructure compared to the OSL model. As this study was simply for comparative reasons with OSL, it was decided that one day was enough.

Due to its importance in the petroleum industry, Stavanger has many travellers both domestically and international, the assumption is therefore that the amount of business travellers travelling from will be high. The research took place on Monday, the 4th March 2019, during the morning and afternoon rush. Even as the actual number of passengers will be considerably lower than at OSL, SVG has a lower amount of security screening agents, machines and space to work on. It can therefore be expected to have a similar level of throughput rates through the x-ray machine.

Therefore, the goal for the observation was to gather relevant data in throughput rate, divest time for passengers in both the regular and fast track lane, followed by reclaim time after the personal x-ray machine and finally, the time it would take for a recheck process of passengers' carry-on luggage. Notes was also made underway about any different methods and norms being used that were not used in OSL. One of the primary differences is that the fast track lane accounts for both passengers from Norwegian and SAS, where in OSL there is a separate lane for the airlines. This gives the observers a mixed bag of fast track passengers.

It was, however, decided *not* to make a statistic for passenger categories whether or not they were taken into passenger recheck, as it was noticed in OSL that it did not matter, as the luggage almost always exceeded the time spent for the passenger to be checked or not.
In order to have as much of a comparative research with OSL, it was important to set the research at the same time of day, and preferably at the same weekday. As one of the research days in OSL was set on a Monday, so too was the research in SVG at this day. The research was to start during the initial morning rush, expected to be at around 08:30. The security agents also told that there was usually very low activity between this rush and the afternoon rush, due to business hours. With this in mind, the research for the afternoon rush proceeded at 14:30.

The research began at 09:00 after an introduction to the security agents and the Avinor representative. The location for observation was conveniently placed on the side of the open security area, at a closed section. After inquiring the security agents on why this section was not open, the reply was that there was no need for it, there had to be an especially high flow of passengers for them to open up that particular section. This section was highly visible for the observers, all the way from the table on where to deliver the luggage, until the x-ray.

As there were only two lanes open at the time, it became possible to observe both fast track and the regular lane at the same time. The observers were strategically placed on the side of another, closed x-ray area, being able to see over to the open section without interfering the process for either passengers and the security agents. The same strategy for observation used at OSL was continued at SVG, with the average divest time and number of trays being the main focus. The average divest time timing is done similarly with the OSL research, where the timing starts when the passenger arrives at a desk for taking out electronic equipment and outerwear. The timer stops when the passenger is finished with his/her final tray. The difference here is that compared with OSL, there are no sections for the passengers to divide themselves into for the divest time. Instead, it follows the traditional "conveyor belt", continuously moving on the x-ray line. Whereas OSL passengers divest timing stops when they push their final tray to this belt, the SVG passengers divest time stops when they take a step backwards to head towards the x-ray machine.

There were several other factors that was noticed during the observation. These observations are generally compared with how the techniques are done in OSL, as there are obvious differences between them.

Firstly, the agent known as Number One, being the primary security agent organizing the incoming passengers and assuring them to follow security protocols by taking out liquids and electronics. SVG does not have a half circle in which the passengers can move to four different areas. In fact, they only have one for fast track, and one for the regular lane. There is, however, a table standing just before this area, where the passengers can set their bags to take out electronics. This table has room for two passengers at the same time.

Number One is observing these passengers and helping them organize the boxes when they approach the conveyor belt. This assistance is done with the majority of passengers and helpful for the screener, as Number One has knowledge and experience on where to set the critical items. Additionally, Number One reminds incoming passengers to remove their headwear and scarves, as this is a continuous factor that many forgets. The beforementioned table is located on the regular lane, whereas the fast track lane has two of these. As the traffic here is lower, there is lower usage of the second table.

During the observations of the fast track section, it was noted that there was a higher tendency for the passengers at this section to delay taking off their outerwear, jackets, coats and hats until the very last second. There were even some cases where this was delayed until the trays were moving towards the x-ray. With this in mind, it was noted that it was a cold, rainy day at SVG, causing the majority of passengers to be wearing wool, raincoats and headwear.

Another factor that the researchers observed during their time at SVG, was the noise level, or rather, the lack of it. The sound volume was lower than at OSL, and even as this can be blamed on the considerably lower amounts of passengers going through, it was noted that the system or sending boxes back from the x-ray is done differently than at OSL.
Even though the boxes used are larger and deeper, it is noticed that people have a tendency to still use two boxes, to separate between outerwear and the contents of backpacks. This is seen throughout the observation period, even if there is little to no content in the passenger's backpack.

There were also cases of passengers arriving at the box section while being on the phone, especially in the fast track lane, wearing Bluetooth sets. The majority of these cases did not start the unpacking process until they ended their call, inefficiently using the time, considering their fellow passengers arriving behind.

Even as the quantity of passengers went down throughout the observation period, being 179 though the x-ray machine over an hour, the first 100 came within the first 15 minutes, as there was a short interval of several outgoing domestic flights to Oslo, Bergen and Trondheim.

### 6.4.1 Presentation of data: Fast track lane Stavanger Lufthavn

These number for the fast track is represented in the figure below

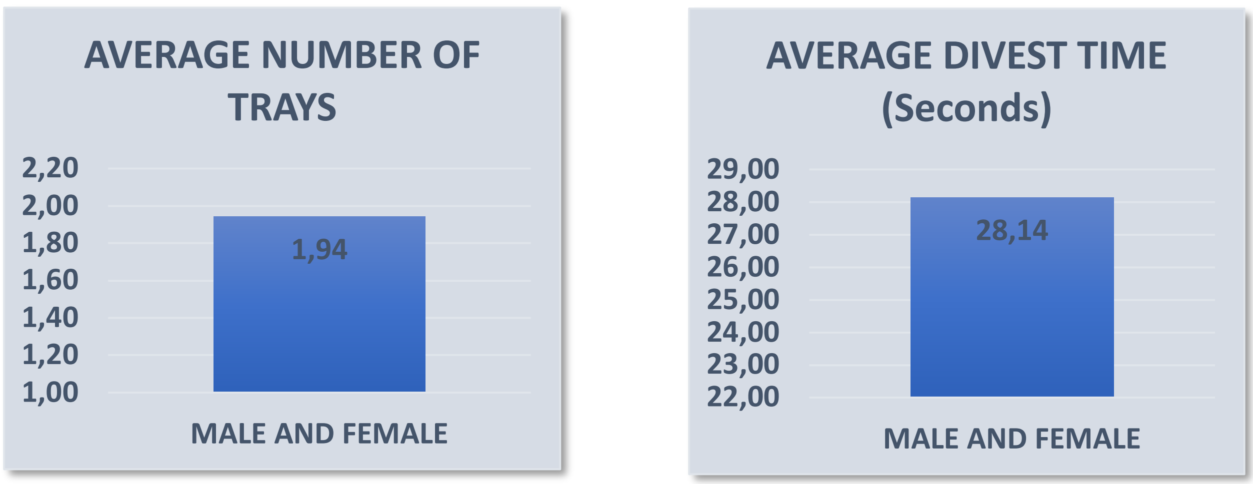



*Figure 23: Average number of trays and divest time for the fast track lane at SVG. Source: (Own work, 2019)*

N of cases = 35 for both male and females measuring the number of trays and divest time

The figure shows that the average number of trays, regardless of age group and gender is set just below two trays per passenger. Similarly, with the OSL research, the average divest time, also regardless of categorization other than being in the fast track, stands at an average of 28,14 seconds per passenger.

The reclaim time is similar to the ones at OSL. When the passenger is finished with the x-ray, the timer starts. From here the passenger, usually, waits for their luggage to arrive and starts packing down again. The timer doesn't stop until the passenger is done and starts to leave the area, similar with the divest timing. The number of passengers observed for reclaim time was, much like the pre-x-ray observation limited where N of cases = 30 passengers. The number for the fast track passengers' average reclaim time is represented in the figure below.

It is however worth noting that due to the limited amount of P2B2 categories in OSL, and while initially proving that being taken into a personal recheck does not drastically alter the total amount of reclaim time due to having to wait for the luggage anyway, along with the limited time available at Sola, it was decided not to categorize the passengers into P(X)B(X) for SVG. Therefore, the reclaim time is only categorized into gender split and age group.

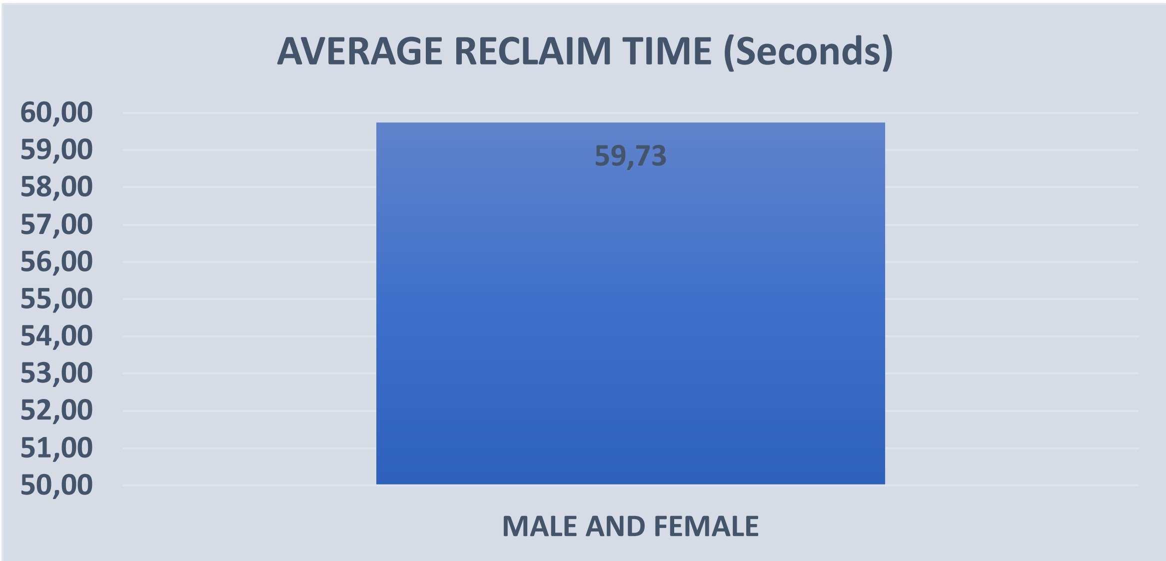



*Figure 24: Average reclaim time for the fast track lane at SVG. Source: (Own work, 2019)*

The figure shows the average reclaim time, again completely regardless of passenger category, other than being a part of the fast track lane, standing at just under a minute per passenger, at 59,73 seconds.

### 6.4.2 Gender split fast track SVG

Just as with the observations done in OSL, the observation subjects were categorized into gender and age groups. SVG also suffered from the same issue that OSL has, the dominant male distribution of the gender roles, especially in the fast track lanes.
N of cases = 25 for males and N of cases = 10 for females for the pre – x – ray observation.

It should be noted that the low number of males and especially females is not sufficient enough in order to generalize the results and findings from the observation. However, the goal from the observation at Stavanger Lufthavn was to get an impression and a data set used for comparison with OSL. Furthermore, the low number of observed passengers is also a result of the fact that only one day was spent for observation compared to two days at OSL.

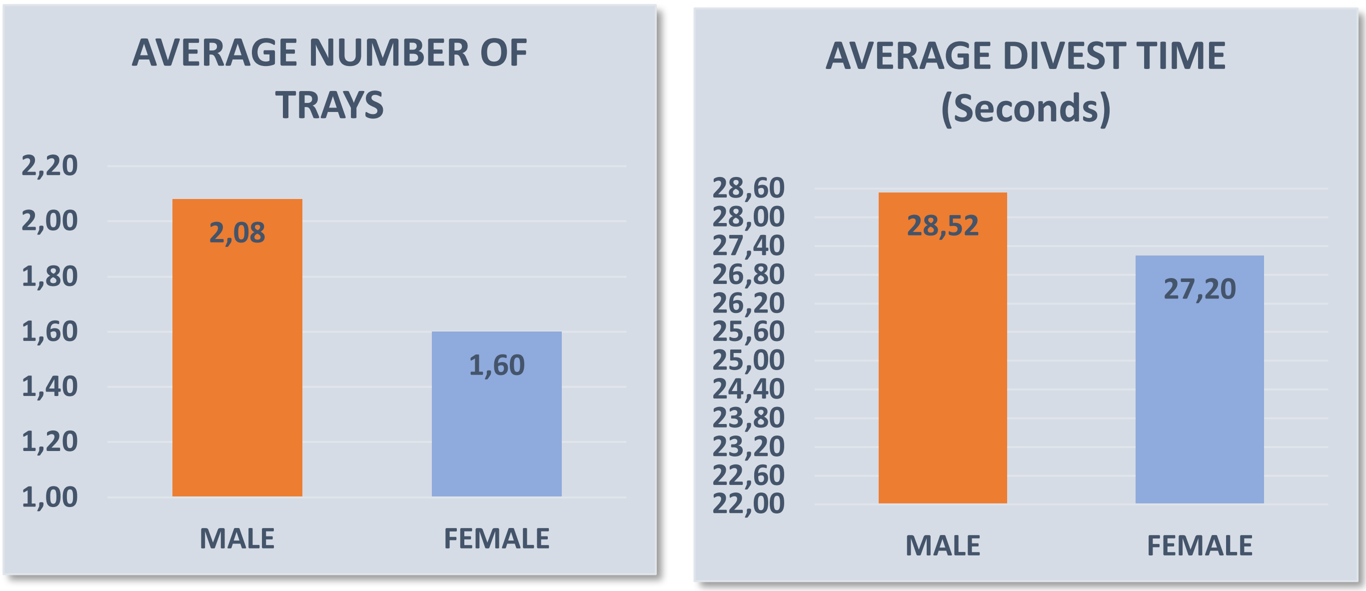



*Figure 25: Average number of trays and divest time for male and female using the fast track lane at SVG. Source:(Own work, 2019)*

As represented from the graph, the average number of trays for fast track passengers is respectively 2,08 for males and 1,60 for females, both of them lower than the OSL comparison. The divest time illustrated that males spend 28,52 seconds on average compared to 27,20 seconds for females. Again, both of these numbers are considerably lower than the OSL equivalent.

## 6.5 After x-ray notes for both for FT and RL

After processing the activity before the passengers' x-ray, the observation was focused on the activities after this section. This means that there would be observations on reclaim time, inspection time and passenger throughput rates. The main observation took place in the initial afternoon rush to see a similar experience as the OSL afternoon sessions and the SVG morning session.

One of the major things noticed from the start was the lack of trays filling up in the recheck counter. And while paying attention to the agent announcing the recheck, it was noted that the majority of the checks were random, as is the mandatory requirement for a given percentage of the boxes. The few who were scanned and sent to recheck that were *not* random usually included a liquid container of nursing formula.

The security agent who are in the process of recheck who finds liquid containers of water is more helpful than in OSL, offering to empty the bottle and give it back to the passenger, rather than throwing it away. There were several accounts during the observations in OSL where the passengers asked if they could empty the container and receive it back, which was ultimately denied.

However, when there actually is a recheck inspection, it is noted that the security agent uses longer time than they do in OSL. They put on a new pair of disposable gloves for each inspection and inspects with their sniffer piece for a longer time than previously researched, at OSL.

Furthermore, there was only one person at the recheck counter, even if there were more boxes lining up at the recheck counter. This would affect the passengers reclaim time.

Furthermore, the rush hours do not mean that there is a continuous pressure on the security agents at all times. These downtimes come at variable intervals and gives the security agents at recheck opportunities to set boxes back into their compartments if the passengers don't. This is absolutely vital, as the reclaim area in SVG is considerably shorter than OSL, as well as it does not have reclaim areas divided into sections.

For the post x-ray observations, the following numbers for reclaim time was observed:

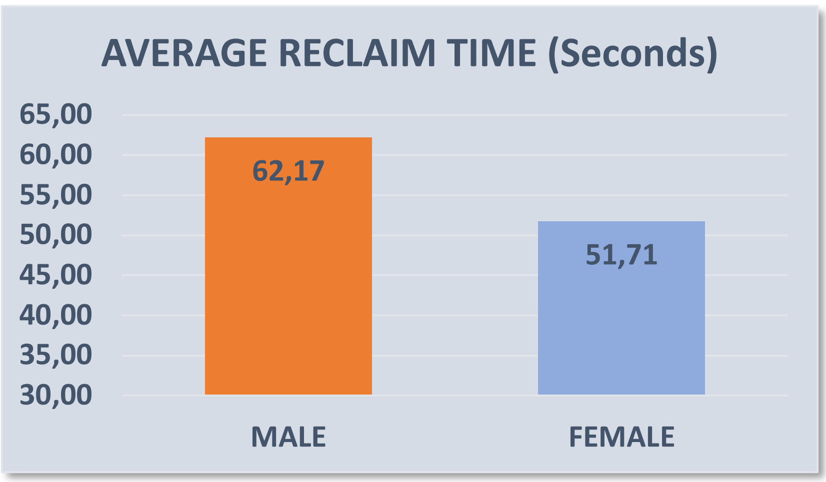



*Figure 26: Average reclaim time male and female using the fast track lane at SVG. Source: (Own work, 2019)*

N of cases = 23 for males and N of cases = 7 females post reclaim time.

On average, the graph illustrates that males spends 62,17 seconds and females 51,71 seconds during the reclaim of personal belongings. As mentioned before, the time is based on the fact that the passengers are not subjected to any personal inspection nor the inspection of their luggage, meaning that the timing starts as soon as the passenger is *cleared* from the x-ray scanning.

For comprehensive comparative reasons, the divest time and reclaim time has been added together, being the actions where the passengers are directly involved in time spent. Males spend the longest amount of time, averaging at just over a minute and a half, at 90,69 seconds. Females on the other hand spend only 78,91 seconds during the same process.

N of cases = 48 males, a combination of 25 observed at divest time and 23 for reclaim time.

N of cases = 17 females, a combination of 10 observed at divest and 7 for reclaim time.

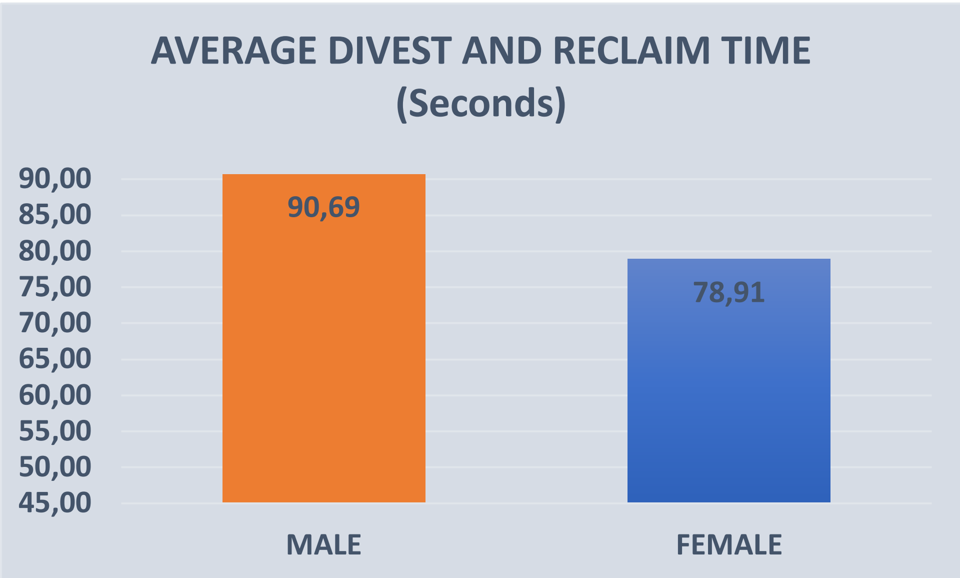


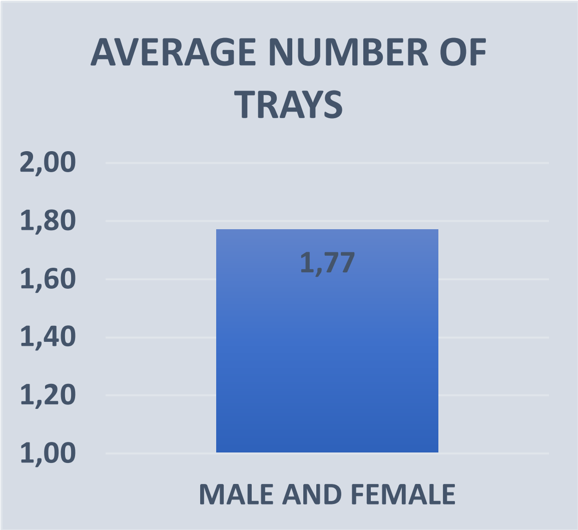

*Figure 27: Average divest and reclaim time for male and female using the fast track lane at SVG. Source: (Own work, 2019)*

## 6.6 Regular lane SVG

As mentioned, the observations for the fast track and regular lane happened at the same time, in which one observer measured the regular lane and the other the fast track lane. In addition, both lanes were using the same type of machine, albeit being mirrored, with the same amount of security agents at the same positions.

N of cases = 70 for both males and females for both the divest time and number of trays.

The number for the fast track is represented in the figure below.



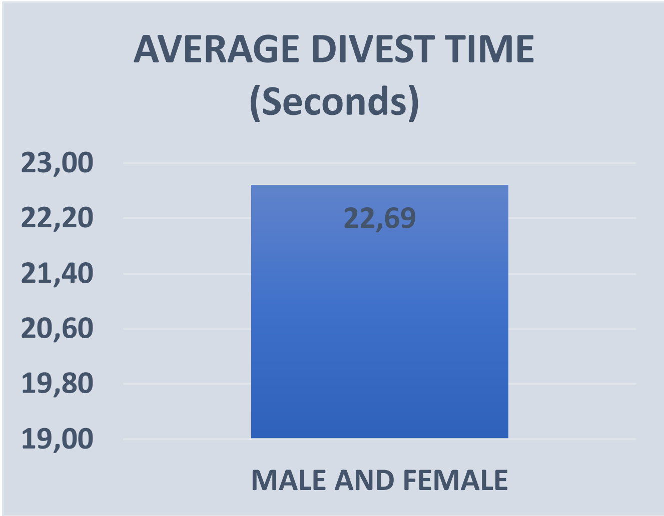




*Figure 28: Average number of trays and divest time for the regular lane at SVG. Source: (Own work, 2019)*

The figure shows the average number of trays, again, regardless of any passenger category for this particular lane. The average number of trays for this lane is somewhat considerably lower than the fast track equivalent with 1,77 compared to 1,94. The same can be stated for the divest time, where the average time spent for the regular lane is 22,69 seconds and 28,14 for the fast track lane.

The same principle of the fast track section also applies to the regular lane in regards to average reclaim time. The figure below represents the regular lane average reclaim time However, since this process takes a longer time than the divest time, N of cases = 33 for both males and females.

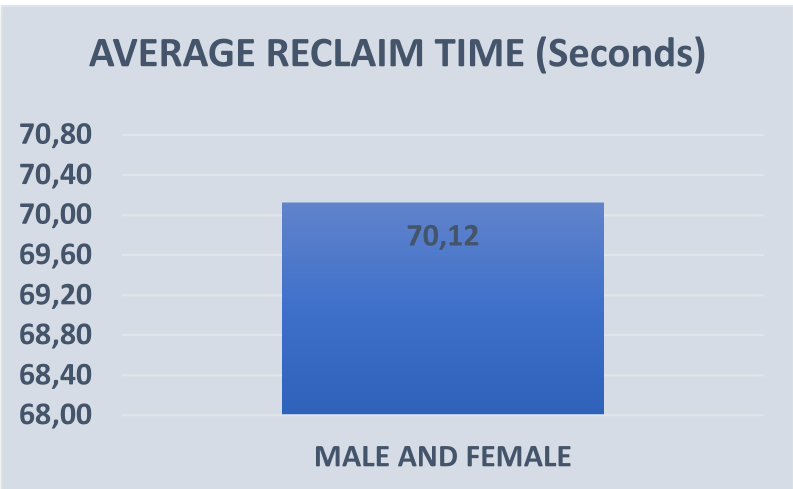
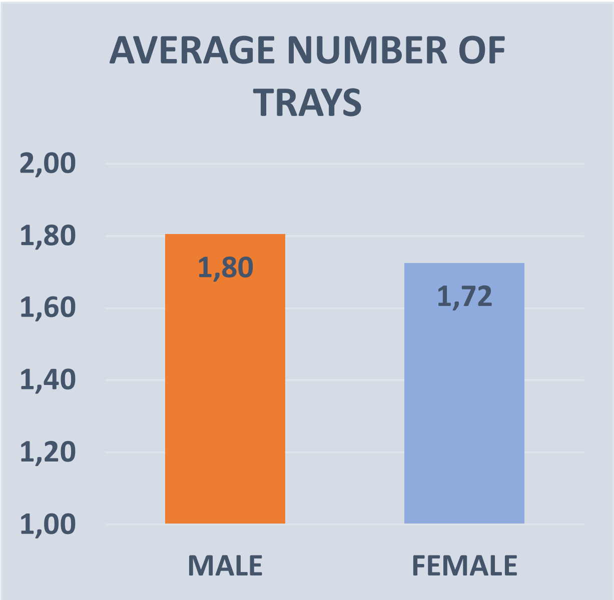



*Figure 29: Average reclaim time for the regular lane at SVG. Source: (Own work, 2019)*

Standing somewhat higher than the reclaim time of the fast track, the average reclaim time is measured at 70,12 seconds.

When splitting into gender roles, as observed already in the SVG fast track study, there are slightly different results. Primarily, the number of males and females observed are somewhat different as well. For the regular lane pre-x-ray, meaning the divest time and the average number of trays used, N of cases = 41 for males, and N of cases = 29 for females.



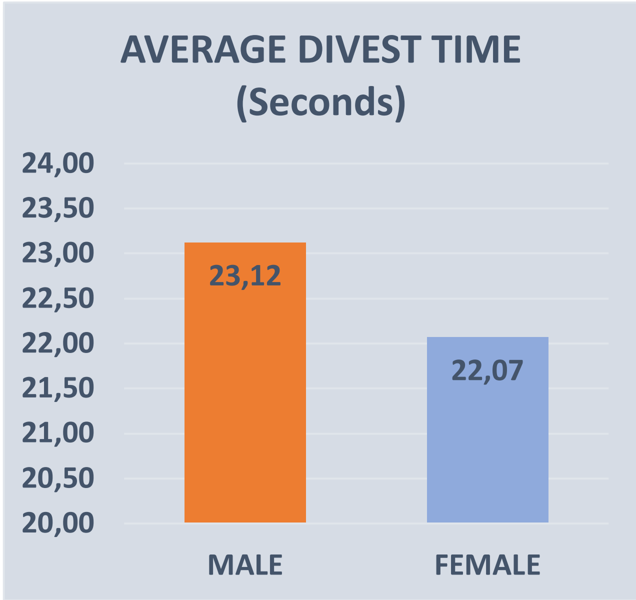




*Figure 30: Average number of trays and divest time for male and female using the regular lane at SVG. Source:(Own work, 2019)*

As represented from the graph, the average number of trays for regular lane passengers is respectively 1,80 for males and 1,72 for females, deviating slightly from the OSL comparison in both directions.

The divest time illustrated that males spend 23,12 seconds on average compared to 22,07 seconds for females. Both of these numbers are considerably lower than the Fast Track equivalent in SVG with 28,52 for males and 27,20 for females.

For the post x-ray observations, the results concerning the average reclaim time for the regular lane is measured by observing N of cases = 19 for males and N of cases = 14 for females.

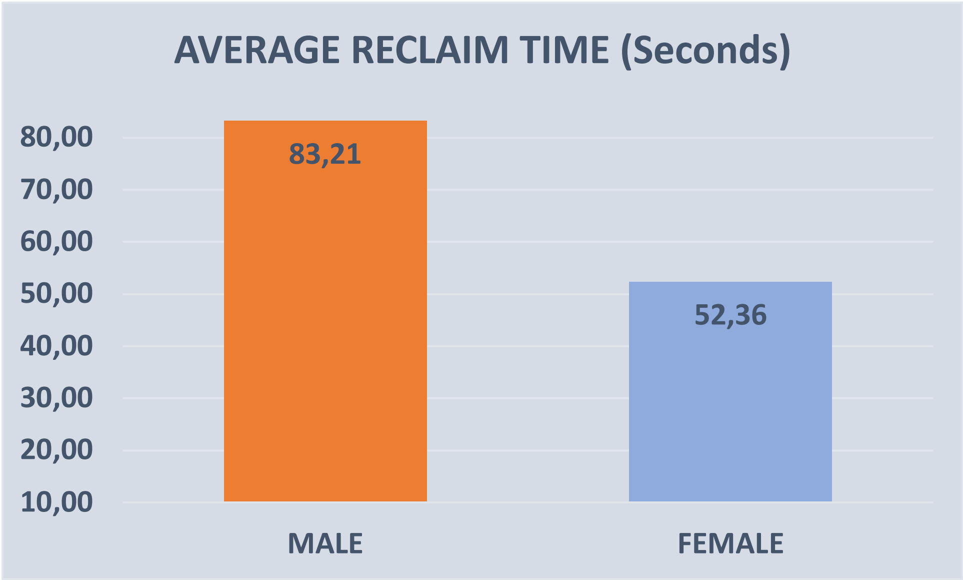



*Figure 31: Average reclaim time for male and female using the regular lane at SVG. Source: (Own work, 2019)*

The average reclaim time for males stands at 83,21 seconds, more than half a minute longer than females who uses 52,36 seconds for the same task.

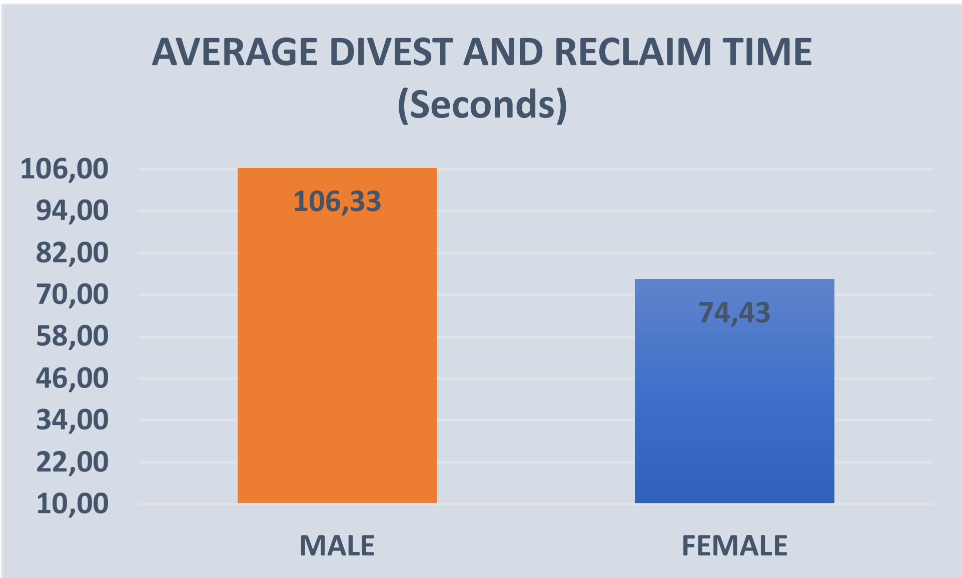



*Figure 32: Average divest and reclaim time for male and female using the regular lane at SVG. Source: (Own work, 2019)*

The average divests and reclaim times added together has also been done for the regular lane.
N of cases = 60 males, a combination of 41 observed at divest time and 19 for reclaim time.
N of cases = 43 females, a combination of 29 observed at divest and 14 for reclaim time.
The results show that females spend 74,43 seconds on average, a significantly lower amount of time than males, standing at 106,33 seconds.

## 6.7 Data collection at Geneva, Switzerland

The rise of C3 machines has given the opportunity for airports to offer passengers to go through the security section without having to take out electronic equipment. In order to do so, these machines offer 3D images instead of a 2D, making the tray content visible from all possible angles, making it more likely to clarify what type of equipment is beneath the trays.
While initially expensive to invest in these types of machines, it can prove as a cost saving method in the long run, by potentially reducing the passenger's stress level and increase the throughput rate. Furthermore, if other, more competitive airports decide to invest in this type of technology and if other does not, it could prove harmful if this technology gives enough incentives for passengers to actually choose the more technological sophisticated airport. One of the major influential factors in passenger's decision on what airport to choose is the airport's location and its services (Heyns and Carstens 2011).
With this in mind, the increase of these C3 machines across the larger airports in Europe makes the representatives in OSL consider an investment in this type of machine for the security section.

On the 11th of April 2019, a delegation from OSL arrived in Geneva Airport, Switzerland along with two MSc students from the Molde University College, with the purpose of witnessing the effectiveness of the newly invested C3 machines for the security checkpoints in Geneva International Airport (GVA). The machine used at GVA allows laptops and liquids to remain in the bag, making it easier for passengers going through the airport security checkpoint. Further, it generates both 3D and 2D images, which makes it easier for the operator to make the right decision and resolve any alarms. The false alarm rate is also low, which in the end contributes to a better flow of luggage and a reduced number of re-checks (L3 Technologies n.d.).

The intention for this trip was *not* to do any observations on passengers, but rather see first-hand how the machine works, as well as being presented on the advantages and disadvantages it has.

There are four preparation possibilities per lane, the same as in OSL. There are two agents for four passengers in the preparation area, both have access to a manual bottom, to create spacing between the trays. In contrast to OSL, were the rotation for the agents is 20 minutes, there is one-hour rotations for the agents at GVA. The flow allows for 15-20 seconds of rest, justifying the longer rotation for the agents. The usage of the machine is from 04:00 to 21:00. The throughput rate allows for 20 seconds of analysis time to make the clearance decision; however, the mean time is 7 seconds.

From the presentation by the GVA representative, a representation of some very interesting numbers was provided. For the summer period, using a conventional x-ray machine and lane, the number of trays per passenger were 1,9 – 2,0 trays. Very identical to the ones observed both at OSL and SVG. For the new lane with the implementation of a C3 x-ray machine the number was significantly better, from 1,1 – 1,2 trays per passenger on average. For the winter period, the number of trays per passenger using a conventional x-ray machine were 2,9 – 3,0 and 1,6 – 1,7 with the new type of x-ray machine. These numbers indicate some very interesting facts, and it illustrates that allowing laptops and liquids to remain in the bag, the number of trays per passenger is reduced. Even if the tray is going to the reject lane, it still has the possibility to be cleared by an operator before being re-checked. The reason for this is to not stop the entire flow of trays through the decision belt while the one in front is being accepted or rejected. Thus, if enough time has been spent without a proper decision, it is sent towards rejection and can be cleared by the time an agent is about to recheck it.

It was mentioned that both the belt speed and images had room for improvement. So, they decided to increase the belt speed from 0,12 m/sec to 0,18m/sec the use of an automatic tray return system is also present. Passengers must put the trays away themselves. A representation of the throughput rate was also given. The result illustrated the potential and a generally high number of throughputs with the use of the new x-ray machine. The winter results were at maximum 646 passengers per hour and averaging between 473 – 519 depending on the time of the day and the number of passengers with continuous flow.

For the summer, the maximum throughput rate is approximately 700. The bottleneck for this type of machine is the gap between the trays at 0,35 m. However, the bottleneck is more about the limitation of the device. The alarm rate is 15 % on average for shoes, and 5 % for the body alarm. This has nothing to do with the throughput of the x-ray machine but compared to OSL, where the alarm rate is 7 % in total.

The C3 machine used in Geneva is also smaller in size compared to a conventional x-ray machine. However, the weight is substantially higher at 1,6 – 1,7 tons compared to 700 kg for a conventional machine. As a result, the flooring underneath needs to be strengthened to withstand the weight of the machine. This is also something that must be taken into consideration if this type of machine were to be implemented at OSL. Another point worth mentioning is the requirement of a tunnel extension to reduce the radiation. If the luggage is too large for the trays, the content unfortunately must be separated. However, most passengers are traveling with luggage that are fitted for the trays.

In terms of the personnel, an agent can use any position at the security checkpoint. The required training for the personnel is expected to be approximately 2-3 months before they are fitted to use the new x-ray machine. Four simulators for 200 agents are available for training purposes. It was stated that the younger agents tend to learn faster compared to the older ones. There is also a dedicated screener room in which the agents receive the x-ray images for inspection. The operator screeners room consist of five operators at most, placed in a remote room away from the security checkpoint. The operators have the possibility to remove the laptop from the image when the x-ray images are being examined.

Further, there are two agents for separation, three for the metal detector, one for throughput, two for hand search and random alarms, one at the front and two right after the portal, three for the area and one checking boarding cards manually. In total, 17 agents are used when the two lanes are being utilized at maximum capacity.

# 7.0 Discussion and Analysis

There are many different variables that needs to be taken into consideration when analysing the results from both OSL, SVG and the field trip to Geneva, Switzerland. These variables make it virtually impossible to draw a definitive conclusion on how, for instance, SVG has a more efficient passenger handling system, or OSL has better crowd control. These variables are indeed numerous, yet critical to mention, as they can be the factor to determine how one process is more superior than another.

## 7.1 Oslo Airport

One of the topics worth discussing is the location of the security areas in OSL. As mentioned, there are at the moment two security areas, one part older, mostly used by SAS passengers, and one newer part, used more by Norwegian passengers. This is not only due to their respective fast track areas being set at this area, but also because the check-in counters, and checked in luggage deposits are located close to these areas.

OSL is considered by both Norwegian and SAS as a hub airport, meaning that there are several passengers coming from one flight, stopping in OSL to be sent forward to another flight, without leaving the terminal. But with these airlines being present, many passengers fly to OSL, followed by another check in process, as they need to fly with another airline. This means that the security queue not only handles incoming passengers from Oslo, but also domestic and international flight passengers who arrive with another airline. This also applies the other way around, as several passengers are coming from these other airlines and will travel domestically and internationally from OSL. The former of these often also brings tax free goods, in this case, mostly alcoholic beverages.

These goods are required to be isolated, but are still subject to inspection controls, both a check of the isolated bag, as well as occasionally breaking the isolation and inspecting the liquids, of course taking its time in the process, both for agents and passengers.
The point of mentioning this argument is that OSL is a hub that acquires both international and domestic passengers, often both ways, and often changing airlines at this airport. This causes several more passengers to go through the security check, often with tax free liquids, that can cause more distress for the agents to handle throughput, especially during high intensity.

The obvious candidate of effectiveness in OSL is the section division in both the divest and reclaim area. The fact that the passengers are able to spread out and divest their equipment, several at the time, was clear to the observers to be calming, as they did not have to be concerned about the passengers approaching behind them, as they could simply go to another opening once it presented itself.

For the divest area, this allows the queue prior to the security check to move smoothly, to wherever an opening presents itself, which could be argued to be effective for the average queue length itself. It was shown that one agent in the Number One position often guided passenger to these available slots. Regardless, the divest process allows the passenger to handle their equipment at their own speed, not having to be cautious of impatient passengers behind them. This also applies for the reclaim area. With passengers having their own section where they can pull their trays from the x-ray belt and start their process without the need of thinking about anyone beside them.

Further, the design and layout of the security checkpoint makes it easier for the agents to control and keep and overview of the passenger. This is mostly done to oversee that laptops, liquids and electronics are handled according to the set rules and regulations and standard to make it easier for the agents operating the x-ray machine.

The new security lanes at OSL are all equipped with an automatic tray return system (ATRS). The implementation of this type of system is not only there to increase efficiency but it is presumably affecting the passenger experience and satisfaction while passing though the security checkpoint. For the agents, the advantage is that they no longer have to physically move or lift the trays once filled up at the reclaim area. Further, this ensures that the agents have more time and can focus on more important security tasks elsewhere. In terms of the passenger satisfaction, passengers do not have to wait for available trays or the security agents to hand them the trays directly. Once the passenger has collected their belongings from the trays at the reclaim area, there are two modules for each lane, in which the passenger can put the empty trays and then they will automatically be returned to the divest area, ready for other passengers. The trays are also fitted with RFID chips, which makes remote screening possible. This, as mentioned earlier, allows other agents to examine images of trays from another lane. The RFID chips ensures that the correct tray and content are re-checked.

However, there is naturally an investment cost for such as system and there has been an assumption that the ATRS is not necessarily justify the investment costs and increase efficiency. To mention an example, the old security section at OSL still requires agents to manually remove the trays once they are filled up at the reclaim area. In practice, this system still works but since the research has mainly been focusing on the new security checkpoint at Terminal 2, it will be difficult to say if and ATRS system will enhanced efficiency if implemented at the older security checkpoint. It should also be stated that SVG are using ATRS as well. SVG does have solid numbers in terms of passenger throughput with the implemented ATRS. Also, worth mentioning is the fact that the design and layout for the divest area only have one station for passenger compared to four at OSL Terminal 2.

The passenger normally passes through the security checkpoint in less than five minutes. Compared to SVG, the design and layout of the new security checkpoint at OSL provides passengers with more place and room both at divest and reclaim area. This enables passengers to more efficiently remove their belts, laptops and other personal belongings for faster inspection and reclaim time. Further, this might contribute to a lower number of stress for the passenger, eventually increasing passenger satisfaction. However, the fact that the passenger does not feel pressured from other passenger standing behind them might result in passenger spending more time at the divest area and/or reclaim area.

Another part worth mentioning is the significant role the agents plays, especially the person who had the responsibility to distribute passengers when there was available space in front of the different airport security gates. The new terminal had approximately 12 security checkpoints open at the time of the observations, all of them with a good flow of passenger throughput. Further, if the passenger is getting an alarm when they are passing through the metal detector, the alarm will be activated. A noticeable observation is that the detector is able to pinpoint the area on the passenger in which the alarm is triggered. This makes it easier for the agent to examine the passenger and locate the area on the passenger.

It can be argued that the design and size of the trays does play a role in terms of the average number of trays per passenger, which might affect both divest and reclaim time. The measurements of the trays at SVG are 56,5 x 73,5 cm. The table below depicts the three different tray concepts used at OSL.

| Position | Height in cm | Width in cm | Length in cm |
|---|---|---|---|
| **Tray concept 1: Security gate 2- 12** | 10 | 50 | 60 |
| **Tray concept 2: Security gate 13 - 28** | 9,5 | 33 | 49 |
| **Tray concept 3: Security gate 29 - 31** | 10 | 39 | 59 |

*Table 8: Tray design OSL. Source: (Avinor Representative, 2019)*

As depicted in appendix 2 and appendix 3, the average number of trays for both the fast track and regular lane at SVG, is lower compared to OSL. The same can be stated for both the divest and reclaim time, where the number is lower in both cases at SVG. Therefore, the assumption and a possible potential for increased efficiency for OSL, might be to take a closer look at the design of the trays. An attempt to use one of the gates as a test subject to see if there is any strong hold in this assumption might be reasonable.

The trays themselves could be the reason for why the reclaim time is higher in OSL than SVG, even if the OSL system has a longer reclaim time and a more passenger friendly approach. As previously discussed, the fact that passengers can have their own space in their divesting area could cause them to spend more time in doing so, without concern of the passengers who may stack up behind them, could also apply in the approach of having their own "sector" in the reclaim area. Even so, there may be several other factors on what keeps the passenger in the reclaim area, both before and after their trays arrive for them.

As stated above, the trays are considerably smaller in OSL than SVG, which caused the average passenger to claim more trays for their belongings. This will, on average, make it more likely for a passenger to have their trays being sent to recheck, on the random check rather than a specific check. If nothing else, having two trays over one requires twice as much time to scan and twice as much space on the belt to handle. It also requires the passenger to have space for two trays at the reclaim area itself.

Regarding the incoming flow from public transportation, especially from Flytoget and Vy, it was obvious that the waves of incoming passengers going through the security system was tied to this flow. With arriving passengers every ten minutes during weekdays, a large number of passengers come in these waves, which ultimately stacks up the queueing by the security section of OSL. When compared to SVG, which has no public transportation other than the bus, that doesn't seem to carry a substantial effect as observed at OSL.

In an earlier chapter, the importance of customer satisfaction was discussed, especially so in airports. This did not only include passengers, but also meet-and-greeters, people in the proximity on business, tenants, and employees. In order to pass into the terminal, all of them, security agent or civilian, needs to be screened and checked at security.

For OSL to remain a liked and preferred place for the passengers, maintaining a healthy customer satisfaction, not only for them to be likely to return, but also for them to purchase more once inside the terminal. After all, more than half of the income from OSL comes from sales and service-related activities.

As the security check is one of the major determinants of whether or not the passengers have a satisfactory experience, it is vital for them to have both a quick and safe journey through the security section. Not only does it have to be safe, but it also needs to give the impression of "looking safe" as well, for the passengers to sink their shoulders. In other words, in order to keep customer satisfaction as high as possible, it is important for the security agent to not only treat the passengers as quickly and as efficiently as possible, but also to keep them satisfied and treated well. This could include smiling, having a calm attitude, assisting those with handicaps or children and generally being kind.

The efforts of understanding the queuing theory is also important for evaluating the efficiency of the passengers arriving the security check. There is a delicate balance between operating enough gates open to minimize the queue while still not overdoing the amount in order to keep security agent costs down.
By analysing the incoming passenger numbers, a variable that the security agents of OSL has a relative account on at any given time, due to their "forecasting app", it is possible to use queuing theory to predict the queue length and waiting time per passenger. With this, it is possible to properly justify the number of security scan areas to keep open at any given time, while still keeping the waiting time at Avinors' wishes, preferably less than five minutes, and no more than fifteen.

However, one of the issues of queuing theory is that it rationalizes the passengers as completely uniform and responsive according to the average time spent both before and after the x-ray scan and the number of trays, something which is not always the case. The passengers do not process their security scan at the average time, some deviate far from this rate. This makes any queuing theory irrational to the extent of passengers are different at an individual level.

One of the mail goals for Avinor is to reduce the costs in terms of personnel. They have expressed the yearly costs of keeping one security agent for a year, an amount that surpasses far beyond his/her salary, due to insurances, training and overtime. Naturally, the agents are essential when in use, but there are several agents on standby, in case the queue starts racking up. Investing in new technology, such as a C3 machine, could potentially make the less need for agents before the x-ray scan and therefore saving personnel costs. Even though it is a vague statement, new technology can potentially limit, or even remove, the need for personnel in certain areas.

Furthermore, the advantages of implementing the results of the queuing theory was recently mentioned, which may also be a sedative to reduce costs. If the number of gates open are kept at an optimal level, and with the number of agents being monitored to fulfil the expected number of passengers, then the need for excessive agents could be kept to a minimum, again lowering costs.

Regarding the gender and age split in the research, both for OSL and SVG, there were some differences, yet none of them stood specifically out in particular. One goal was to see if there were any particular time deviations between them, or if one gender/age group were using more trays than any other. The only noticeably specification is the amount of age group two, being between age 24-60. This was expected, as the age group correlates with people in an age of work and business travel.

Again, the evidence in this study shows inconclusive results, as the most efficient passengers before the x-ray were the fast track females in age group two, spending only 39,81 seconds divesting their items on average, while the number of trays being used were regular lane females in age group three, using only 1,67 trays on average. This may give an edge to the female part of the studied group, but the males were absolutely dominant in all reclaim time categories, except for regular lane males in age group three.

In fact, in nearly all categories, age group two, regardless of gender, were slower in the reclaim area than the other age groups, one and three, respectively. The only exception were females in the fast track. A possible explanation for this could be that the younger generation of age group one could be quicker and more reactive to packing electronic equipment such as laptops and pads, whereas the elder generation of age group three more likely than not are not carrying this equipment at all. It was also noticed that most passengers in age group two who appeared to be on business travel were dressed so, carrying coats and suit jackets that was being re-equipped before packing other equipment.

A brief and biased conclusion based on the results on the observations could say that females are more efficient before the x-ray, as females were using less time than males in the divest area, regardless of lane and age group. The same observational results could conclude that that males are more efficient post x-ray, again except for regular lane males in age group three.

## 7.2 Stavanger Airport

After completing the research in Sola, even before analysing the numbers, it was obvious that the average passenger was being processed more efficiently when compared with the OSL findings, both in times of high pressure, as well as when the rush hour was fading out. It is however worth noting that despite its efficiency, there is only room for one passenger to be processed at the time, a factor that could be a problem when considering if a passenger uses an excessive amount of time. The divest time is only started when the passenger is starting their process at the divest table, so counting individual time at Sola with individual time at OSL can seem misleading, as OSL has the capacity of handling several passengers for the divest time than SVG.

In fact, all the average times, regardless of gender or age group was more efficient in Sola, other than the inspection time, where the passenger has little to no control on its efficiency after the luggage has been taken to inspection. It was observed that the inspectors were taking more steps in SVG than in OSL, most clearly was the fact that they were equipping disposable rubber gloves for each inspection. As the timer for this inspection started at the time when the inspector asks to whom the bag belongs to, the process of equipping these gloves and doing a thorough inspection will naturally take its time, further enforced when considering the fact that the agents will handle the passengers' liquids if they are brought through in their luggage, to so give back the container.

Compared with the OSL agents, the ones in SVG give the passengers a choice of drinking up their liquids then and there, or to dispose both the liquids and its container. While more efficient in terms on time saved, it can be discussed on the level of distress it causes the passengers, something that was noticed during the OSL observations. Considering how there is no drain for the agents to empty the bottles, and as some passengers brought expensive water bottles, often filled up. If they cannot drink all of its content, the bottle is set for destruction.

It is worth mentioning that any observations done at SVG concerning its dual screening split between the fast track and the regular lane does not take into consideration the fact that during the initial morning rush hours, only the fast track lane is open. This means that the passengers coming from the fast track ticket scan interchanges with the regular lane queue after proceeding through this system. In practice, this means that the fast track has a shorter route between the ticket scan and the actual security system than the regular lane and will be processed faster.

With this, the average queue time before the security system is slower and generates significantly longer queues for the regular lane passengers. There was no definitive flow and several regular lane passenger observations were recorded to stand still for several minutes during this period, due to continuous arriving fast track passengers.

One of the probable factors that determine the steady flow of incoming passengers when compared to OSL is that Stavanger does *not* provide a railway to its airport. This railway, Flytoget and Vy, is immensely popular in OSL due to the airports' relatively remote location from the city centre, and can carry hundreds of passengers at a time, meaning that OSL needs to handle a capacity of hundreds of passengers coming in waves according to Flytoget.
This gives Sola an advantage in terms of steady flow, as passengers arriving will come either by bus or car, which does not give the same wave effect as OSL. This may be one of several reasons on why SVG has a faster process time than OSL.

Another analytic viewpoint is to consider the role that the agent known as Number One has at Sola. Simply by being available for the passenger to remind them on which items needs to be taken out of backpacks or purses makes the passenger more efficient in practice, even more so when the attendant assists in setting the equipment to appropriate sections of the trays, making it less likely that the tray will trigger a recheck. Also, it was noticed that the Number One was repeatedly telling passengers to remove scarves, especially since it was a particularly cold day during the observation.

Ironically, the divest time was shorter for the regular lane when compared with the fast lane on the other side, with the fast track and regular lane spending 28,14 seconds versus 22,69, respectively. An argument to explain this could be that fast track passengers are more likely to carry more electronic equipment and consequently uses more trays, proved in the observation of them using 1,94 trays on average, compared with the regular lanes' 1,77 on average. It is also worth mentioning again the fact that the gender split is quite substantial in this comparison, where, in the fast track section, females only use 1,60 trays and males 2,08. There is more equality found in the regular lane, with the males and females using 1,80 and 1,72 trays, respectively.

Another possible explanation on the extensive divest time is that business passengers, who could be argued is more likely to use fast track rather than leisure passengers, are more likely to be formally dressed, with belts, suits and jackets. This assumption was seen during the observations at Sola, that these apparent business type passengers were more likely to spend a somewhat longer time divesting.

On the other side of the x-ray comes the discussion on the reclaim time, where there are notable observations as well. The reclaim time is, like the divest time, substantially higher for males rather than females, both in the regular and fast lanes. The highest deviation is seen at the regular lane, more than 30 seconds longer for males to recollect their trays. This was usually due to equipment of belts, a tendency most seen with males. The reclaim time for the fast track, while not as high difference between the genders, still shows that females are dominantly more effective than males, where an explanation can be aligned with what has been stated above, that males spend more time equipping their belts, jackets and outerwear. Since females have a higher probability to carry a purse, they may have a slight advantage in time effectiveness when carrying utilities.

Another topic of discussion is the effective length of the reclaim area available at Sola. Even with a lower number of trays on average being used, the trays are larger and consequently takes a larger amount of space when proceeding towards the reclaim area. Even if the reclaim time is lower than OSL, there is no organized return system of these trays other than at the very end of the line, which needs to be handled manually. This gives reason to believe that there is a lower chance of passengers returning their trays to this return system, a fact that was noticed during the observation. This causes the trays to stack up and eventually cause delays and a somewhat chaotic scenery.

It was also noticed by the observers that the passengers waiting for their trays to pass through the x-ray seemed to stack up at the very start of the reclaim area, instead of evening themselves out through the area. As some people were taken into a personal recheck, this caused other passengers to gather in front of them, even if their luggage comes after. While this did not cause problems directly, it did show passengers constantly looking over other passengers' shoulders in order to spot their trays.

SVG has not adopted OSL's divest system where the passengers have their own sections, a system that allows them to take their own time in unequipping articles of outerwear and electronic equipment. They have also not adopted the reclaim system where the passengers can somewhat have their own sections to gather their trays and store their belongings again. This means that the trays are sent on a straight line from the x-ray until it either reaches the tray return system or is stopped by another tray. Even though there are "re-equipping" tables available in the area, it was observed that very few passengers actually use them, possibly due to the passenger needing to physically lift the tray(s) to this section. Instead, the passengers will wait until their tray is at a convenient place on the straight line, before he/she starts their reclaim process.

Even still, the reclaim time is significantly lower in SVG rather than OSL, both in the regular lane and fast track. A possible explanation could be that the pressure and stress the passengers in SVG are challenged with could make them act faster. Or seen in another perspective, perhaps the OSL reclaim area, with their own section being more private and there is no continuous rush, causes the passengers to perform them reclaims at a more comfortable speed to them.

That being said, there is one factor that could definitely be a contributing factor for the SVG speed in the reclaim area, compared with OSL; the fact that the reclaim area is smaller. Of course, the number of passengers going through in SVG is lower than OSL, but even so, the

throughput rate for each x-ray was at a similar level at certain points, as there were fewer openings in SVG, namely *one* for regular lane and *one* for the fast track.
This means that the pressure is still high, but there are fewer amounts of passengers being able to perform the reclaims at a given time. This gives a statement on how many passengers SVG can perform reclaims at a time interval, a number where OSL will probably have a higher rate, given their extensive reclaim area, despite the actual reclaim time per passenger is lower.

The levels of stress are mentioned in this thesis, meaning here the level of discomfort for the passengers. Even as this level is not quantifiable by the researchers, its tendencies and general mood can be observed. The observations in SVG and OSL has been subject to these types of observations, and there are some factors that are mentionable:

During the ticket scan prior to the security check, several passengers had a difficult time scanning their tickets, both in paper form and on the cell phone app. With several passengers lining up behind them, the stress level was clearly seen, especially for passengers with large carry-on luggage or accompanying children. If this stress level starts this early in the security process, it can be argued that there are lower chances of being more efficient during the actual security screening. Efficiency here means being aware and considerate to other passengers, unequipping jackets and outerwear and removing electronic equipment from its containers.
During this observation, there was also no agents at the location, which left several passengers without guidance to keep trying. Several passengers tried to scan their tickets for a few seconds before giving up and stepping to the side. A staff member in this area, or any notification that the system is slow to process could help the passengers to reduce this pressure.

Observing the merge between fast lane and regular lane passengers seemed to cause confusion and a higher stress level. Without proper guidance on *exactly where* the merge would take place, some regular lane passengers were allowed in front of fast track, while others were effectively standing still while fast track passengers pushed themselves forward.

If the C3 standard would become the new standard in Norwegian airports, the stress levels that arises from the beforementioned problems of not being able to properly scan one's tickets could be reduced if the process of not having to remove anything from backpacks or purses is implemented.

## 7.3 Geneva Airport

The GVA representatives illustrated the potential that a C3 qualified security system could have if implemented at OSL. The machines were handling trays similar to the SVG trays, large and deep, meaning that not only one's backpacks or carry-on luggage could be set in, but also allowing jackets and extra equipment to go into the same tray. The researchers from HiM were allowed to try this system on the return journey to Norway.

The presented numbers for both the summer and winter period is very relevant to OSL.
This is because the Norwegian climate is subjected to all four seasons across the year, meaning spring, summer, autumn and winter. The passengers clothing does play a role, depending on the time of the year. For example, winter time would mean more clothing such as larger jackets and scarfs. Therefore, the mentioned improvement from 2.9 – 3,0 trays for a conventional x – ray machine compared to 1,6 – 1,7 for the C3 machine could potentially be beneficial for OSL regarding the throughput time and number of trays during the winter period.

If Avinor were to implement this type of machine at OSL, it would most likely require adjustment to the flooring underneath and potentially design changes to fit the machine with the other parts of the security checkpoint. Even though the machine indicates promising rates of throughput at GVA, it does not necessarily mean that the result and performance will be the same at OSL. Furthermore, the weight of the x-ray machine is considerably heavier than any other machine in today's market. In fact, the tiling on the floor had to be evaluated so that it wouldn't break under the weight of the machine.

If OSL is considering an investment for this type of machine, a dedicated lane that could serve as a test lane to see if it`s performing better than a conventional x-ray machine will be natural before any major investment is made. The size of the trays also needs to be considered, whether to go for the same size that are already in use at OSL or use larger and similar like the ones at GVA.

The required training is also something to be considered. It would naturally take time before the agents are fully trained, but the level of experience is also low, so taking advantage of the full potential of the new machine would take some time. Further, OSL does not have a dedicated room in which the images from the x-ray machine examined and cleared. As mentioned, the operators at the screening stations are still located with the x-ray machine. OSL has considered using a dedicated room in the past but decided that this was not in their best interest at the moment.

How the setup at OSL compared to GVA will affect the overall efficiency by using a C3 machine is difficult to predict. It should also be mentioned that the efficiency and throughput rate can be affect by other factors such as the layout and design of the security checkpoint. In addition, would the different system of rotation for the agents affect the efficiency? As mentioned, the rotation of agents at OSL is 20 minutes compared to one hour for the ones at GVA. The agents of GVA has about 10-15 seconds of blank screen per imaging for better concentration on the following image to compensate for this.

In terms of passenger satisfaction, an assumption is that this type of machine will probably increase the satisfaction level. This is because the passenger must only place the bag and jacket in the tray, without removing the laptop or electronics, at the security checkpoint. It also increased the flow through the airport security checkpoint the fact that passengers do not have to remove their laptops or other electronic products makes both the time spent at divest and reclaim area better, and the number of trays lower. However, it will put more pressure and requirement of the operators to spot and look for potential prohibited items. This becomes more challenging due to the increased number of items per tray than before.

The rule and regulations also set requirement for random control and alarm rates. False alarms need to personally be re-checked by an agent, which can result in increased throughput time and cost related to staff. As mentioned from the GVA representatives, the generation of both 3D and 2D images makes it easier for the operator to make better decisions if the content in the trays are cleared or not, hence contributing to a lower number of false alarm rates. Even though the regulations require a certain amount of false alarms, the new type of machine might change the required rate, increasing throughput and flow.

It should also be mentioned that we personally observed a slight congestion at the reclaim area. Even though the divest time and the number of trays appeared to be lower, the reclaim time still seemed to take its time. Even if the time of packing electronic equipment sequence was reduced, the people standing at the reclaim area where noticeable.

In a way, the bottleneck is simply moved from before the x-ray to after, as the reclaim area is not made more efficient. This means that the passengers whose efficiency in the divest area is partially lost in the post x-ray area while waiting for their luggage to be cleared. In both OSL and SVG, it was noted that the divest time is by far shorter than the reclaim time, regardless of categorization. This type of technology will likely further to increase the time gap between these two areas.

The investment of this type of machine could potentially also benefit the airport itself, in terms of staying competitive. Passengers might prefer OSL as their main airport or HUB for further travel which again could affect the airports revenue by having more satisfied passengers, with more time to spend money once they pass the security checkpoint.

# 8.0 Findings

## 8.1 Oslo Lufthavn

| **Hypothesis** | ***Findings*** |
|---|---|
| **Hypothesis 1:**<br>*The number one security personnel have a critical impact on how the rest of the process flows.* | *Number One does have a significant effect, but not as important as SVG's setup has.* |
| **Hypothesis 2:**<br>*The oval structure in which the passengers put their belongings on the trays will ensure that passengers take much more responsibility on their own.* | *The oval structure seemed to help passengers relax and take their time more so than a straight divest system.* |
| **Hypothesis 3:**<br>*The screening process conducted using the X-ray machine is being 100 % utilized due to the implementation of Centralized Image Processing.* | *The process is indeed utilized, but the flow itself can be improved with an implementation of a C3 machine.* |

| | |
|---|---|
| **Hypothesis 4:**<br>*Reduction of dial back could potentially increase flow and efficiency of the security check.* | *A decrease in dial back would potentially make the bottleneck smaller.* |

## 8.2 Stavanger Lufthavn

| Hypothesis | *Findings* |
|---|---|
| **Hypothesis 1:**<br>*The number of boxes per passenger will on average be lower compared to the findings from OSL.* | *The number of trays per passenger is indeed lower than OSL.* |
| **Hypothesis 2:**<br>*The divest time will be higher than in OSL as a whole due to older design without oval shape.* | *The divest time was even lower than OSL.* |
| **Hypothesis 3:**<br>*The passenger's total throughput rate would in general be higher at Stavanger Lufthavn due to a considerably lower number of available airport security checkpoints at a daily basis, when compared with OSL.* | *The total amount of time spent in the SVG security system was lower than any of the observed OSL equivalents, except if the passengers' luggage were subject to a recheck.* |

The findings in both OSL and SVG showed results, in both expected and unexpected categories. The first hypothesis finding in OSL regarded the importance of the Number One agent, and his/her expression towards the coming passengers. The results showed that passengers were often reminded on how to best place their equipment in their trays, making the section helpful for the next sections, potentially reducing the number of unnecessary rechecks. However, as the results progressed in SVG, it was observed that the importance of Number One's role is more important, especially since SVG has a single passenger to be processed for the divest table at the time.

The next finding showed that the amount of seemingly more relaxed passengers was increased with the oval shape of the divest security check area. This was shown as the time spent in the divest area was considerably higher when compared with a traditional setup, such as the one seen in SVG. Even so, it is already mentioned that the OSL setup allows several passengers to be processed in the divest area at once, meaning that more efficient passengers will be done in their own swift time, even if the average time spent is lower.

The finding on whether or not the process is optimized is per today up for more discussion, but the process itself looks to be operating at a high capacity, considering space options, passenger waiting time after the queue to the security section, the number of agents and their apparent downtime. However, an investment in technology, such as a C3 certified system, could potentially make both the divest and reclaim areas more efficient, where the passengers will not have to take out and repack their electronic equipment. However, this time spent could come at the expense of the extra time it would take for the decision-making agent to process and clear/reject the trays. As there is no research available to make an estimation on exactly *how much longer* time is spent with the image processing and analysing the C3 images, this makes it difficult to see how much time is saved, if any.

For the SVG findings, there were also some surprises. As mentioned, most average times were much lower in SVG when compared with OSL. This also included the number of trays used. It is highly suspected that the number of trays is lower due to its larger size in width, length and height, meaning that more items can fit into the tray, including jackets and scarves.

The divest time in SVG was lower than OSL, a fact that came as a surprise due to OSL's investment in the oval shape divest area. However, as already mentioned, more passengers are being handled at the same time with OSL's system, even if the average time spent there is higher. Even so, SVG has a highly efficient system per passenger, where the Number One role is vital, as he/she organizes the trays and its content so that the number of trays being unnecessarily sent to the recheck area are avoided.

This means that, on average, almost all areas of time being recorded in SVG has been shorter than OSL on average. The only section that SVG uses longer time is in the recheck area, using a longer time to check both the random searches and the trays not being approved in the x-ray scan.

## 8.3 Identification of bottlenecks at OSL

As stated in the theoretical framework, the first step of the process of on-going improvement would be to identify the constraint/bottleneck. Based on this, the areas highlighted in red illustrates the identified bottlenecks for this research paper at the security checkpoint at OSL.

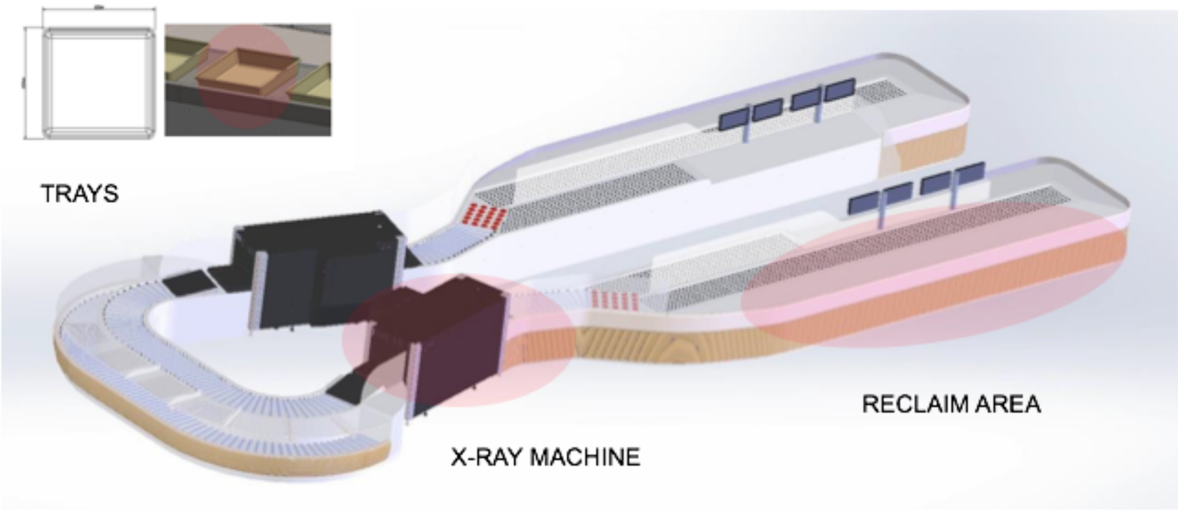



*Figure 33 - Identified bottlenecks at OSL T2 security checkpoint. Source: Own work based on (Avinor confidential report 2019 with permission to publish illustration of the OSL security checkpoint)*

Trays: The findings from the observation and statistical number does imply that the size of the tray have an effect on the average number used by each passenger. For OSL, the average number of trays were two or higher. Comparing this with the findings from SVG, that uses larger and deeper trays, the average numbers are under two trays per passenger for both the fast track and regular lane. Further, with fewer number of trays per passenger this would indicate that the time spent at the reclaim area is lower. OSL with the highest average number of trays has an average reclaim time of 98,86 seconds and 94,18 for the fast track and regular lane. For SVG, the average numbers are 59,73 and 70,12 seconds in the reclaim area. This implies that passengers who uses more trays, do spend more time waiting in the reclaim area.

X-ray machine: The current x-ray machine being used at OSL has also been identified as a potential bottleneck due to the fact that there exist other x-ray machines in the market which takes advantage of new technology to improve and give a more accurate image when the trays passes through the machine. Findings from the observations at OSL indicates that trays are being subjected to an additional x-ray scan, in which items or the x-ray image itself is not sufficient enough for the agents to make the clearance call. A C3 machine offers both 2D and 3D images, which could result in a more accurate representation of the content in the trays, reducing the number of rejects and recheck of the trays. This would give the agents more time and capacity to be used elsewhere at the security checkpoint.

Reclaim area: The findings from the observation does indicate that passenger spend the most time either waiting or collecting their items at the reclaim area. In fact, the time spent here is approximately 2/3 compared to the time spent at the divest area. The assumption is that the longer passenger waits, the level of satisfaction decreases. Therefore, the reclaim area should be addressed and studies in greater detail to find possible implementations to reduce the time spent for the passengers.

## 8.4 Exploiting the constraints

The bottlenecks are the most critical areas for optimizing flow as the other components, both before and after the bottleneck, is not able to function optimally due to it being either halted by the bottleneck, or simply doesn't receive its intended flow. Before anything is done with the bottleneck, it is important for the constraint to be working at a maximal capacity, preferably being utilized at 100%.
This case has established three major bottlenecks: the trays, the x-ray machine and the reclaim area. In order for them to operate at the highest possible capacity, they must handle their maximum intended flow of passengers at any given time. For the x-ray machine, this means that it needs to continuously handle trays with minimal downtime.

That being said, it is not necessarily the machine itself that needs to be optimized, but rather the agents processing the images it generates. This happens at an irregular pace, depending on the contents of the trays. However, keeping the agents busy with handling as many images as possible and making the decision on whether or not the tray is sent for a recheck swiftly is paramount for keeping the x-ray process flowing at a high level.

When considering the reclaim area, it is also important to keep this bottleneck at a high capacity. As the passenger spends two thirds of their time waiting here, this means that passengers coming from the divest area are more likely to stack up while waiting for the passengers ahead of them. In order to utilise this area as much as possible, it is important to keep the recheck protocols as short as possible, and making the passengers gather their equipment from their trays as quickly as possible.

The trays themselves can also be utilized by making the best use of them before gathering another one. As the observations showed in SVG, having larger trays helped reduce the entire process from divest to reclaim. As there is a certain distance between each tray, and the belt speed is moving slowly forwards, utilizing the number of trays used per passenger is important for the speed of the entire security process.

## 8.5 Subordinate and synchronize to the constraint

Making the other components 'adapt' to the constraining effect can indeed be difficult, as the process of the security section does not handle lifeless components, but living people. So, in order for the non-constraints to *not* produce as much capacity so that the constraint cannot handle it is indeed difficult.

The main non-constraining section is the divest area. By following the subordinating & synchronization of the constraint's theory, this would mean to limit the number of passengers entering the security section in order to keep an optimal flow at, for example, the x-ray machine. SVG has proven this, as they can handle one passenger to divest at a time, whereas OSL passengers can handle between three and four passengers per belt. Subsequently, the SVG passengers are being processed faster.

## 8.6 Elevating the constraint

What further actions could be done to either improve or altogether remove the bottlenecks at hand? Some of them would require new thinking and investment of capital in new and innovative technology, while others would be to think about larger dimensions. Ideas regarding these improvements are written in detail in Chapter 9 regarding the recommendations for OSL.

## 8.7 Repeat the process

The last step would be to repeat the process by analysing the newly implemented solutions to find any potential new bottlenecks or constraints. In this case, this could mean finding potential new bottlenecks as a result of the any newly implemented ideas or investments such as the C3 machine, layout of the reclaim area, or the change in size of the trays.

# 9.0 Recommendations

Based on the observations done in Oslo Lufthavn, Stavanger Lufthavn Sola and Geneva International Airport, combined with the theory analysed in an earlier chapter, has given this thesis suggestions that may improve efficiency and provide better customer satisfaction for the passengers.

## 9.1 Trays

The first recommendation is to change the size of the trays to potentially increase efficiency, both before and after the x-ray scan. By altering the design of the passenger's trays, or increasing their size, more specifically, may drastically reduce the number of trays being used per passenger, meaning that the belt will handle fewer trays. This is also mentioned due to the minimum distance between per tray is today at 40cm. This distance added with around two trays per passengers means that there goes considerable belt length per passenger, and with it goes time.

The observations done at SVG showed that the passengers use fewer trays on average with larger trays, not only larger in length and width, but also in height. SVG also has a lower divest time and reclaim time, which may be directly linked with the tray sizes. The trays also allow scarves and jackets to be placed in the trays with a lower chance of it falling off during its x-ray scan. This was observed several times during the observations in OSL.

If the trays are being updated, so too would the areas it covers. Adjusting the x-ray machine, the checking of x-ray pictures and potentially the decision-making time would be necessary, which could cause several other problems. If the size of the trays would increase, perhaps the distance between them should increase for the sake of the scanners as well. However, if the distance is increased with 25%, from 40 cm to 50 cm per tray, but the number of trays per passengers decreases from 2,20 to 1,77 trays, as was presented in the observations between the regular lane of OSL and SVG, respectively, it could potentially be justified just by these numbers.

It could also be worth investigating the implementation of a common tray size for Avinor airports, not only for the sake of the passengers getting used to a routine-based system, but also for further research to see a standardized system of trays.

The tray system is one of the few problems in the security scan that affects the divest, reclaim area *and* the x-ray process itself. By altering the sizes, it could potentially prove more efficient for all three areas.

## 9.2 C3 – x ray machine

Avinor request was to consider the investment of a C3 machine regardless of the investment cost. The first suggestion is to implement this new type of x-ray machine. This suggestion is made on the basis on both increased efficiency and passenger satisfaction. The reason for this is that the machine has proven in Geneva to increase efficiency in the divest area, as well as reduce the number of trays being used per passenger. The average number of trays per passenger is 1,6 – 1,7 and the throughput rate for passengers was reportedly as high as 700 per hour during summer peak times.

The machine will make it needless for passengers to take out their electronic equipment from their packs, saving both space and time for the passenger and his/her distribution on the divest table. In some cases, even certain liquids are accepted by this machine to be taken into the terminal. This was however entirely trivial, as demonstrated in GVA, due to the passengers not being able to choose which security system they were being placed in, the new one where it could be accepted, or the old one, where it would not be.

The officials at GVA expressed their satisfaction with the results even with the high investment costs for the machine. The machine has proven to be a potential solution for GVA, and could be helpful for OSL to improve their customer satisfaction and efficiency per passenger. With this in mind, the number of security agents could potentially be reduced which in turn, decreases labour costs related to staff.

## 9.3 Reclaim area

In all observations conducted, both in OSL and SVG, the larger majority of time spent for the passengers is waiting for the trays to arrive at the reclaim area. This could in other words be described as one of the bottlenecks. With this in mind, the next suggestion for improving the OSL security check would be to seek options for expanding the reclaim area. Avinor has made their intentions clear on that the reclaim area should be at least 50% larger than the divest area.

As the figures below illustrates, nearly the double amount of time being spent in the security process in OSL is done in the reclaim area. This applies to both regular and fast track passengers. If the first suggestion on introducing the C3 machine is being put into practice, the suggestion on increasing the reclaim area should also be taken into consideration. With the C3 machine, people would spend *even less* time in the divest area, but the time spent waiting for the trays to pass through would still be approximately the same. This means that any bottleneck that is solved from the divest area could potentially be moved to the reclaim area, meaning that more space is absolutely needed.

However, as already stated, expansion further into the terminal is a problem for Avinor, with constraints on where they may build more and not. This causes limitations on whether or not any expansions can take place, especially in the older terminal, as stated by Avinor. While a problem, the expansion of the reclaim area should absolutely be considered in order to answer the threat of the bottleneck that may arise as a consequence of the potential upgrades.

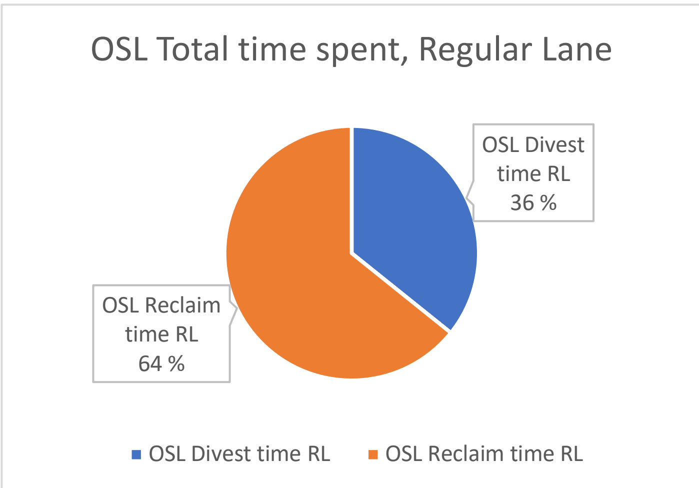



*Figure 34 - OSL Total time spent, Regular Lane. Source: (Own work, 2019)*

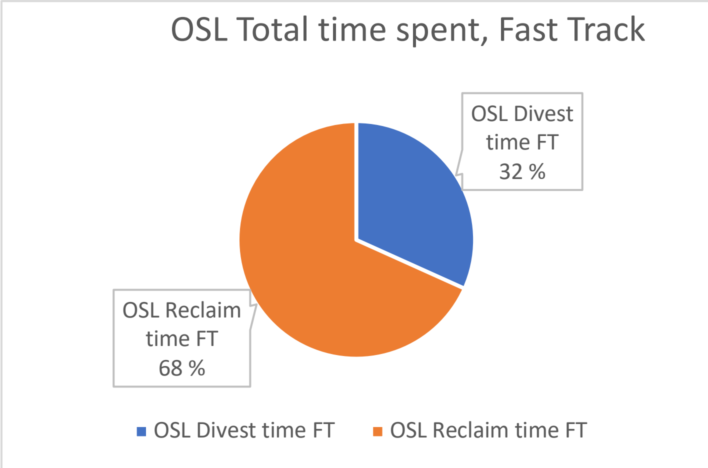



*Figure 35 - OSL Total time spent, Fast Track. Source: (Own work, 2019)*

## 9.4 Queuing Theory

Another suggestion would be to properly utilise the queuing theory to find the optimal number of security lanes to have open at any given time. It is vital that the mobile app that the security agents uses is being constantly updated and up to standards, in order to give a proper estimate on the arriving passengers. Even as it is based on historic data, it should give a trend estimate on how the approximate number of passengers arriving. With this, and by using the queuing theory should give Avinor and the security agents enough information on how many lanes to open in order to keep Avinors goal, making the passengers wait for less than *five minutes* in line before being processed. This process, as mentioned in the discussion, could potentially reduce the need for excessive personnel costs, a factor that is one of Avinors highest priorities.

# 10.0 Research limitations, future research and summary

## 10.1 Research limitations

A major airport such as OSL has several components, which makes it necessary to define where the actual research area of effect will take place. For this thesis, focusing on the security measurements between the terminal and the outside area for check-in limits the scope to where the passenger is about to enter the queue system for the security checkpoint, until the point where the passenger has recovered their luggage and/or passed through the security check. The ending in Norwegian airports are usually marked with a point of customer feedback, illustrated with a station consisting of four buttons, ranging from red, representing a bad experience, to green, representing a good experience.

However, the research may just as well look beyond this horizon both concerning before the security check, and after. It may be necessary to look at the passenger income flow from peak and bottom estimates.

In terms of research after the security measurements, it may also be necessary to address passenger satisfaction in the terminal after the security check. If there is a particularly long queue, it is possible that this will affect satisfaction levels, potentially causing lower sales in terminal-based stores, or possibly even boycotting the airport altogether for an alternative.

Getting an insight, obtaining and gathering sensitive information on how the airport security company operates and deals with the security process will be of high importance. However, we must keep in mind that it can be challenging to collect sensitive data regarding security procedures and processes. The information we receive must also be threated will caution and might perhaps not be suitable for publishing in general. Therefore, it can be challenging to obtain the necessary information to get understand how the whole process functions, which is a possible limitation that we must keep in mind.

Furthermore, the observation was conducted within a limited timeframe. It was therefore of highly importance to make all the necessary preparations in order to ensure a successful process concerning measurements and data collections for OSL, the observations were conducted at the course of two days with specific timeslots. For SVG, there was only one day of observation.

There is also an obvious dominance of the second age group, more specifically those between 24-60 years of age. This is a delicate subject, as the decision on what age group each observed individual is based on is the researchers estimated guess. This has been discussed between the researchers several times, but it was decided that a more specific age group is not necessary, only those where age is either very low or very high. In other words, the age group between 25 and 64 is here considered as a working age, where frequent travelling by aviation is more normal than a retired senior or a youngster without travelling experience.

The reason for this is that those outside this age group usually spends more time than the experienced travellers, distorting average times not necessarily to make a specific observational research for them. In addition, obtaining the specific age from each observed passenger would have required the observes to ask them in person which would have been too demanding and affected the number of observed passengers through the security checkpoint.

Nevertheless, the ones in age group 2 were dominant in the number of passengers observed, representing 63% and 91% of the females and males in the OSL fast track, pre-x-ray, respectively. They also represent 66% and 72% in the equivalent regular lane, pre-x-ray in OSL. The post x-ray observations, specifically the reclaim time, amounted 50% and 65,52% of the females and males in the fast track, respectively, and 61% and 79% for the regular lane. This does not mean that this is the average for all passengers, simply the ones being observed.

Regarding the reclaim time, the observation of each passenger will be put into a specific category. However, it would most likely be an uneven number of observed passengers within each specific category. The assumption would be that most of the passengers will fall into a category in which they are not subjected to any extra control, neither by the security personnel, body scanner or their luggage. Taken into consideration the limited time frame for the observation, this will result in fewer passenger falling into the other categories, making generalization more difficult.

## 10.2 Future research

This chapter will list suggestions for future research that could be beneficial and help to improve the airport security checkpoint at OSL further. The reason for most of the suggestions below are due to the general limitations of the thesis.

If Avinor decides to invest in a C3 machine, additional observations should be conducted to measure the potential improvements for this investment. Further, this would be necessary in order to find other potential bottlenecks as a result of the C3 machine. Avinor might experience that people are using a smaller number of trays per passenger which could increase the throughput rate. However, other steps might be affected by the new x-ray machine such as longer inspection and decision time that could potentially be the new bottleneck. Therefore, little is known about the full effect by investing in a C3 machine before it is actually operational and new observation has been conducted.

As this research had two full days of observation at OSL and one day at SVG, increasing the time spent on observation could be more beneficial to generalize findings. Especially related to the different categories such as age group and if the passenger is subjected to any additional inspection as some of these categories was considerably lower which makes generalization difficult for the specific group.

The main focus for this research has been on the security checkpoint where the passenger and carryon luggage go through. Another area that should be studied and observed more would be from when the passengers enters the line of where the queue starts in which a queue theory might be applicable. In this area, information distributed to passengers that are waiting in line could be further examined to find potential improvements that would be helpful to increase flow through the security checkpoint.

The passenger satisfaction should also be measured to really get an understanding of the level of satisfaction that the passengers are experiencing. This could be in a form of questionnaire or other means of surveys. This would be relevant in terms of potential revenue for the shops after the security checkpoint and it would also affect if the passenger will return and continue to use the airport.

# References


"Air Transport, Passengers Carried | Data." 2017. The World Bank Group. 2017. https://data.worldbank.org/indicator/IS.AIR.PSGR.

Alards-Tomalin, Doug, Tamara L. Ansons, Tara C. Reich, Yumiko Sakamoto, Rita Davie, Jason P. Leboe-McGowan, and Launa C. Leboe-McGowan. 2014. "Airport Security Measures and Their Influence on Enplanement Intentions: Responses from Leisure Travelers Attending a Canadian University." *Journal of Air Transport Management* 37 (May): 60–68. https://doi.org/10.1016/J.JAIRTRAMAN.2014.02.004.

"Åtte Nye År Til Nokas | Aktuellsikkerhet." n.d. Accessed April 4, 2019. http://aktuellsikkerhet.no/atte-nye-ar-til-nokas.

"Aviation Security." n.d. European Commision Mobility and Transport. Accessed April 3, 2019. https://ec.europa.eu/transport/modes/air/security_en.

*Aviation Security International*. 2017a. "Centralised Image Processing: The Impact on Security Checkpoints - Aviation Security International Magazine," 2017. https://www.asi-mag.com/centralised-image-processing-impact-security-checkpoints/.

———. 2017b. "Smart Security: Is It Really 'Better Security' and a 'Checkpoint of the Future'?," 2017. https://www.asi-mag.com/smart-security-really-better-security-checkpoint-future/.

Avinor. n.d. "Facts and Background OSL - Avinor." Accessed April 18, 2019a. https://avinor.no/en/corporate/airport/oslo/development/facts-and-background/.

———. n.d. "Flyplassens Historie - Avinor." Accessed March 7, 2019b. https://avinor.no/konsern/flyplass/stavanger/om-oss/flyplassens-historie/historie.

———. n.d. "Hvorfor Tredje Rullebane - Avinor." Accessed April 18, 2019c. https://avinor.no/en/tredje-rullebane/hvorfor-tredje-rullebane/.

———. n.d. "Oslo Airport Facts - Avinor." Accessed January 31, 2019d. https://avinor.no/en/aviation/market/oslo-airport-facts/.

———. n.d. "Role in Society - Regulations." Accessed April 5, 2019e. https://avinor.no/en/corporate/about-us/role-in-society/regelverk.

———. n.d. "The Avinor Network - Avinor." Accessed January 31, 2019f. https://avinor.no/en/aviation/route-development/avinor-network/.

———. 2017. "Traffic Statistics - Avinor." 2017. https://avinor.no/en/corporate/airport/oslo/about-us/traffic_statistics/trafikkstatistikk.

———. 2018. "Års-Og Samfunnsansvarsrapport 2017."

https://avinor.no/globalassets/_konsern/om-oss/rapporter/avinor-arsrapport-2017.pdf.

Baur-Ahrens, Andreas, Marco Krüger, Regina Ammicht Quinn, Matthias Leese, and Tobias Matzner. 2015. “How Smart Is "Smart Security"? Exploring Data Subjectivity and Resistance.” *Eberhard Karls Universitat Tubingen - Internationales Zentrum Fur Ethik in Den Wissenschaften (IZEW)*. https://doi.org/10.15496/publikation-8318.

BBC. 2019. “Future of Airport Security on Show in London - BBC News.” 2019. https://www.bbc.com/news/technology-46906935.

“Befolkningen - SSB.” n.d. 2018. Accessed January 31, 2019. https://www.ssb.no/befolkning/faktaside/befolkningen.

Biesecker, Calvin. 2018. “TSA Wants to Take Airport Security Into the Future - Avionics.” *Avionics International*. https://www.aviationtoday.com/2018/05/11/tsa-wants-take-airport-security-future/.

Campbell, Donald T, and Donald W Fiske. 1959. “Psychological Bulletin CONVERGENT AND DISCRIMINANT VALIDATION BY THE MULTITRAIT-MULTIMETHOD MATRIX 1.” http://languagetesting.info/articles/store/C&F1959.pdf.

Cardiff University. 2018. “New Passenger Scanner Uses Space Technology to Speed up Airport Security - News - Cardiff University.” 2018. https://www.cardiff.ac.uk/news/view/1389672-new-passenger-scanner-uses-space-technology-to-speed-up-airport-security.

Cento, Alessandro. 2009. “The Airline Industry.” In , 1st ed., 184. Physica-Verlag Heidelberg. https://doi.org/10.1007/978-3-7908-2088-1.

Chen, James K.C., Amrita Batchuluun, and Javkhuu Batnasan. 2015. “Services Innovation Impact to Customer Satisfaction and Customer Value Enhancement in Airport.” *Technology in Society* 43 (November): 219–30. https://doi.org/10.1016/j.techsoc.2015.05.010.

Chen, Jiaqi, Shengnan Xu, and Liangbi Wu. 2017. “Optimizing the Passenger Throughput at an Airport Security Checkpoint” 123 (Icesame): 453–58. https://doi.org/10.4236/ojapps.2017.79035.

Creswell, John W. 2003. “RESEARCH DESIGN Qualitative, Quantitative. and Mixed Methods Approaches SECOND EDITION SAGE Publications International Educational and Professional Publisher Thousand Oaks London New Delhi.” https://pdfs.semanticscholar.org/73b7/18e508fa943dfb22a9cb5fb17f888239ad0e.pdf.

Crocker, William, Mary Catherine Hult, Alana Finley, Lara Kaskie, Thomas Lombardi, Clarence Tull Cathleen, and A Berrick. 2008. “GAO-08-933R TSA’s Explosives Detection Canine Program: Status of Increasing Number of Explosives Detection Canine Teams.” http://www.gao.gov.

Edwards, Brian, and Brian Edwards. 2005. *The Modern Airport Terminal New Approaches to Airport Architecture*. Spon Press. https://books.google.no/books?id=K2F4AgAAQBAJ&pg=PT54&dq=airport+customer+satisfaction+factors&hl=no&sa=X&ved=0ahUKEwib8_D94obiAhWLmIsKHZujBY8Q6wEIVTAF#v=onepage&q=airport customer satisfaction factors&f=false.

Erlang, A. K. 1920. “Telefon-Ventetider. Et Stykke Sandsynlighedsregning.” *Matematisk Tidsskrift. B*. Mathematica Scandinavica. https://doi.org/10.2307/24530438.

Eurostat. 2017. “National Air Passenger Transport by Reporting Country.” 2017. http://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do.

Findlay, Justin. 2015. “The Busiest Air Routes in Europe - WorldAtlas.Com.” 2015. https://www.worldatlas.com/articles/busiest-air-routes-in-europe.html.

Gardham, Duncan. 2009. “Airline Terror Trial: The Bomb Plot to Kill 10,000 People - Telegraph.” *The Telegraph*, 2009. https://www.telegraph.co.uk/news/uknews/terrorism-in-the-uk/6153243/Airline-terror-trial-The-bomb-plot-to-kill-10000-people.html.

Ghobrial, Atef, and Ken Fleming. 1994. “A Model for Developing an Airport Security Plan A MODEL FOR DEVELOPING AN AIRPORT SECURI7Y PLAN.” *Journal of Aviation/Aerospace Education & Research JAAER Winter* 4 (2). http://commons.erau.edu/jaaer/vol4/iss2/1.

Gillen, David, and William G. Morrison. 2015a. “Aviation Security: Costing, Pricing, Finance and Performance.” *Journal of Air Transport Management* 48: 1–12. https://doi.org/10.1016/j.jairtraman.2014.12.005.

———. 2015b. “Aviation Security: Costing, Pricing, Finance and Performance.” *Journal of Air Transport Management* 48: 1–12. https://doi.org/10.1016/j.jairtraman.2014.12.005.

Gkritza, Konstantina, Debbie Niemeier, and Fred Mannering. 2006. “Airport Security Screening and Changing Passenger Satisfaction: An Exploratory Assessment.” *Journal of Air Transport Management* 12 (5): 213–19. https://doi.org/10.1016/j.jairtraman.2006.03.001.

Goldratt, Eliyahu M., and Jeff Cox. 1984. *The Goal: A Process of Ongoing Improvement*. *Book*. https://doi.org/10.2307/3184217.

Goyat, Sulekha. 2011. “The Basis of Market Segmentation: A Critical Review of Literature.” *European Journal of Business and Management* 3 (9): 45–54.

https://doi.org/10.1073/pnas.1211491109.

Grinberg, Emanuella. 2009. "Federal Air Marshals Back in Spotlight after Attempted Plane Bombing - CNN.Com." *CNN*, 2009. http://edition.cnn.com/2009/TRAVEL/12/30/federal.air.marshals/.

Haight, Frank . 1967. *Handbook of the Poisson Distribution*. New York: John Wiley & Sons.

Hainen, Alexander M., Stephen M. Remias, Darcy M. Bullock, and Fred L. Mannering. 2013. "A Hazard-Based Analysis of Airport Security Transit Times." *Journal of Air Transport Management* 32 (September): 32–38. https://doi.org/10.1016/J.JAIRTRAMAN.2013.06.002.

Halliday, Hannah. 2016. "Quantitative, Qualitative, Inductive and Deductive Research." https://www.slideshare.net/hallidayhannah/quantitative-qualitative-inductive-and-deductive-research.

Harrison, Alan, Remko Hoek, and Heather Skipworth. 2014. *Logistics Management and Strategy: Competing through the Supply Chain*. *Logistics Management and Strategy: Competing through the Supply Chain*.

Hawksworth, John, Hannah Audino, and Rob Clarry. 2017. "The Long View. How Will the Global Economic Order Change by 2050 ?" *Price Waterhouse and Coopers*. Vol. Februrary. https://www.pwc.com/gx/en/world-2050/assets/pwc-world-in-2050-summary-report-feb-2017.pdf.

Heyns, Gert, and Stephen Carstens. 2011. "Passenger Choice Decisions at a Regional Airport in South Africa." *Journal of Transport and Supply Chain Management* 5 (1). https://doi.org/10.4102/jtscm.v5i1.73.

Hill, Nigel, Greg. Roche, and Rachel. Allen. 2007. *Customer Satisfaction : The Customer Experience through the Customer's Eyes*. Cogent. https://books.google.no/books?id=uKQPo_FibAQC&printsec=frontcover&dq=customer+satisfaction&hl=no&sa=X&ved=0ahUKEwjqrYLm0YTiAhWC6aYKHSrYDKYQ6wEILDAA#v=onepage&q=customer satisfaction&f=false.

"IATA - 20 Year Passenger Forecast." 2019. IATA. 2019. https://www.iata.org/publications/store/Pages/20-year-passenger-forecast.aspx.

Jain, L. C., Himansu Sekhar Behera, Jyotsna Kumar Mandal, and Durga Prasad Mohapatra. 2014. *Computational Intelligence in Data Mining. Volume 3 : Proceedings of the International Conference on CIDM, 20-21 December 2014*. https://books.google.no/books?id=RwHRBQAAQBAJ&pg=PA388&dq=lifo+queuing&hl=no&sa=X&ved=0ahUKEwj_yJbiz4TiAhVjoosKHVI4BJsQ6AEIKTAA#v=onepage

&q=lifo queuing&f=false.

Johannesse, Asbjørn, Per Arne Tufte, and Line Christoffersen. 2016. *Introduksjon Til Samfunnsvitenskapelig Metode*. Abstrakt forlag.

Johannessen, Asbjørn, Per Arne Tufte, and Line Christoffersen. 2016. *Introduksjon Til Samfunnsvitenskapelig Metode*. Abstrakt forlag.

Jost, Stefan. 2016. "An Overview to Qualitative and Quantitative Research Methods in Design," 1–6. https://medium.com/digital-experience-design/an-overview-to-qualitative-and-quantitative-research-methods-in-design-de034a92f45c.

Knill, B. 1992. *Continuous Flow Manufacturing, Material Handling Enfineering*.

Kramer, Lois S., Aaron Bothner, Max Spiro, National Research Council (U.S.). Transportation Research Board, Airport Cooperative Research Program, and United States. Federal Aviation Administration. 2013. *How Airports Measure Customer Service Performance : A Synthesis of Airport Practice*. Transportation Research Board. https://books.google.no/books?id=xT3pAAAAQBAJ&pg=PA9&dq=airport+customer+satisfaction&hl=no&sa=X&ved=0ahUKEwjNovSV2obiAhXElYsKHQbHDhgQ6AEIKTAA#v=onepage&q=airport customer satisfaction&f=false.

Kristiansen, Tonje. 2017. "Norge På Flytoppen." https://www.framtiden.no/aktuelle-rapporter/811-norge-pa-flytoppen-2/file.html.

"L3 Security and Detection Systems." n.d. L3 Technologies. Accessed April 19, 2019. https://www.sds.l3t.com/aviation-checkpoint-screening/ClearScan.htm.

Labaree, Robert V. 2009. "Research Guides: Organizing Your Social Sciences Research Paper: Quantitative Methods." https://libguides.usc.edu/writingguide/quantitative.

Laguna, Manuel, and Johan Marklund. 2011. *Business Process Modeling, Simulation, and Design*. https://books.google.no/books?id=d-V8c8YRJikC&pg=PA178&dq=%22First-come,+first-served%22+business&redir_esc=y&hl=no#v=onepage&q=last-come&f=false.

Lange, Robert De, Ilya Samoilovich, and Bo Van Der Rhee. 2013. "Virtual Queuing at Airport Security Lanes." *European Journal of Operational Research* 225 (1): 153–65. https://doi.org/10.1016/j.ejor.2012.09.025.

Lawrence, Stephen R., and Arnold H. Buss. 1995. "Economic Analysis of Production Bottlenecks." *Mathematical Problems in Engineering* 1 (4): 341–63. https://doi.org/10.1155/S1024123X95000202.

"Low Cost Carriers - ICAO." n.d. ICAO. Accessed January 16, 2019. https://www.icao.int/sustainability/Pages/Low-Cost-Carriers.aspx.

Lowhorn, Greg L. 2007. "Qualitative and Quantitative Research: How to Choose the Best Design." *Paper Presented at the Academic Business World International Conference*, no. 2003: 1–5.

Marsh, Nigel, and David Calder. 2018. "Study on Reducing Security Threats by Optimising Passenger Flow Background : Scope :" *O&i Consulting*.

Martin, Christopher. 2011. *Logistics & Supply Chain Management*. *Communications of the ACM*. https://doi.org/10.1007/s12146-007-0019-8.

Meltzer, Matt. 2015. "A Brief History of Airport Security." 2015. https://www.thrillist.com/travel/nation/why-do-we-have-to-take-our-shoes-off-at-airport-security-history-of-the-tsa?fbclid=IwAR2NkvOL8XFr5bXYdGmATcnBwR54iCcmvxZvMrTNvQTlOIENRVnX3BV-sIY.

Morpace International., Cambridge Systematics., National Research Council (U.S.). Transportation Research Board., Transit Development Corporation., and Transit Cooperative Research Program. 1999. *A Handbook for Measuring Customer Satisfaction and Service Quality*. National Academy Press. https://books.google.no/books?id=KITwr9GxTSMC&pg=PP5&dq=what+is+customer+satisfaction&hl=no&sa=X&ved=0ahUKEwjB-9Hq34biAhXq-SoKHVgOBLYQ6wEIVTAF#v=onepage&q=defining&f=false.

"New Passenger Scanner Uses Space Technology to Speed up Airport Security." 2018. Phys Org. 2018. https://phys.org/news/2018-12-passenger-scanner-space-technology-airport.html.

Newman, Isadore., and Carolyn R. Benz. 1998. *Qualitative-Quantitative Research Methodology : Exploring the Interactive Continuum*. Southern Illinois University Press. https://books.google.no/books?hl=no&lr=&id=xumf1ABFz8cC&oi=fnd&pg=PR9&dq=newman+benz+1998+qualitative+quantitative&ots=NF2BIZHHVH&sig=GXCCO1tENgoMuooeUNZMp_NQ4jQ&redir_esc=y#v=onepage&q=newman benz 1998 qualitative quantitative&f=false.

Nokas. n.d. "Flyplass." Accessed April 3, 2019. https://www.nokas.no/produkter/flyplass/.

Nowacki, Gabriel, and Bohdan Paszukow. 2018. "Security Requirements for New Threats at International Airports." *TransNav, the International Journal on Marine Navigation and Safety of Sea Transportation* 12 (1): 187–92. https://doi.org/10.12716/1001.12.01.22.

"Oslo Airport Terminal 2 - Airport Technology." n.d. Airport Technology. Accessed January 18, 2019. https://www.airport-technology.com/projects/oslo-airport-terminal-2/.

Pearce, Brian. n.d. “The Shape of Air Travel Markets over the next 20 Years Chief Economist.” Accessed January 29, 2019. www.iata.org/pax-forecast.

Pring-Mill, David. 2018. “It’s Time For an Airport Security Tech Upgrade.” https://singularityhub.com/2018/11/21/its-time-for-an-airport-security-tech-upgrade/#sm.00002r70y613nmd1dxkdy4u7e3k7x.

Regjeringen. 2006. “Securityforordningen, Sivil Luftfart,” January. https://www.regjeringen.no/no/sub/eos-notatbasen/notatene/2006/jan/securityforordningen-sivil-luftfart/id2431139/.

Ryen, Anne. 2002. *Det Kvalitative Intervjuet. Fra Vitenskapsteori Til Feltarbeid*. Bergen: Fagbokforlaget.

Scanna. 2019. “People Screening Archives - Scanna X-Ray Systems UK.” 2019. https://www.scanna-msc.com/uk/shop/category/people-screening/.

Senguttuvan, P. S. 2007. *Principles of Airport Economics*. Excel Books. https://books.google.no/books?id=oQN4SZSbBsoC&pg=PA314&dq=airport+customer+satisfaction+factors&hl=no&sa=X&ved=0ahUKEwib8_D94obiAhWLmIsKHZujBY8Q6AEIKTAA#v=onepage&q=customer satisfaction factors&f=false.

Sztrik, János. 2012. “Basic Queueing Theory.” Budapest. https://irh.inf.unideb.hu/~jsztrik/education/16/SOR_Main_Angol.pdf.

Teichert, Thorsten, Edlira Shehu, and Iwan von Wartburg. 2008. “Customer Segmentation Revisited: The Case of the Airline Industry.” *Transportation Research Part A: Policy and Practice* 42 (1): 227–42. https://doi.org/10.1016/j.tra.2007.08.003.

“The Ultimate Guide to TSA Pre-Check | LoungeBuddy.” 2018. 2018. https://www.loungebuddy.com/blog/tsa-pre-check-ultimate-guide/.

Thune-Larsen, Harald, and Eivind Farstad. 2016. “International and Domestic Air Travel in Norway 2015.” www.toi.no.

“Ticket Options, KLM.” n.d. Accessed January 17, 2019. https://www.klm.com/travel/nl_en/plan_and_book/ticket_information/ticket_options/index.htm.

Transportation Security Administration. 2017. “TSA -- [ About TSA ].” 2017. http://www.tsacarriers.org/about.html.

Vasel, Kathryn. 2016. “Who’s to Blame for the Long Airport Security Lines?,” 2016. https://money.cnn.com/2016/05/18/pf/blame-for-airport-security-lines/index.html.

Waage, Thor Erik. 2015. “SAS Legger Ned Houston-Ruten Fra Sola - Rogalandsavis.” 2015. https://www.dagsavisen.no/rogalandsavis/sas-legger-ned-houston-ruten-fra-sola-

1.499408.

Wang, Yongcai, Qianchuan Zhao, and Dazhong Zheng. 2006. “Bottlenecks in Production Networks: An Overview.” *Journal of Systems Science and Systems Engineering* 14 (3): 347–63. https://doi.org/10.1007/s11518-006-0198-3.

Wei, Jianan. 2017. “Optimization of Airport Security Process.” *AIP Conference Proceedings* 1839. https://doi.org/10.1063/1.4982519.

“WHO | Summary of SARS and Air Travel.” 2003. *WHO*. https://www.who.int/csr/sars/travel/airtravel/en/.

Wilkinson, Christer J., and Art Kosatka. 2017. “Airport Security System Standards Development: Challenges and Outcomes.” *Proceedings - International Carnahan Conference on Security Technology*, 1–6. https://doi.org/10.1109/CCST.2016.7815716.

Xu, Xiangqian, Zhexuan Zhou, Yajie Dou, Yuejin Tan, Tianjun Liao, Xiangqian Xu, Zhexuan Zhou, Yajie Dou, Yuejin Tan, and Tianjun Liao. 2018. “Sustainable Queuing-Network Design for Airport Security Based on the Monte Carlo Method.” *Sustainability* 10 (2): 1. https://doi.org/10.3390/su10020001.

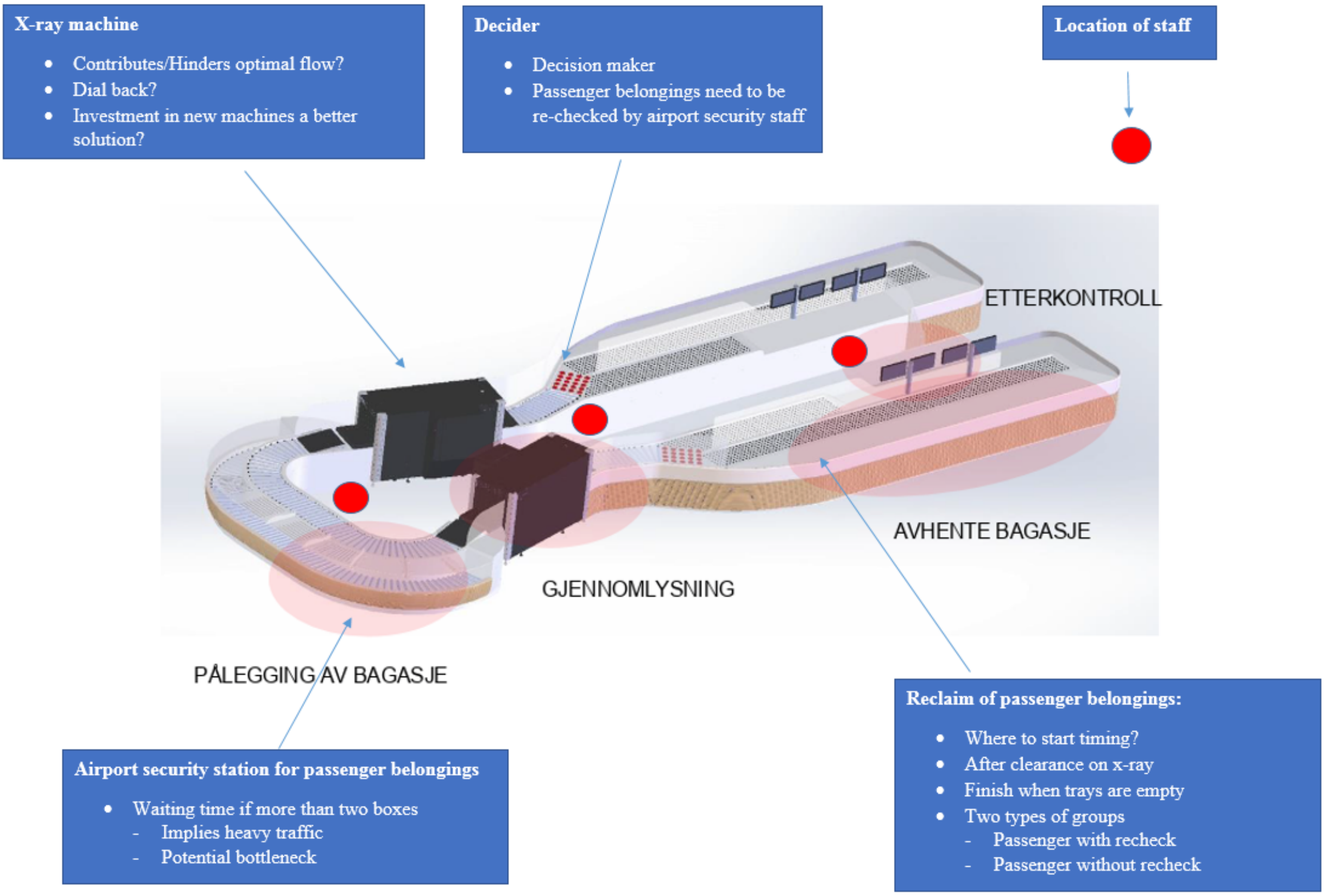
Yilmaz, Kaya. 2013. “Comparison of Quantitative and Qualitative Research Traditions: Epistemological, Theoretical, and Methodological Differences.” https://pdfs.semanticscholar.org/f45f/993702833849749b3ddd83e1673728d569eb.pdf.

Yin, Robert K. 1984. “Case Study Research and Applications: Design and Methods.” *Sage Publications*. https://doi.org/10.1016/j.jada.2010.09.005.

———. 2016. *Qualitative Research from Start to Finish Second Edition*. *THE GUILFORD PRESS*. https://doi.org/10.1007/s13398-014-0173-7.2.

# Appendix 1

Representation of the Airport security checkpoint at OSL



# Appendix 2

A representation of the numbers for passengers using both the regular and fast track lane at OSL.

| FAST TRACK – BOTH MALES AND FEMALES | | REGULAR LANE – BOTH MALES AND FEMALES | |
|---|---|---|---|
| AVERAGE NUMBER OF TRAYS | 2,22 | AVERAGE NUMBER OF TRAYS | 2,20 |
| AVERAGE DIVEST TIME | 45,95 | AVERAGE DIVEST TIME | 52,43 |
| AVERAGE RECLAIM TIME | 98,86 | AVERAGE RECLAIM TIME | 94,18 |
| FAST TRACK - CATEGORY | | REGULAR LANE - CATEGORY | |
| AVERAGE NUMBER OF TRAYS | | AVERAGE NUMBER OF TRAYS | |
| MALE | 2,31 | MALE | 2,38 |
| FEMALE | 2,10 | FEMALE | 2,00 |
| AVERAGE DIVEST TIME | | AVERAGE DIVEST TIME | |
| MALE | 49,16 | MALE | 56,90 |
| FEMALE | 41,62 | FEMALE | 47,34 |
| AVERAGE RECLAIM TIME | | AVERAGE RECLAIM TIME | |
| MALE | 88,03 | MALE | 95,40 |
| FEMALE | 113,14 | FEMALE | 92,69 |
| AVERAGE DIVEST AND RECLAIM TIME | | AVERAGE DIVEST AND RECLAIM TIME | |
| MALE | 137,20 | MALE | 152,30 |
| FEMALE | 154,76 | FEMALE | 140,03 |
| AVERAGE INSPECTION TIME – BOTH MALE AND FEMALE | | | |
| 63,88 | | | |

# Appendix 3

A representation of the numbers for passengers using both the regular and fast track lane at SVG.

| FAST TRACK – BOTH MALES AND FEMALES | | REGULAR LANE – BOTH MALES AND FEMALES | |
|---|---|---|---|
| AVERAGE NUMBER OF TRAYS | 1,94 | AVERAGE NUMBER OF TRAYS | 1,77 |
| AVERAGE DIVEST TIME | 28,14 | AVERAGE DIVEST TIME | 22,69 |
| AVERAGE RECLAIM TIME | 59,73 | AVERAGE RECLAIM TIME | 70,12 |
| FAST TRACK - CATEGORY | | REGULAR LANE - CATEGORY | |
| AVERAGE NUMBER OF TRAYS | | AVERAGE NUMBER OF TRAYS | |
| MALE | 2,08 | MALE | 1,80 |
| FEMALE | 1,60 | FEMALE | 1,72 |
| AVERAGE DIVEST TIME | | AVERAGE DIVEST TIME | |
| MALE | 28,52 | MALE | 23,12 |
| FEMALE | 27,20 | FEMALE | 22,07 |
| AVERAGE RECLAIM TIME | | AVERAGE RECLAIM TIME | |
| MALE | 62,17 | MALE | 83,21 |
| FEMALE | 51,71 | FEMALE | 52,36 |
| AVERAGE DIVEST AND RECLAIM TIME | | AVERAGE DIVEST AND RECLAIM TIME | |
| MALE | 90,69 | MALE | 106,33 |
| FEMALE | 78,91 | FEMALE | 74,43 |
| AVERAGE INSPECTION TIME – BOTH MALE AND FEMALE | | | |
| 92,31 | | | |