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# Competitiveness of train and airport express bus between the city of Trondheim and Trondheim Airport, Værnes

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Abstract:

In order to develop a better transportation corridor between the city of Trondheim and the town of Steinkjer in Sør-Trøndelag county, Norway a number of infrastructure investments will be made. Among them a double track railway will be built between Trondheim Central Station and Trondheim Airport, Værnes. The new railway infrastructure between the city center and the airport together with enhanced NSB's (Norwegian State Railways') service is going to improve the ground access at Værnes Airport significantly, even though two major airport express bus services are well established in the city.

The goal of this study was, thus, to examine how big market share of the airport ground access will the new train service have on the route the city of Trondheim-Værnes Airport compared to the airport express buses. The investigated hypothesis was, if the train service would actually have such big market as NSB's forecast predicts. In addition, the main factors lowering the attractiveness of today's and future train service were found.

A literature review was conducted to gather existing knowledge about factors influencing modal split in airport ground access and how it is changed when new transportation services are introduced. Knowledge on different survey technics, especially stated-preference survey, was also obtained. Next, a stated-preference survey with conjoint analysis was conducted among passengers at Værnes Airport in order to obtain the basis for a utility function describing the transportation modes (train and bus) on this route in relation to each other. The respondents were tasked to choose either the train or the airport express bus in several hypothetical situations regarding a trip between the city of Trondheim and Værnes Airport, while different attributes (travel time onboard, ticket price, departure frequency) of the train service were changing. The results were then analyzed in SPSS program and were used (binary logistic regression was performed) to build utility function for the train service in relation to the airport express buses (the service offered by both buses are very similar to each other and were regarded as one service). Probability values were also obtained by assuming several different cases. In addition, several multiple choice questions helped to investigate why the train service available today has so low market share, and what can be done in the future to address this issue.

Keywords:

- |                          |
|--------------------------|
| 1. Airport ground access |
| 2. Modal split           |
| 3. Train                 |
| 4. Bus                   |



## Preface

This report is a result of the master thesis of the fifth year student of civil and environmental engineering (transportation specialization) at NTNU Szymon Adamski. This master thesis is divided into two parts. Part I is a process report, consisting of 15 main chapters. The process report was not intended to describe the study and the production of scientific publications, but to present the research process itself, the challenges that were encountered by the author of the report on his way during the period in which the work was produced and the learning outcome from the whole process. Part II is a scientific article, presenting and discussing the most important findings of this research. Some parts of the scientific article are also included in the process report, in order to achieve a coherence in both Part I and Part II. The attachments are placed at the end of this work. The study had two supervisors, Eirin O. Ryeng as the main supervisor and Trude Tørset as co-supervisor.

The author of this report was a student of the fifth year of civil and environmental engineering at the Norwegian University of Science and Technology in Trondheim, Norway. The author's specialization was transportation engineering, consisting of a number of subjects related to planning, designing and building of road and rail infrastructure and planning the activity of transportation, including traffic flow and urban planning. In addition to that, the author had finished courses related to railway technology, including the advanced course. The author's personal interest and his previous knowledge gained in the course of studies led him to focus on the subject, which also connects the issues of transportation and railways. The intent was to find a thesis topic, which would treat about rail transportation (but not about railway technology), preferably in relation to other means of transportation.

The master thesis was preceded by the so-called project report, produced during the previous semester – fall 2015. The supervisor for this part of the study was Trude Tørset, who then became the co-supervisor for the following master thesis. The project report presented and introduced to the subject of the master thesis. In the report one could find information on the planned modernization of the railway line between Trondheim City Center and Værnes Airport, the current modal split between Trondheim and the airport and a description of the analysis of the future modal split in Trondheim and its surroundings, carried out by the NSB (Norwegian State Railways). In addition, the test method (surveys with a stated-preference game) has been thoroughly described and its significant advantages and disadvantages were presented. An important part of the project report was a preliminary version of the questionnaire, which was later used for data collection, and a preliminary time schedule for the whole research process. As it turned out, both the schedule and the preliminary version of the questionnaire had to be significantly modified after completion of the project report.

The study was conducted in cooperation with NSB, which were interested in the research's results. Both the Trondheim and Oslo department were engaged in the work. NSB's representatives from Oslo, Erlend Dysvik, senior analyst and Ida Rossvoll Hanssen, transportation analyst/data administration from NSB Oslo, assisted with many useful suggestions during the questionnaire design process. On the other hand Hylde Lyng, sale - and marketing manager from NSB Trondheim helped a lot with practical aspects of the research, such as obtaining contact information to different decision makers at various institutions or providing free train tickets for the interviewers who conducted the survey at Værnes Airport.

The author would like to thank his supervisor Eirin O. Ryeng and co-supervisor Trude Tørset. Both ladies have given close supervision and contributed to progress and motivation throughout the whole research process. They have also given positive feedback, both in terms of academic and formal requirements for the process report and the scientific article. Thanks go also to Erlend Dysvik, Ida R. Hanssen and Hylde Lyng from NSB for helping with issues described above, and to Kristin H. Sørnes for giving the permission to conduct the data collection among passengers at Værnes Airport.



## Summary

In order to develop a better transportation corridor between the city of Trondheim and the town of Steinkjer in Sør-Trøndelag county, Norway a number of infrastructure investments are going to be made. Among them a double track railway is planned to be built between Trondheim Central Station and Trondheim Airport, Værnes. The new railway infrastructure between the City Center and the airport together with enhanced Norwegian State Railways' service is going to improve the ground access to Værnes Airport significantly, even though two major airport express bus services are well established in the city. This master thesis aimed to examine the future competitiveness between the new train service and the airport express bus service, that is how the new train service is going to influence the modal split when accessing Værnes Airport. The examined hypothesis was if the train's modal share after introducing the new service will be much higher than it is today, as it had been forecasted by NSB (NSB), and how much higher it possibly may be. In addition, an attempt to find the main factors lowering the local train service's attractiveness was made.

Only competitiveness between train and airport express bus was examined. Due to the similarities (fixed onboard travel time, departure times and monetary travel cost) between these two transportation services, car and other transportation modes were excluded from the research. The study focused thus only on the relationship between the two most popular public transportation modes when accessing Værnes Airport.

First, a literature review regarding ground access modal split to various airports in the world and how it changes when new transportation services was conducted. In addition other factors that influence modal split were a focus of the literature study. A particular focus was put on today's ground access modal split to Værnes Airport, factors influencing choosing public transportation services when accessing Værnes and other airports in Norway. Secondly, a questionnaire used to collect data from passengers at Værnes Airport was designed. The central part of the survey was a stated-preference game, where the respondents were asked to choose between train and bus in eight hypothetical situations related to a trip from Værnes Airport to Trondheim. In those situations the attributes of the hypothetical train trip (onboard travel time, departure frequency and ticket price) varied, whilst the attributes of the bus service stayed unchanged and were identical with today's values. In addition to the stated-preference game, the questionnaire consisted of several multiple choice questions investigating the respondents' background and their opinion on today's train service. Finally, possible reasons for not wanting to choose the train service in the hypothetical situations were surveyed. After the stated-preference interviews were conducted, the collected data was analyzed. The analyses used, were binary logistic regression and frequency analysis.

Based on the study, several utility models were made to calculate the utility of choosing the bus and the train service. Based on the models an approximated train's modal share (probability for choosing train) depending on different variables when accessing the airport was found. The results were positive for the train, meaning that the train service would most probably take over many passenger from the airport express bus, as the probability for choosing train was found to be much higher in the future than it is now. In addition the major factors and variables influencing choice of the train service in this particular area were discovered and discussed.



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**PART I**  
**PROCESS REPORT**



# 1. Introduction

The subject of the thesis was the competitiveness of train and airport express bus between the city of Trondheim and Trondheim Airport, Værnes. The aim of this study was an attempt to examine the train service's attractiveness today and after the construction of the double track between Trondheim Sentralstasjon (Trondheim Central Station) and Stjørdal (a town right by Værnes Airport). Attractiveness of the train service to the airport was defined as the number of travelers compared to other means of transportation, which provided transportation services along the same route as the train. On the basis of the number of passengers who would use the train service it may be concluded afterwards how useful the development could be for the coverage of the local community's transportation needs. The share of passengers who would choose other means of transportation after changing the train service's properties was the main aspect to research. As the bus service will most probably be unchanged in the future, the only option is to improve the train service, which would result in the transfer of part of the users of the bus to the train. This was accomplished by using a stated-preference survey, where different abilities of the two means of transportation were presented and varied in several combinations. Respondents were then tasked to select the alternative that he/she found most attractive. This survey gave later an input for a utility function in a logit model, that illustrated mathematically the benefit observed in selecting the specific means of transportation. The study's results were obtained through surveys conducted among passengers at Værnes Airport. The results were then analyzed using a specialized program, and several utility functions were constructed.

This report is build up chronologically. This means that the issues describe in this work happened in the sequence as they are presented in this report. In the beginning the major happenings were described, starting with a description of the work done during fall 2015. The following activities, such as finishing the survey, testing it and finally, data collection were presented. Afterwards the data analysis together with the obtained results were described. The report ends with a description of the learning outcome from the whole research process and a process evaluation. Table 1 presents the content of the process report in a brief form:

The content of the process report	
Chapter	Content
1. Introduction	Introduction to the report and the study's topic.
2. The study's scope	The scope of the conducted study is shortly presented.
3. Fall 2015	The work related to this study done during fall 2015 is described.
4. Work on the survey	The design process of the survey used in the study is described. The content and amendments done to the first version of the questionnaire are presented.
5. The first survey test	The first test of the second version of the questionnaire.
6. After the first survey test	Description of events that happened after the first survey test. Challenges related to the data collection are also presented.
7. The final survey test	The second (final) test of the second version of the questionnaire.
8. Meeting with NSB after the final survey test	Consulting on the survey's content with NSB and the amendments done to the second version of the questionnaire are described.
9. Preparation of the plan B	The process of preparation of the plan B for data collection, it's content and the reason why it may have been needed are presented.
10. Data collection	The process of collecting data from passengers at Værnes Airport is described.
11. Preparation of the budget	The process of preparation of the study's budget together with the reason for why it was done so late is presented.
12. Result analysis	Description of how the data set was analyzed, what methods and tools were used.
13. Obtaining results	The obtained results (the utility models and the results of the frequency analyses) are presented and commented on.
14. Learning outcome	Different experiences gained during the process of working on the study are described.
15. Process evaluation	The evaluation of the whole research process together with a brief description of the limitations when working on the study.

Table 1: The content of the process report

To give a clear overview over the course of the whole research process, a short summary in form of a table was made. Table 2 shows when the different activities described in the process report took place:

Period	Activity
Fall 2015	Literature study
	Clarification of the study's scope
	Preliminary survey design
January and February	Survey design
26th of January	The first survey test
15th - 17th of February	The final survey test
Second half of February	Preparation of the plan B
1th - 18th of March	Data collection
First half of March	Preparation of the budget
Second half of April	Preliminary data analysis
May	Final data analysis and report writing

Table 2: Course of the research process

## 2. The study's scope

Several scientific papers (some of them presented in the scientific article, which is supplementary to the process report) present various research on modal split to and from various airports in the world and how passengers' travel behavior changes when a new transportation infrastructure, which changes the available transportation services, is introduced. Because of the big future changes in the railway infrastructure in the corridor between the city of Trondheim and Værnes Airport it was decided that a similar research would supply much useful information for both the local transportation authorities and the scientific community. Different similarities and/or differences between the foreign results were planned to be found and discussed.

*The aim of this study was an attempt to examine the future competitiveness between the new train service and the airport express bus service, that is how big share of the passengers the new train service would be able to take over from the airport express bus service. The examined hypothesis was if the train's modal share after introducing the new service would be much higher than it is today, as it had been forecasted by NSB (NSB), and how much higher it possibly may be. In addition, an attempt to find the main factors lowering the local train service's attractiveness was made.* This study is supplementary to NSB's research, in the way that this work's results are backed up by data collected among passengers, while NSB's forecast was based on only a computer model. In addition to that, several correlations between passengers' choices, their background and opinions were planned to be discovered. The plan was to check what kind of factors influence the passengers' transportation mode choices when travelling to/from Værnes Airport and possibly compare the findings with the accessible scientific literature in this field.

### 3. Fall 2015

As already mentioned in the preface, the work on this project had started in fall 2015. The work during that semester consisted mainly of clarification of the research's scope (presented in chapter 3), literature study and preliminary design of the questionnaire, although other things were also discussed. The work was topped by a project report, where the results and the activities related to the study were presented.

The literature study conducted during the fall consisted of finding and investigating relevant studies from different countries, preferably Norway and other European areas. Although no analogous studies to this one were found, several papers on related topics were found and presented in the project report. Results from those works helped to understand how such research is conducted and what kind of phenomena can be investigated by collecting data from passengers. In some cases the results obtained from this research were compared with the results found in the papers to find any possible similarities or differences and possibly explain them. The majority of the works investigated during the fall were used as sources in the process report and the scientific article. An important part of the literature study was investigating NSB's modal split forecast on route Trondheim-Stjørdal (NSB). It was found that the new train service would dominate the modal split in this section (very high train's modal share). At the same time it was shown that a significant part of the new passengers using the train would come from today's bus service.

In addition to the multiple choice questions about the respondents' background and their opinion on today's train service, the central part of the survey had to be determined. During the fall semester it was decided to use stated-preference survey (experimental, orthogonal, full-factor design with conjoint analysis) as the key method in the study. Different advantages and disadvantages were found, examined and described. The description was followed by a discussion whether this method was actually suitable for the study. The preliminary questionnaire was tested at the end of the semester among few people in order to check if the questions were easy to understand and answer, and at the same time if the survey's extent was not too high.

An analogous process was done when the data collection was investigated. The project report included both presentation of different data collection methods, together with their advantages and disadvantages. Finally, the method of distributing questionnaires was found to be most effective. Simultaneously, the practical aspects of the data collection were described, such as the time frame, places where it was planned to take place and the number of filled questionnaires which was planned to be collected.

Data analysis was also planned and described during the fall. It was decided to use SPSS program or some other similar digital tool to create utility models based on the answers obtained from the respondents. The utility models were then planned to be used to produce several probability values for choosing the train service under different circumstances, although it was not decided back then what kind of situations it would be. This question was let to be open until the data analysis itself was begun.

After starting the new semester it turned out that the supervisor for the study would be changed. Trude Tørset, who had been the main supervisor up to that point was replaced by Eirin Ryeng. Trude Tørset became then the co-supervisor for the study.

## 4. Work on the survey

### 4.1 The first version of the questionnaire

The first stage of work on the master thesis was the completion of the survey presented in the project report delivered in the fall (Appendix 1). Because of time shortage during the fall semester, the survey had to be drafted in January. The questionnaire developed during the fall has been attached to the project report as an appendix. The survey design was an effect of my work, which I consulted with NSB and Eirin Ryeng to a small extent. The first version of the questionnaire, like its final version, contained a number of multiple choice questions describing the respondent's background, which contained i.a. questions about gender, age, type of travel (leisure or business trip), the final destination or the origin of the trip and preferences concerning traveling to the airport (Appendix 1, questions 1-9). It is important to note that the survey did not actually make a distinction between the direction in which the respondent was traveling. The first version of the survey treated journeys to and from the airport as a kind of mirror reflections, which meant it treated them in the same way.

Next, the questionnaire presented a stated-preference game, where the respondents were asked to select one of the two available means of transportation to or from the airport (Appendix 1, question 10). In this part eight different situations were shown, where the respondent could only choose between train and bus. The difference between these eight situations were based on the fact that the attributes of the train service were different in different situations. Only three factors were included in the study, i.e. onboard travel time, departure frequency and ticket price. So low number of variables was chosen due to that the tasks in stated-preference surveys should not be too complex. The answers can be unreliable if more than 2-3 variables vary at once (Ryeng 1998: 18). It was therefore necessary to limit the extent of the research. The three factors chosen for the study are called heavy factors, since they are what passengers put the greatest emphasis on when choosing means of transportation. It is important to note that only the attributed of train trip were changed, the bus trip was exactly the same in each situation. The train service had three factors, while each factor had two levels (high and low). This gave eight different options (2<sup>3</sup>). The train tip's attributes were based on Jernbaneverket's (Norwegian National Rail Administration) train schedule predictions (JBV 2013: 13) after building the new railway line, while the attributes of the bus trip were based on today's service quality. Other variables, such as comfort, punctuality and the possible need to change to other transportation mode during the trip were not taken into account. The questions related only to travel between the airport and Trondheim Sentralstasjon (Trondheim Central Station) (Figure 1), and the respondent was tasked only to indicate which means of transportation (bus or train) he/she chooses given the circumstances. This meant that if the respondent was traveling with another means of transportation or was travelling to a different location than Trondheim Sentralstasjon, the respondent had to imagine a very hypothetical situation for him. The advantage was that the survey was very simple, and the results would be easy to be interpreted and analyzed. However those strongly hypothetical choices would give an uncertain basis for drawing conclusions on the future mode choice for airport trips in the city.

At the end of the survey questions about the reasons for which the respondent did not wish to travel by train and another hypothetical question were asked. Respondents had to answer, how likely it was that they decided to travel by bus to the train station to take the train to the airport after introducing the new train service, if they lived outside the City Center. The answer, that the respondent could give was "very likely," "more likely," "unlikely," "improbable" and "do not know" (Appendix 1, question 12). The last question asked about the reasons, that make the respondent skeptical towards taking train from Værnes to Trondheim Sentralstasjon and then switch to another means of transportation. The available options to choose from were i.a. that Trondheim Sentralstasjon lay too far away from the respondent's final destination, the train's departure frequency was too low and the city buses' departure frequency was too low (Appendix 1, question 13).

A small survey test before delivering the project report showed that filling out the survey took from 4 to about 6 minutes. The entire survey consisted of 13 questions, where the stated-preference game counted as one question.

#### 4.2 Amendments to the first version of the questionnaire

Based on a thorough review of the first version of the survey and its purpose, it was decided to implement a number of amendments. Some questions have been changed, some removed completely, or replaced with other. Most of the questions at the beginning of the survey remained unchanged. The survey was divided into three parts, according to its content. In the first part questions on the respondent's background were asked. Those (questions about gender, age, type of travel (business or leisure trip), number of items checked in at the airport, final destination or origin of the trip, means of transportation used on the trip and reasons why the person chose the train (if the respondent did) or why not (if the respondent did not)) remained in large part unchanged. Only minor amendments to the possible selection of responses to the question were applied, so that the survey was clearer and more universal (e. g. conversion „koffert” to „kollit”, (Appendix 2, question 4)) or to take into account the most important answers (adding Gløshaugen as the destination or origin of the trip in (Appendix 2, question 5)). For this part the question about the direction of travel was added. Since then, the respondent had to specify which way (to or from Trondheim) was he/she going. Quite a change was also not including the respondents, who answered that the train as a means of transportation to the airport was not relevant for them in Part 2 of the survey (the stated-preference game) and in the question about ranking the various airport ground access trip properties from most important to least important (Appendix 2, question 9).

The stated-preference game itself has not been changed very much. The main change was an different layout of the content of the question, so that it was clear and understandable for the respondent (adding pictures showing train and bus, and putting a frame around each hypothetical situation). More answer options we also added to the questions. In the second version of the survey the respondents had more choice options, which took into account their indecision when choosing means of transportation in the hypothetical situations. In the second version of the questionnaire the answer alternatives consisted of four options: certainly train, probably train, probably bus and certainly bus. When analyzing the responses from the stated-preference game, the responses "certainly train" and "probably train" were simplified to just „train” and were treated equally. The other two answer options were treated similarly. The greater variation of possible responses had a purpose of making the answering to the questions easier and avoiding random and hasty responses.

The biggest change in the survey was the extension of Part 3 (questions after the stated-preference game) with new questions. To better identify the entire route, which the respondent was taking on the way to or from the airport, a multiple choice question about the distance (in minutes of travelling regardless the transportation mode) from the nearest stop for a bus going to the airport was added. The respondent had to answer how far according to him, the nearest bus stop was from the origin or the destination of the trip (Appendix 2, question 11). A precise knowledge was not required from the respondent. Another new question asked about how long it would have taken to travel between Trondheim Sentralstasjon and the origin or destination of the trip (Appendix 2, question 12). This question had a goal to identify how far the respondent would have to travel after choosing the train from the airport to the city. The question about probability of choosing the train, and then interchanging to a city bus has been removed, as it has been partially included in the stated-preference game. On the other hand, the question about the reasons for which the respondent was not willing to travel by train was limited to respondents who had stated that the train was not relevant means of transportation and to those who had not chosen a train in any of the hypothetical situations in the stated-preference game. At the end, an open question was added about the possible things or

conclusions that were not covered in the survey, but are important to the respondent (Appendix 2, question 14).

The amendments done to the first version of the questionnaire are summarized in Table 3:

Amendments done to the first version of the questionnaire		
Part	Change	Reason
	The questionnaire divided into three parts: 1. Background questions 2. Stated-preference game 3. Additional questions after the stated-preference game	To achieve better layout and readability
Part 1	A multiple choice question about the direction of travel added	To distinguish trips made to and from the airport
	Question 4: the word "baggasje" changed to "kolli"	To make the question more flexible
	Question 5: "Lerkendal, Singsaker, Berg, Nardo, Tempe" changed to "o Gløshaugen, Lerkendal, Singsaker, Berg, Nardo, Tempe"	To include an important trip attractive place
	Question 9: respondents answering that the train is not relevant for them in question 8 excluded from answering the question	To include only the respondents who would participate in the stated-preference game
Part 2	Respondents answering that the train is not relevant for them in question 8 excluded from the stated preference game	To exclude respondents whose choices in the stated-preference game would be known in advance
	Pictures showing train and bus added, a frame around each hypothetical situation put	To achieve better layout and readability
	Answer options "certainly train", "probably train", "probably bus" and "certainly bus" instead of "train" and "bus"	To make answering the question easier
Part 3	Question 12 removed from the questionnaire	The question was indirectly included in Part 2
	A multiple choice question (now question 12) about the travel time to/from the nearest airport bus stop added	To map the hypothetical egress time when travelling by bus
	A multiple choice question (now question 13) about the travel time to/from Trondheim Sentralstasjon added	To map the hypothetical egress time when travelling by train
	Question 14 (previously 13) limited to respondents who had stated that the train was not relevant for them and to those who had not chosen a train in any of the hypothetical situations in Part 2	To map the reasons why the train service is perceived to be unattractive
	An open question (now question 15) about the possible things or conclusions that were not covered in the survey, but were important to the respondent added	To give the respondents a possibility to give feedback

Table 3: The amendments done to the first version of the questionnaire

## 5. The first survey test

After making the amendments the second version of the survey was pre-tested on a group of 22 consisting of master students and professors. The test was held on 26<sup>th</sup> of January. The test was an opportunity to pre-test the questionnaire in terms of comprehensibility of questions, the length of the questionnaire and the possible things that were not included in the survey, and according to the test subjects should be included in it. The time that was needed to complete the survey was also tested. Most people needed about 8 minutes to answer all the questions. Some people filled out the survey in about 5 minutes, while it took up to 10 minutes for others. It was much longer time than about 4 minutes needed to complete the questionnaire prepared during the fall (the first version of the questionnaire). The first version of the survey was much shorter, thus filling it took much less time. On the other hand, there were no negative comments on the length of the survey. Despite of the fact that the original survey was related to the trip the respondents were undertaking in the moment of

answering the questions, the questions in the copies the respondents received at the test were related to their last trip to/from Værnes Airport, since the test was held at NTNU Gløshaugen.

Generally it could be concluded that the survey test was successful. The number of questions related to filling out the survey asked by the participants during the test was low. The asked questions concerned mainly the way in which they had to answer the questions included in the survey. These questions were mainly due to inaccurate reading of the content of the questions, which contained all the necessary instructions on how to answer them. For example, questions where the respondent could select more than one answer contained an adequate information about that. It showed that the respondents quite often did not read precisely the content of the questions in the survey. This gave an indication that perhaps the surveys should be conducted personally, instead of handing out the questionnaires to the respondents, so that they filled them out by themselves. The final test of this method was planned to be carried out later in the final test of the survey at Værnes Airport.

The survey results, especially the results of the stated-preference game were roughly in line with previous expectations. A large majority of respondents did not use the train last time they travelled to/from the airport. The majority chose either a bus or a car, or a combination of these two. Simultaneously, a large majority of the respondents did not choose the train to the airport as the optimal means of transportation in the stated-preference game. Very often, it was also the case when the train service was much better than the bus service (lower ticket price and shorter onboard travel time). The main arguments for not choosing the train service were difficult access to the train station and poor connections to other means of transportation (e.g. city buses) at Trondheim Sentralstasjon. It confirmed clearly the previous predictions that these were the main reasons why passengers do not use and will not use the train service willingly, even if the train trip itself gets more attractive.

Still, there were some respondents who would choose to use the train. These individuals argued that the train to the airport would be a cheap and quick alternative. Better adaptation of train departures to plane arrivals and departures (that is higher departure frequency) and discount on city buses when continuing the trip were also mentioned as things that would increase the attractiveness of train service even more.

## 6. After the first survey test

After the successful first test of the survey it was necessary to get permission to carry out the final test and the data collection in the most relevant places. The intention was to carry out surveys at Trondheim Sentralstasjon, on board Flybussen (Værnesekspresen was excluded for this reason, that it had a similar route as Flybussen, but it had a much lower frequency) and at Værnes Airport itself.

Obtaining the permission from Jernbaneverket (the owner and manager of Trondheim Sentralstasjon) was not a problem. The permission for data collection was obtained via e-mail, and the only condition for receiving it was to share the final results of the study with Jernbaneverket.

Flybussen, on the other hand, was not willing to cooperate. When an email was sent to the company's e-mail contact address, the message was forwarded to two other employees of the company, asking if they could reply to it. After more than a week later another e-mail was sent (this time directly to one of the persons to whom the first mail was forwarded). A short reply was then received that Flybussen was not interested in cooperating in the research. The second version of the survey which was supposed to be used in the test was sent in the attachment, so that the decision makers at Flybussen could get familiar with its content.

A contact information for a decision maker at Avinor (the owner and manager of Værnes Airport) was also received. After sending the second version of the survey, Kristin H. Sørnes from Avinor responded that in February Avinor carried out its own survey among passengers at the airport. Therefore, it was not possible to carry out a survey among passengers in February. It was attempted to find out if it would be possible to carry out data collection in March, before the Easter break. No answer was received before the final survey test described in chapter 7 was carried out.

## 7. The final survey test

Lack of permission for carrying out the final test of the survey at the airport led to concerns that further delays in testing the survey may adversely affect the further research process. Conducting the test not until March would lead to the fact that data collection would end up probably until the end of April. As it was needed more time to analyze the data set and present the research results in the form of a report, it would have been too risky. An alternative variant was selected, which was to carry out the test at Trondheim Sentralstasjon, which was already permitted, and two popular Flybussen stops in Trondheim, Moholt Studentby and Studentersamfundet. This alternative allowed to carry out the test among actual train and Flybussen passengers as early as in February. Figure 1 shows location of the places where the final test was conducted.

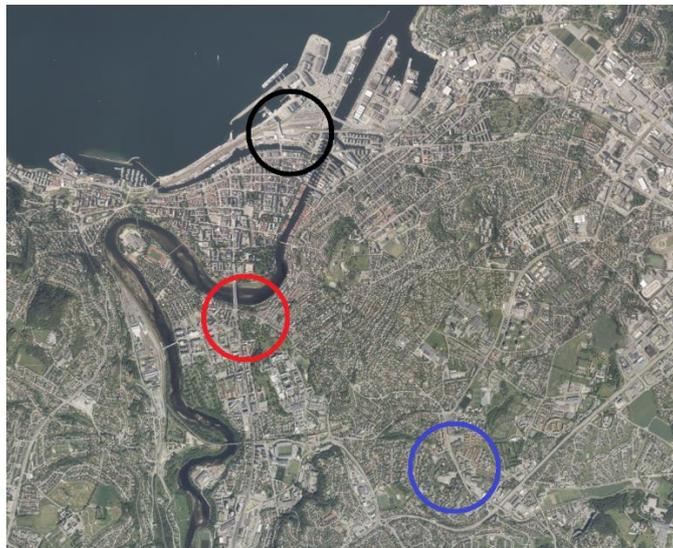


Figure 1: Location of the places, where the final survey test was conducted (black ring – Trondheim Sentralstasjon, red ring – Studentersamfundet, blue ring – Moholt Studentby)

Thanks to this solution a lot of time was spared, that was later used to analyze the results of the survey test. On the other hand, the form of the survey was not optimal for this study. The survey test included namely just train and Flybussen passengers, while passengers traveling to/from the airport by car (driver or "kiss and fly") or taxi were not included (no respondent that provided such a response was found). In addition, the study included almost only people, who started or ended their trip near the place, where the test was conducted. Most of the respondents answered that they needed about 10-15 minutes to travel the distance between the end/beginning of the trip and the place, where the survey test was conducted (Trondheim Sentralstasjon, Moholt Studentby or Studentersamfundet). The survey test did not therefore include travelers, whose trip origin or final destination lied in other districts than the City Center, Moholt and Gløshaugen.

The test was conducted on 15-17<sup>th</sup> of February, between the hours of 10 and 15. In all these days I was the only interviewer participating in the data collection. On February 15<sup>th</sup> a test at Trondheim Sentralstasjon was carried out, both among train and Flybussen passengers (Flybussen services

Trondheim Sentralstasjon). In order to diversify as much as possible an attempt was made to include more or less equal number of both Flybussen and train passengers. On February 16<sup>th</sup> a survey test was carried out at the Flybussen stop at Moholt Studentby (both at the stop towards the airport and at the stop in the opposite direction), which services the largest dormitory in Trondheim. On February 17<sup>th</sup> an analogous test was performed at the Studentersamfundet Flybussen stop, situated close to both NTNU Gløshaugen and St. Olav Hospital.

The final number of respondents was 32 people, that is 10 at Trondheim Sentralstasjon, 12 at Moholt Studentby and 10 at Studentersamfundet. The test was conducted by coming up to the passengers waiting for their means of transportation, and then asking them whether they had time to participate in a short survey about their travel behavior. High percent of travelers had unfortunately no time to participate in the survey. It was not noted how big part of the people interviewed responded to the survey, but it is estimated that it was between 10-20 %. A higher percentage of people travelling from the airport, that is getting off the train or bus was willing to participate in the survey. Therefore, most of the answers in the test were related to a trip from the airport to the city. In the beginning the test was carried out by distributing the forms and pens to the respondents. The respondents were asked to fill out a questionnaire by themselves without any help from the interviewer. It turned out after some time however, that in most cases the respondents needed assistance from the interviewer to answer the questions, especially the elderly people. During the survey test it was therefore decided, that the survey would be carried out in the form of an interview with the respondent (or two at a time), where the interviewer reads the questions from the survey to the respondent, to which he/she replies orally. The interviewer noted then the answers on paper. It has been seen that by using this method, the respondents' answers became fuller and more accurate. It turned out that the oral explanation of the questions resulted in a better understanding of its contents by the respondents. As a result, they were able to provide a more realistic response, took into account more factors that could influence their decision (see Appendix 2Appendix 2, question 10). In other cases, the respondents preferred to check with the interviewer that they had understood the questions included in the survey properly. In this way most of erroneous or not fully correct answers were avoided.

It also turned out that the question 9 (rank the various airport ground access trip properties from most important to least important (see Appendix 1, question 9) was too time-consuming for the respondents. Most respondents, especially elderly people, devoted too much time to this question, which was not adequate to its importance. Ranking the various properties of the trip (including total travel time, number of transfers, comfort etc.) turned out to be quite a complicated task, which was not observed during the preliminary survey test during the seminar. It was then decided, that the question should be removed from the survey or altered in such a way that the answering would require much less time.

## **8. Meeting with NSB after the final survey test**

After the final survey test a meeting with the supervisors and the NSB representatives was called. At the meeting the results of the survey test and the final form of the questionnaire were discussed. It was agreed first of all, that question 9 (Appendix 1, question 9) could actually be changed, so that answering did not take too much time and was not too complicated. It has been proposed that question 9 could ask for an indication of the most important and least important features of the trip, or ask to identify the two most important characteristics of it. It was decided afterwards that the best solution would be to ask for the two most important features of the trip (Appendix 2, question 9), because it was very likely that most people would pick the total travel time as the most important feature anyway. Much more interesting results would be obtained when asked about the two most important features of travel, since then the precise preferences of passengers would be discovered.

Another change to the survey was also proposed, that was to change the ticket price levels in the stated-preference game. It was proposed by the NSB representatives to set the ticket price to 50 and 150 NOK, instead of previous 90 and 120 NOK. Although the numbers were not backed up by any specific study or other sources, it was agreed upon that the bigger difference between the low and high ticket price would show the correlation between the monetary travel cost and the respondents' choices much clearer. Table 4 summarizes the amendments made to the survey after the meeting:

Amendments done to the second version of the questionnaire		
Part	Change	Reason
Part 1	Question 10: ranking the various airport ground access trip properties from most important to least important changed to choosing two most important properties	To make answering the question easier
Part 2	Ticket price levels changed from 90 and 120 NOK to 50 and 150 NOK	Possible correlation between the monetary travel cost and the respondents' choices would be much clearer

Table 4: The amendments done to the second version of the questionnaire

Table 5 presents also the final form of the values of attributes used in the stated-preference game:

	Train low	Train high	Bus
Onboard travel time [min.]	20	30	30
Departure frequency [min.]	15	25	10
Ticket price [NOK]	50	150	130

Table 5: The final values of the attributes of bus and train trip used in the stated-preference survey with their respective values

The final form of the survey was later discussed. Including car as a means of transportation in the stated-preference game was discussed. It was argued that the study would be more complete, as the competition between both car, train and bus would be tested. It was however opposed and the rhetorical question was asked, what the purpose of the survey and the whole study was. Its aim was namely to examine only competitiveness between the train and airport express bus, as these two transportation services were quite similar to each other and had similar attributes (fixed onboard travel time, departures and price ticket). This was summarized by saying that the study was researching only the competitiveness between these two types of public transportation and nothing more. The car, however, is a different type of transportation and the monetary costs associated with its use are calculated in a different way. The monetary costs associated with traveling by car consist not only of fuel and possible road tolls, but also, e.g. of parking fees. In addition, a car trip to/from the airport can be performed at any time, which makes it difficult to compare with public transportation, which has fixed departures. All of this would make a comparison of the car, train and bus strongly imprecise and, above all, change the purpose of the study, which had been defined already during the previous semester. For this reason it was decided to keep the current form of the questionnaire, despite comments from the NSB representatives.

Besides, it was agreed at the meeting that the most important thing was that the final data collection was carried out at Værnes Airport, not at Flybussen stops, as it had been done in the final survey test. Everyone present at the meeting agreed, that it would be the best place to conduct the survey, since passengers travelling by many different means of transportation were present at the airport, not only train and bus passengers, but also taxi or car users (both as a passenger and driver). As a result a greater differentiation of respondents would be obtained, and thus more representative the respondent group would be. Thanks to this some trends about shifting to other means of transportation among passengers who do not use the train nor the bus to the airport could also be discovered. The problem, however, which could not be solved was the lack of the permission from

Avinor to conduct the survey at the airport in February. The only thing that could be done was to hope that the data collection could be started with the beginning of March. Any further delays would lead to a problematic lack of time when analyzing the collected data, evaluating it and commenting on it in the final report. All the participants were afraid how the study would continue in case of not receiving permission to conduct the survey at the airport in March. Therefore it was instructed to develop a plan B, which would be implemented in the event of inability to carry out the data collection among passengers at the airport. In addition, a task of calculating a budget of the study was given, depending on whether plan A (data collection at Værnes Airport) or plan B would be implemented.

## 9. Preparation of the plan B

Because of being afraid of not getting a permission to carry out data collection at Værnes Airport or receiving it quite late, which would delay the course of the research, it was decided to develop an emergency plan B. This plan was aimed at finding ways to acquire the necessary data by methods other than conducting the data collection among passengers at the airport. In January and February two proposals for an alternative method for data collection appeared. Both of them had their advantages and disadvantages, that had to be taken into account when the final choice of the alternative solution was done.

The idea, which appeared at the beginning was to conduct the data collection on the Internet. The solution consisted of handing out a link to the survey placed on the online platform [surveymonkey.com](https://www.surveymonkey.com) to passengers at various points in the city and/or the airport. Respondents would have answer the questions in the questionnaire based on their most recent trip to/from the airport. However, this would have required the permission from Avinor to handing out links to the survey in the form of a QR code or a link to a website. This placed the entire solution under a big question mark, as it was hard to imagine obtaining permission for only handing out links to the survey, while conducting survey among passengers at the airport would be prohibited. The reason why Avinor was not willing to grant a permission to conduct data collection in February was that another study was conducted at that time. Conducting of a different study ruled out other, that would have be held at the same time. Avinor argued that the passengers would have be disturbed too much because of two separate surveys being performed at the same time at the airport. It was then hard to imagine that Avinor would grant permission for distributing links to surveys, which was de facto to conduct a separate research. Another drawback was that most probably a small percentage of passengers, which would have gotten the link would have answered the questions later (Kjørstad & Norheim: 16). For this reason, it would have been necessary to hand out even a few thousands of such links, to get the right amount of answers.

For these two reasons the only option, that was still relevant was the second solution. It came down more or less to how the final survey test was conducted. The data collection would have taken place among the passengers at Flybussen stops and Trondheim Sentralstasjon. The main drawback of such a solution would have been missing the passengers traveling to the airport by car and taxi. For this reason, the scope of the study would have been slightly changed. The results would have shown only the attitude of today's airport bus users. On the other hand, a major advantage of this solution was that it was already roughly known data collection method as it had been used during the final survey test. The experience from the purely practical aspects of this method (percentage of passengers involved in the data collection and the time required to collect the right amount of data) was sufficient. Despite of this, however, it would be far from the optimal solution, because a large part of the transportation market between Trondheim and Værnes Airport would have been missed.

## 10. Data collection

The main concern about the conducting of the data collection was due to the fact that it was not known when the study conducted by Avinor at the airport would be finished. Avinor was unable to give an exact date of the end of their research. It was known only that the study would most likely last until the end of February, but it was not certain whether it would be extended to mid-March. It was decided, therefore, that with the beginning of March plan B, assuming data collection at stops supported by Flybussen, would be implemented. Early March was the last period when the data collection could be started without simultaneous serious delay in the entire course of the research process.

In late February, it turned out, fortunately, that the study by Avinor would end with the end of the month. This meant that the data collection among passengers at the airport would be able to begin on 1<sup>st</sup> of March. The permission was valid until Easter, that is for weeks 9-12 and was in force only at the arrival hall. This meant that the study would be carried out in such a way that had been previously scheduled. It was a very good news, which meant that the study's scope would not have to be changed because of the type of collected data (unrepresented car and taxi). On the other hand, the time limit imposed by the Avinor meant that data had to be collected intensively, i.e. many hours should be spent each day at the airport to collect the adequate number of responses (between 300 and 500). Fortunately, thanks to a free train tickets provided by NSB for me and my assistants, the trip between Trondheim and Værnes Airport was easy and free of charge. This meant that despite the fact, that the location of the place, where the data collection was conducted lay quite far away from the city, it did not have an impact on the research budget.

Having a permission to conduct the data collection at only the arrival hall at the airport meant that only passengers travelling to Trondheim would be questioned. This caused that the question about the direction of travel was redundant. It was therefore removed from the final version of the survey used to collect data at Værnes Airport (Appendix 2).

On the first day of data collection two people have been involved, me and an assistant (María Díez Gutiérrez, PhD student at the BAT institute). After arriving to the airport about 13 o'clock and receiving instructions on the principles, which had to be followed in the course of data collection at the airport, the arrival hall was made available to the interviewers. As previously arranged, the data collection was conducted among passengers in the arrival hall, who were not very busy, including only, those who were not eating at the moment. After some time, the interviewers came to the conclusion that the most effective way to collect data would be waiting for passengers who had just arrived at the airport and were waiting for luggage at the baggage claim belts that were located in the hall. Passengers in other parts of the hall, that is bars, meeting points and at the bus stop outside the arrivals hall were usually busy, or unwilling to participate in the research.

At this day data collection lasted a little over an hour due to tight schedule. On the other hand, the conditions during the day at the airport were not conducive to collecting large amounts of data. Traffic in the arrival hall at this time (between 13 and 14 o'clock) that day was small and planes landed roughly every half an hour, and with each flight, relatively few passengers claimed their luggage at the arrival hall. Fortunately, many of the passengers waiting at the luggage were willing to answer the questions. Despite of that, a very slow pace of collecting answers from passengers gave rise to serious doubts whether the planned amount of data could be collected during the period for which the permission to conduct the study was given by Avinor (up to week 12). During the first day, i.e. little longer than an hour, both assistants managed to collect about 10 filled out questionnaires. This meant that if the state of affairs would hold throughout the data collection period, many dozens of hours would have to be spent to collect 300-500 planned surveys. The situation was also complicated by the fact that Maria

could not help more as an assistant at the data collection at the airport. Her other duties made that she was too busy to be able to devote more time to conduct research among the passengers.

A few days later, after making the announcement at a working group on It's Learning student willing to assist with data collection turned up. She expressed willingness to participate in the study as an assistant questioning passengers alone at the arrival hall. Unfortunately, because of the excess of other duties she could conduct research at the airport only two times, only few hours at a time. In total, the assistant collected about 10 filled out questionnaires.

For this reason, I was the only one who carried out the surveys at the airport. The conditions at the airport that had taken place during the first day and the pace of about 10 questionnaires per hour remained more or less to the end of the data collection period. The subsequent data collection proceeded more or less like during the first day, but with the difference that the data collection was carried out from morning (about 9-10 o'clock) to afternoon hours (about 14-15 o'clock). The passengers waiting for luggage at the baggage claim belts at the arrival hall were approached and asked a question if they wished to participate in a study under the auspices of NTNU on the travel behavior of passengers using Værnes Airport. About 50 % of the passengers questioned in this way wanted to participate in the survey. The surveys were carried out often in the form of interviews, that is the respondent read questions or they were read to him and then he/she dictated answers to the interviewer that was noted in a separate notebook. It was recognized early that writing answers on a tablet or a laptop would have been too bulky. In other cases, the survey was distributed to respondents, and they filled them out by themselves. This second form of collecting responses was used most often while gathering responses from many passengers at the same time, while having a time shortage. The form of the interview with the respondent was used most often at low respondent densities, and if the respondents were elderly people or foreigners who did not understand the Norwegian language to such a degree to understand the questions' content presented in the questionnaire.

The data collection at Værnes Airport was carried out until week 11. By this time a total of 291 completely filled out questionnaires was collected, including those gathered on the first day together with María Díez Gutiérrez and those gathered by the other assistant. The entire data collection process took about 40 hours. At the same time the data was transferred into a computer to Microsoft Excel, and then copied to SPSS.

Unfortunately, the shortage of time meant that the goal of collecting the minimum required number of questionnaires was not achieved. If the period for which the permission from Avinor was issued had been longer, the goal would have certainly been achieved. The second reason for dissatisfaction was that about one third of respondents (34%) did not participate in the stated-preference game included in the questionnaire. This was due to the fact, that the respondents had previously answered that access from the airport to the city by train was not relevant for them in any case (Appendix 2, question 9). Such a response disqualified the respondent from the stated-preference game, since his/her choices between the train and the bus could be predicted in advance. All this meant that only two-thirds (66%) of those who had responded to the survey could be used to analyze and create a modal split model, which was supposed to be the next part and the main output of the master thesis. In any case, these two failures were not dependent on me and they must be classified simply as a random unfavorable circumstances.

## 11. Preparation of the budget

One of the points of planning the study was to create a budget for expenses associated with the data collection and the data analysis. It was believed that the greatest expenses would be related to the data collection, because the program, in which the data were to be analyzed would have been purchased regardless of the study (anyway it turned out later that the data analysis would be performed in SPSS, for which NTNU had a license already). It was assumed, therefore, that the costs associated with the study would cover mainly the costs of travel to places where the data collection would take place and cover salaries for any assistants who could help in the process. It was very hard to determine the costs associated with the data collection. It was not known for how long this phase of the project would last and where exactly it would take place. Depending on obtaining the permission to conduct the research at Værnes Airport the budget could have change significantly. This was due to the fact, that the travel costs for the interviewers would have decreased multiple times if the data collection would have to be carried out at Trondheim Sentralstasjon and Flybussen and Værnesekspresen stops. Besides, it was not clear how long it would take to conduct the study, since it was hard to determine at what rate answers from passengers would be collected. For this reason, setting up the budget for the research was delayed for a long time.

At the end of February, the circumstances in which data collection was to be carried out became completely clear. After receiving the permission to conduct the data collection at Værnes Airport in the period from the beginning of March until Easter, it was possible to set up the budget of the study very easily. It was assumed that each day one person (me or one of the research assistants) would be spending a few hours at the airport collecting responses from passengers. This allowed to calculate with a considerable accuracy the costs associated with commuting. This is, because at the same time the option of conducting data collection in other places (Trondheim Sentralstasjon and Flybussen and Værnesekspresen stops) was rejected.

At the same time, an attempt to get the travel costs refunded by NSB was made. It turned out that NSB was not interested in covering the cost of commuting to the airport by Flybussen or Værnesekspresen, but it was willing to issue a free train tickets on the route Trondheim Sentralstasjon - Værnes Airport for the entire period of data collection for all interviewers. This resulted in the cost of commuting to the airport dropped to virtually zero, as the interviewers covered the costs of travel to Trondheim Sentralstasjon by themselves. This meant that the entire budget of the study was limited to a very large extent. At the same time, as already described in chapter 10, almost all of the data have been collected by me. Due to determining early how much time in March my assistant would be able to devote to work at the airport, it was found that the cost of her work would amount to around 1 000 NOK (150 NOK per hour of salary). At the end of data collection period, it turned out that the assistant had spent a total of about 7 hours questioning respondents. This meant that the budget had been slightly exceeded.

## 12. Result analysis

After obtaining answers from the respondents the data set had to be manually transferred into a data management program. Microsoft Excel was used in the first step to sort the data set. An important change to the data set was to multiply each line belonging to one respondent eight times to get one line per one answer in the stated-preference game. It was not done in the beginning of the data set transferring, which caused a little delay in the analysis process. This way of arranging the data set made it possible to use every answer in the stated-preference game separately, regardless of the identity (background) of the respondent who had given the answer. The data set consisted thus of 2 328 answers (including those who had not participated in the stated-preference game), which were then used in many different analyses including setting up several utility models. It is important to note that

only 66 % of the respondents (192 people) participated in the stated-preference game. The other 34 % found neither the future train service attractive enough for them to choose in any hypothetical situation nor they were willing to consider choosing the train service even after construction of the double track.

The data analysis consisted of both logistic regression and frequency analysis in SPSS program. The frequency analyses were mainly examining frequencies of answers given to the multiple choice questions (Appendix 2, Part 1 and 3). This made it possible to discover any correlations between the respondents' statement about their transportation mode preferences when travelling to/from an airport and their answers in the stated-preference game. Moreover, the frequency analyses were a basis for possible hints for NSB on designing the future train service in the area. The respondents' preferences and opinions could be a significant source of inspiration in NSB's future work.

The other crucial element of the data analysis was producing several utility models. To achieve this the binary logistic regression function in SPSS program was used. Despite of being able to choose between four different options when answering the stated-preference game (certainly train, possibly train, possibly bus and certainly bus), the answers were simplified to only "bus" and "train". This was done for simplicity reasons, since it allowed binary regression to be used, which deals with situations, in which the observed outcome for a dependent variable can have only two possible types. The utility functions produced this way gave utility for choosing the bus service dependent on different attributes of the trip. To calculate the probability for choosing the bus, the utility value was substituted into the logit model probability function:

$$P_{Bus} = \frac{1}{1 + e^{U_{Bus}}} \times 100 \%$$

where:

$P_{Bus}$  – probability for choosing bus  
 $U_{Bus}$  – utility value of choosing bus

The probability of choosing the train service was obtained the by using the following formula:

$$P_{Train} = 100 \% - P_{Bus}$$

where:

$P_{Train}$  – probability for choosing train

## 13. Obtaining results

### 13.1 Utility models

Table 6 shows the answer frequencies for bus and train in total in the data set. It can be seen that the share of choices of bus is slightly higher than the share of choices of train. It somewhat shows that the choices were not exactly obvious in many situations.

	Frequency	Percent	Valid percent
<b>Bus</b>	827	35,5	53,8
<b>Train</b>	709	30,5	46,2
<b>Total</b>	1 536	66	100
<b>Did not answer</b>	792	34	
<b>Total</b>	2 328	100	

Table 6: Frequencies for bus and train in total in the data set

Based on those answers given by the respondents in different hypothetical situations several utility models were estimated. The dependent variable in the model was “simplified choice”, which was the choice given by the respondent in each situation simplified to just “bus” or “train” as described in chapter 12. The independent variables in the models were in every case difference in onboard time ( $\Delta$  onboard time), difference in egress time to the transport mode ( $\Delta$  egress time), difference in the transport mode’s departure frequency ( $\Delta$  departure frequency) and difference in the ticket price ( $\Delta$  ticket price). In other words, the independent variables were differences between the trips’ attributes in the stated-preference game plus difference in the egress time. Difference in onboard travel time meant the time used onboard the transportation mode measured from the airport (bus stop by the arrival hall or the train station at the airport) to the nearest bus stop from the final destination or to Trondheim Sentralstasjon (depending on if the respondent had chosen to travel by bus or train). Difference in egress time meant the difference in time used on accessing the final destination after leaving the transportation mode (bus or train). This variable could include both walking time from the bus stop of Trondheim Sentralstasjon or time used on continuing the journey by other means of transportation, e.g. city bus. The time used on accessing the bus stop outside the arrival hall or the train station at the airport was neglected. The difference in departure frequency included the difference in minutes between every departure of the transportation mode, e.g. if the bus left every 10 min. and the train left every 15 min.,  $\Delta$  departure frequency was -5 ( $10 - 15 = -5$ ). The variables were differences between the bus’s and the train’s attributes (bus – train), which caused that bigger variables values were favorable for the train service, e.g. bigger difference in onboard travel time meant that it took longer time to travel by bus than by train. The last variables included only the difference between the ticket price for bus and train, so that it did not include possible travel costs when interchanging to e.g. a city bus after arriving at Trondheim Sentralstasjon.

In the beginning the general utility model was produced based on the whole dataset, including every district, gender, journey type etc. The general model was followed then by other utility models, where the data set, that was the basis for the model was limited to certain areas in the dataset, e.g. only respondents travelling to a certain district or by a certain transportation mode were selected (for examples of utility models see Appendix 3).

An important result of the utility model production was setting up utility models for the districts City Center, Trondheim East and Gløshaugen, Lerkendal separately. Those districts had most answers from respondents that participated in the stated-preference game (736, 344 and 320 respectively). Four different sets of coefficients were then substituted into the model. The first one was the most train favorable situation, where the train service had the most attractive combination of attributes. The second one was the least train favorable situation with similarly the least attractive combination of train attributes. The third one was the most equal situation, where both transportation services had almost identical attributes. Finally, today’s coefficient values for the train service were used to compare the model’s output with the actual modal split when accessing Værnes Airport (Denstadli et al. 2012: 8).

Those four situations were chosen to test different variable combinations in the models. The most and least train favorable situation were chosen to examine what the possible maximum and minimum share of the public transportation passengers the train service may have. In other words, the situations showed how many passengers were (in accordance with the model) strongly attached to either the train or the bus and would most probably be not taken over by the other means of transportation. The situations were based on the most and least train favorable variable combinations found among the values in Table 5. The most equal situation was chosen to investigate in order to compare two most equal services that can be available on this route, and to examine if any of the services has a clear domination on the market. The only difference in the transportation modes' variables is the departure frequency, which includes a train departure every 15 min., since it would be quite unrealistic to have a 10 min. departure frequency on this route (JBV 2013). The last situations was comparison of today's train service with the airport express bus. The situation is based on today's train service quality (NSB Travel Planner) and was used to compare the model's results with the actual modal split found by (Denstadli et al. 2012: 8).

In every situation the difference in the egress time was an average value, that is each egress time value multiplied by the respective number of respondents and divided by the total number of respondents for the district. By doing so, the situations got much more representative than if only the most extreme values for difference in egress time were used, which may be related to very few respondents. Coefficient values for each situation used in the utility models for the mentioned districts are presented in Table 7:

City Center				
	Most train favorable	Least train favorable	Most equal	Actual (today's)
<b>Δ onboard travel time [min.]</b>	10	0	0	-5
<b>Average Δ egress time [min.]</b>	-5	-5	-5	-5
<b>Δ departure frequency [every min.]</b>	-5	-15	-5	-50
<b>Δ ticket price [NOK]</b>	80	-20	0	50
Trondheim East				
	Most train favorable	Least train favorable	Most equal	Actual (today's)
<b>Δ onboard travel time [min.]</b>	6	-4	0	-5
<b>Average Δ egress time [min.]</b>	-7,5	-7,5	-7,5	-7,5
<b>Δ departure frequency [every min.]</b>	-5	-15	-5	-50
<b>Δ ticket price [NOK]</b>	80	-20	0	50
Gløshaugen, Lerkendal				
	Most train favorable	Least train favorable	Most equal	Actual (today's)
<b>Δ onboard travel time [min.]</b>	30	15	0	-5
<b>Average Δ egress time [min.]</b>	-25	-25	-25	-25
<b>Δ departure frequency [every min.]</b>	-5	-15	-5	-50
<b>Δ ticket price [NOK]</b>	80	-20	0	50

Table 7: Attributes for each situation used to calculate the probability values

After obtaining the probability values it was possible to draw a small map over districts in Trondheim for every situation showed in Table 7 with their respective probability values for choosing the train service in each situation (see Appendix 4).

The results for the most and least train favorable situation shown in Appendix 4 may seem to be too extreme, because of the high probability of choosing the train service in the most favorable situation

and high probability of choosing the bus service (very low probability for choosing the train service) in the least favorable situation. On the other hand the results from the most equal situation were very close to the most train favorable situation. This may indicate a very strong tendency to choose train, even though the bus service's quality is very similar. Other reasons may also supply an explanation.

The first one is the small size of the respondent group, which as it was found, was quite representative in terms of age distribution (the age distribution in the data set was similar to Norwegian demographics statistics) and modal split (compared with Denstadli 2012). I was also found that 73 % of the trips were leisure trips, while 27 % were business trips. Although the respondent group may have been representative in some ways, the normal practice when investigating modal split to/from airports is to use data sets, that are double the size or even bigger (Akar 2013, Psaraki & Abacoumkin 2002, Gupta et al. 2008). This may have contributed to inaccurate results, especially when it is taken into account that the individual districts in this analysis were represented by only a fraction of the whole data set.

Another important aspect was that the egress time variables was not described in the questionnaire and was defined by the respondents. In other words, the passengers had to include their hypothetical egress time to the final destination, when choosing the train or the bus in the hypothetical situations. Egress time included both the time used accessing (walking, driving etc.) the train station/bus stop and the waiting time. This variables may thus be characterized by a high degree of uncertainty, since it may be very challenging to include a reasonable time frame in a such hypothetical conditions. This was supported by the fact that some obtained values for egress time were suspiciously low. It meant that many different aspects may have been omitted or misjudged by the respondents, such as travel time on a city bus or waiting time related to transportation mode interchange. Some answers in the data set may even indicate that the respondents did not always counted the possible waiting time into the egress time, since the value supplied by them was not high enough compared to the distance which they would have needed to travel. It may also turn out that in a real-life situation like this in the future, the actual egress time (and at the same time difference in egress time) may differ significantly from that found in the research.

The last thing worth mentioning are the local factors that were characteristic for the area, that the research is related to. One of the biggest problems, that contributes to the unattractiveness of the train service (both today's and future) was the localization of Trondheim Sentralstasjon. Even though it is marked as the city's central station, it is not placed directly in the City Center, but it is located about 1 km away from hearth of the City Center, where the most trip-attractive places can be found (Figure 2). To the low attractiveness of the train service contributes also the fact that the city bus lines servicing the train station do not make it easy to travel to other part of the city, even the City Center. Only few bus lines with few hourly departures service Trondheim Sentralstasjon, while the biggest public transportation node, Sentrumsterminalen (The City Center Bus Terminal) is located about 1 km away from the station. It is then much more inconvenient for passengers travelling to/from the airport even from the City Center to get to Trondheim Sentralstasjon first, compared to getting to one of the airport express bus stops, that are located in many different spots around the city, especially the City Center. This well-established and well-known airport bus service (both Flybussen and Værnesekspressen) would still be a very serious competitor to the future train service because of this factor. The flexibility of the bus makes it much more attractive transportation mode than the train, which would service only Trondheim Sentralstasjon with competitive enough frequency and onboard travel time, since other train stations in the city would still be connected by a single track. This is also one of the main reasons why the probability values presented in Appendix 4 are so extreme, since the most favorable situation includes very short average egress time from the train station, while the least favorable one includes the opposite (see Table 7). This can be also seen in Appendix 3, while looking at the ratio between the coefficients  $\Delta$  onboard time and  $\Delta$  egress time. It can be seen that  $\Delta$  egress

time was most often valued approximately 3 to 4 times higher than  $\Delta$  onboard time. This makes even a slight change in the egress time having a big impact on the probability of choosing the train service.

The extremely low probability for choosing the train service, when substituting the current train service attributes can be easily explained by the fact, that the utility model worked outside its range. It means that the values substituted into the utility function were not in the range of the answers given during the stated-preference game. For example,  $\Delta$  departure frequency of -50 gave a disproportionate impact on the resulting utility value, since 60 min. departure frequency of today's train service was a value that was higher than the attributes given in the hypothetical situations. As it turned out, the ticket price (80 NOK) and the onboard travel time (38 min.), that were inside the models range or just not too far outside it, did not helped to make the obtained probability values more realistic. The probability values obtained this way did not of course tally with the actual modal split to the airport (Denstadli et al. 2012: 8).



Figure 2: Distance from Trondheim Sentralstasjon to Sentrumsterminalen located in the hearth of the City Center (Source: Google Maps)

### 13.2 Frequency analyses

In addition to the utility models and probability values presented in Appendix 3 and Appendix 4 the following results based on the multiple choice questions have been obtained. Table 8 shows the share of yes answers to each factor that would possible convince the respondents to choose the new train service on the trip to the city (Appendix 2Appendix 2, question 8). Only the respondents who did not travel by train when participating in the survey were asked to answer this question. The respondents were able to choose as many factors they wanted, except for choosing the first option, which excluded from choosing the other ones. In addition, after choosing the first option, the respondent did not participate in the following stated-preference game, since his/her answer in all the hypothetical situations would have been known in advance. As it can be seen, the most popular answers were "shorter onboard travel time", "more frequent departures" and "different departure times" together with "better correspondence with other transportation modes". It may be commented, that the two first mentioned options will definitely be satisfied to a certain degree by building double track between Trondheim Sentralstasjon and Værnes Airport. On the other hand the two other factors would need to be addressed separately.

Share agreed				
Statement	All (N=245)	City Center (N=74)	Trondheim East (N=39)	Gløshaugen, Lerkendal (N=57)
The train service is irrelevant for me anyway	40%	18%	21%	32%
Shorter onboard travel time	52%	69%	69%	63%
More frequent departures	57%	78%	77%	65%
Better punctuality	15%	16%	15%	25%
Different departure times	36%	42%	44%	51%
Better correspondence with other transportation modes	32%	23%	56%	44%
Low ticket price	16%	16%	18%	26%
More sitting places	27%	22%	59%	33%
More/better space to work during the trip	15%	18%	18%	23%
Easier access to the train station	24%	32%	23%	28%

Table 8: Factors that would convince passengers to choose the new train service. "If you are not going to take the train: what change has to be made, so that you are willing to choose the train service?" (Appendix 2, Appendix 2, question 8)

Table 9 shows answers given by the respondents, who either had chosen only the bus in every hypothetical situation or had stated that the train service was not relevant for them anyway (Appendix 2 Appendix 2, question 13). Also in this question the respondents were able to choose as many factors as they were willing to. It is clear, that the distance from Trondheim Sentralstasjon was the most problematic factor in this issue. In addition, all the other factors listed in the table, except for the money cost for possible interchange, contributed significantly to the train service's unattractiveness.

Share agreed				
Statement	All (N=128)	City Center (N=19)	Trondheim East (N=16)	Gløshaugen, Lerkendal (N=32)
The station is too far away	95%	79%	94%	94%
The trains departure frequency is too low	41%	42%	63%	47%
The city buses' departure frequencies are too low	44%	26%	63%	63%
The interchange costs too much	11%	16%	13%	16%
It is necessary to interchange	49%	47%	63%	59%
The city bus connections are too bad/few	58%	32%	81%	66%

Table 9: Reasons why some respondents do not see the future train service relevant for them. "Why is the train service irrelevant for you?" (Appendix 2, question 13)

The last results presented here (Table 10) is a table presenting the most important attributes of an airport ground access trip (Appendix 2, question 9). It is important to note that only two most important options could be chosen from among all the options presented and only those who participated in the stated-preference game (had not answered that the train service was irrelevant for them) answered this question. The answers are not related to a specific airport ground access trip, but have more of a general nature. It can be clearly seen that the most popular option is "total travel time", which includes all of the time spent on travelling from the final destination to the airport or vice versa. "Few (preferably no) interchanges" and "frequent departures" were also quite popular answers among the respondents.

Statement	Share agreed			
	All (N=193)	City Center (N=92)	Trondheim East (N=43)	Gløshaugen, Lerkendal (N=40)
<b>Total travel time</b>	86%	84%	74%	100%
<b>Few (preferably no) interchanges</b>	33%	47%	28%	18%
<b>Enough time between interchanges</b>	8%	5%	14%	10%
<b>Punctuality</b>	6%	9%	5%	3%
<b>Frequent departures</b>	44%	27%	47%	63%
<b>Comfort</b>	22%	24%	33%	10%
<b>Short distance to the station/bus stop</b>	6%	7%	2%	10%

Table 10: Most important attributes of an airport ground access trip. “What is most important for you when travelling to/from an airport (despite of the ticket price)? Choose to most important trip attributes.” (Appendix 2, question 9)

### 13.3 Recommendations for NSB

The conclusion, that can be drawn from the results presented above is that there were two main reasons for which passengers did not choose the train service on regular basis when travelling to/from the airport and most probably they will not choose it after the construction of the double track. The first one was the train service itself (Table 8), that was perceived as too slow (long onboard travel time) and had too few hourly departures compared to its biggest competitor – the airport express bus service. This is going to be solved to a certain extent after introducing the new train service in the future, but it may still be not enough for some passengers. NSB cannot do a lot about this unfortunately.

The second reason for the train’s low attractiveness was mainly the location of Trondheim Sentralstasjon and the city bus connections leading to and from it to other parts of the city. This problem would not be as easy to address, as it demands at least redesigning the local bus network in such way that the interchange from the city bus to the train would be as least problematic as possible (short waiting time, low monetary cost etc.). It can be easily seen that the respondents valued the total travel time and frequent departures highest when talking about an airport ground access trip in general (Table 10). The answers that described the low attractiveness of the train service were also related mostly to that (Table 9). Although it is very unlikely that Trondheim Sentralstasjon will be relocated so that its location is more attractive to the passengers, an as efficient as possible correspondence with other transportation modes (mainly city buses) should be ensured, so that the negative effects of interchanging at the train station get minimalized in a highest possible degree. NSB should therefore cooperate closely with AtB (the local public transportation company) to develop a such transportation service, so that the it attracts more passengers to use the train. By doing so such factors lowering the train attractiveness as “the city bus connections are too bad/few”, “the city buses' departure frequencies are too low” or even “the station is too far away” (Table 9) would not have such significant effect. Thanks to this some passengers having a comparable or longer egress time when travelling by the bus would surely consider to start using the train when accessing the airport. Other passengers having short egress time when using the bus would most probably continue to use the bus service. That is why the train will probably never achieve so high marked share in the whole city as it would have in the City Center and Trondheim East, where many passengers have quite short egress time to the train. Although attempts to reduce the egress time for the train service should be made.

## 14. Learning outcome

The whole research was a continuous and differentiated process, which started as soon as in fall 2015. Back then the research activity consisted of literature review and clarification of the issue investigated later in the study. Many different problems were raised at that time, first of all the study's scope and the questionnaire design. As already described in the report, later on the practical implementation became an issue, which had to be solved as efficiently as possible. All those situations led to many chances, where a valuable experience was gained.

In the beginning the clarification of the study's scope was challenging to achieve. It was known that the construction of the new railway line between Trondheim Sentralstasjon and Værnes Airport was going to bring major changes in the transportation pattern between those two places. Even though, it took quite a long time to clarify the focus on an estimate of the modal split on the line segment between Trondheim and the airport. Other alternatives did not meet the necessary requirements for a research topic. Other topic options neither included any scientific hypothesis, that could be abolished or corroborated, nor were complicated and absorbing enough to be a satisfying research problem. The process of finding a relevant question to focus the study on was very enlightening and helped to understand the fundamental principles for scientific research, that is finding hypotheses, that could possibly be used to enrich already existing knowledge in a certain topic regardless of possible case, the study was focused on. For example the chosen topic in this research put a better light on the future situation in the local transportation system and how this may be developed later. The results from the research may be also used by the local transportation authorities in future analyses and/or decision making. But simultaneously, this work may become an example on a national or even an international scale how travel habits change after an introduction of a new transportation service. This example may contribute to the general transportation engineering knowledge and go beyond the local conditions and interests.

The literature study, that was also an important part of the research process in the fall, had a significant learning outcome. It is important to note that no NTNU courses teach topics related to this work, except for utility models. Issues concerning questionnaire design and data collection had to be addressed only with the knowledge supplied by the literature found and investigated during the literature study and the supervisors' advice. The literature supplied an important knowledge regarding different survey technics such as stated-preference and reveal-preference and different data collection methods together with their positive and negative aspects. The literature study contributed also a lot to the questionnaire design process making it much easier, since much useful information on how to set up survey questions depending on desired type of future results were obtained from the investigated scientific sources. Thanks to thorough examination of different survey design options experimental, orthogonal, full-factor design with conjoint analysis was found to be most appropriate in the study. Simultaneously, except for a significant contribution to the questionnaire design process, the literature study made my knowledge regarding travel behavior survey design much broader than before. This knowledge may certainly turn out to be useful in my future professional work as a transportation engineer.

The questionnaire design was a long and challenging process, that started as early as in the fall included a small preliminary survey test conducted with a handful of people. The purpose of this test was to check if the questions were easy to understand and answer and at the same time if the survey's extent was not too high. Since that time many changes have been applied to the questionnaire, which also slightly changed its purpose and future results. The most challenging part of the questionnaire design process was setting up the stated-preference game. Before the final form of the stated-preference game was settled, many different options had been considered. Finally, the experimental, orthogonal, full-factor design with conjoint analysis was chosen. Using experimental design means planning an

experiment in such a way that an effective analysis of all relevant variables is ensured. It implies also the opportunity to study each independent variable effect on the dependent variable (main effects), simultaneously with any interaction effects. On the other hand, conjoint analysis means that the respondent is inserted in a hypothetical situation and faces two or more choice alternatives. The respondent must make a choice and choose the option that is most appealing to him. All of this meant that the biggest challenge of the questionnaire design was to design the survey in such a way that the respondents were able to answer the questions easily and at the same time their answers were valuable in terms of data interpreting and obtaining the results. The answers obtained from the respondents were supposed to be used afterwards to design several utility models. To ensure that the models are as accurate as possible, the respondents' answers had to be as realistic as possible, even though they related to hypothetical situations (sometimes very hypothetical, since car drivers were asked to choose between shuttle bus and train, while both of them were not their first choice). The main challenge was therefore how to design a questionnaire which is very easy to understand and simultaneously ensures obtaining valuable and relevant data for the research. This task was even more challenging, since I did not possess any knowledge about questionnaire design concerning passengers' travel behavior before I started working on this study. It was decided that the hypothetical situations in the stated-preference game would relate to the trip, that the respondents were undertaking at the moment of filling out the questionnaire. By doing this, the survey was very realistic and easy to understand, but the problem of complexity of respondents' trips appeared. There were many different routes and destinations in Trondheim, that had to be taken into consideration, and it was too difficult to include those in the survey. The solution to this problem was quite easy, but also quite risky at the same time. The respondents were asked to take into consideration the different aspects of their trip to their final destination in the city (possible longer travel time, need for interchange, higher monetary cost etc.), while choosing the most relevant means of transportation in the stated-preference game. It was made the stated-preference game very easy, but at the same time many of the aspects of the respondents' trips were not described by them (the respondents made their choice in their minds), which created the risk that the respondents did not think about and/or underestimated certain consequences of choosing the bus or the train. Anyway, it was the only way to make the respondents to describe their whole „journey chain” (their whole journey from Værnes Airport to the final destination).

The other aspect of the questionnaire design was its volume and content apart from the stated-preference game. Many additional questions had to be included in the survey to make the respondents' background clear. The data obtained from those questions were later used to explore any possible correlations between certain characteristics of the passengers (age, gender, the final destination etc.) with their choices. On the other hand the questionnaire must not have been too extensive, since it would have made it too boring to answer, so that the risk of obtaining inaccurate responses rose. It turned out at the end that it took about 50 % longer time to fill out the final form of the questionnaire compared to the first and second version. Luckily, it was observed afterwards that the surveys volume did not have as serious importance as it had been anticipated earlier.

It may be summarized that the whole process of questionnaire design was very rich in learning outcome. A lot of information on questionnaire design had to be obtained in advance, and the process of designing, discussing and testing different versions of the survey (three different survey tests including the preliminary one in the fall) gave a significant experience on this research method. This experience was of course based on only a participation in a small project and some literature research, but it may turn out to be very helpful and significant in my future professional work.

Other activities during the research process gave also some useful experience. During the data collection and the survey tests it was possible to experience how data collecting in form of distributing questionnaires and individual interviews look like. By participating in this form of research one may

easily learn how to conduct interviews and organize data collection in such way that it goes as efficiently as possible. Thanks to using SPSS program during the data analysis I obtained significant amount of knowledge about the different functions, that can be used when analyzing different high-volume data sets in the program. Finally, report writing gave a very valuable insight in the way scientific papers and reports are produced.

## 15. Process evaluation

As already described, the research process was differentiated and sometimes challenging. Several different stages of this process have been described in this report including questionnaire design, data collection and result analysis. During this and previous semester several problems, which may have caused different problems, including significant delay of the work process, occurred. They had however limited influence on the work's course. The whole research process in general can be thus evaluated as positive. Even though I was not very familiar with the topics discussed in this work in the beginning of the research process, thanks to the continuous hard work and obtaining knowledge about different issues related to this study (survey methods, modal split, data collection) the study's scope have been achieved. This means that the analyzed data set produced desired results in form of utility models with probability values plus other several charts and tables showing interesting correlations between the respondents' answers. A scientific article based on the research process and the obtained results was also produced. On the other hand the learning outcome described in the previous chapter was very rich and satisfying. Anyway two vital limitations need to be discussed. Although it may be argued, that the results obtained in the study were imperfect and inaccurate to a certain degree, one must take into consideration few important limitations that characterized this project. It is also important to note, that those limitations were independent on me.

The biggest limitation on this project, that turned out at one point to be central, were available resources in form of time and human resources. The research work was conducted mainly during spring 2016. During this period, data has both been collected, processed and analyzed. A report in the form of a master thesis or a process report and a scientific article was to be produced as well. It turned out, therefore, that the time frame was limited, so that the study (and especially the data collection) had to be conducted efficiently to ensure an effective use of the allocated resources. The data collection process was believed to take the longest time in the whole master thesis work process. The number of interviewers was central considering how comprehensive data basis would have been obtained. Unfortunately no significant help from assistants was received during the data collection. This contributed significantly to the size of the data set, which may be perceived as insufficient for this type of study. The size of the data set had also a big impact on the quality of the results obtained as the output of the work.

The other important limitation was the unexpected delays in the work process. Originally in the project report the data collection was scheduled to start in the beginning of February. This had to be moved to the beginning of March because of lack of permission from Avinor to perform data collection at Værnes Airport. Luckily, this delay did not have any serious negative effect on the course of the research work, but it may be disputed if it would have been possible to obtain a bigger data set (even with only one interviewer engaged) if the permission had been given earlier. Regardless of that the limitations described above were not depended on me, so that they need to be perceived as unexpected, unfavorable circumstances, that had to be dealt with as efficiently as possible.

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**PART II**  
**SCIENTIFIC ARTICLE**



# Competitiveness of train and airport express bus between the city of Trondheim and Trondheim Airport, Værnes

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This study investigates possible future ground access mode choices of passengers travelling to Trondheim Airport, Værnes in Trondheim, Norway. The survey was conducted with 291 respondents at the airport in March 2016. The questionnaire included a stated-preference survey with conjoint analysis, where the respondents were asked to choose between the today's airport express bus service and possible future enhanced train service on a hypothetical trip to the city. Binary logit models comparing both transportation services were estimated in order to analyze the passengers' interest in choosing the new train service instead of the shuttle bus. The results show that people travelling to the areas closest to the City Center would be more likely to choose the train service than the bus, if their egress time was low. In addition the most important factors that influence the train service's low attractiveness in other parts of the city are presented.

## Introduction

Access transportation to airports is carried out in many different ways (by various means of transportation) throughout the world. In Norway the biggest civilian airports are supported by at least one public means of transportation - a shuttle bus. Several airports are though supported by train service going from the nearest largest city right to the airport building (Oslo Airport, Gardermoen and Trondheim Airport, Værnes) or to a railway station close by, from where the passengers are then transferred by bus to the airport building (Sandefjord Airport, Torp and Moss Airport, Rygge). Although several transportation options are always available when accessing airports, passengers still often prefer travelling by car. Figure 1 shows modal split when accessing Norway's biggest airports: Oslo Airport, Gardermoen (OSL), Trondheim Airport, Værnes (TRD), Bergen Airport, Flesland (BGO) and Stavanger Airport, Sola (SVG).

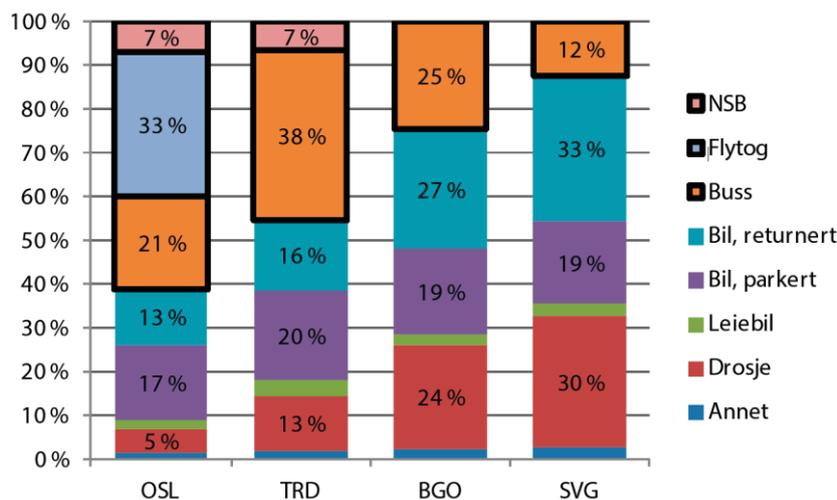


Figure 1: Modal split when accessing Norway's busiest airports in 2011. NSB – Norwegian State Railways, Flytog – Airport Express Train, Buss – Bus, Bil, returnert – Car, returned, Bil, parkert – Car, parked, Leiebil – Rental car, Drosje – Taxi, Annet – Other. Source: Denstadli 2012

As figure 1 shows, only Oslo Airport, Gardermoen has a ground access public transportation share of over 50%. Ground access to other biggest airports is dominated by car usage, that causes several

significant problems for both the local and the global environment, and the transportation and living conditions in the area. As part of the efforts to reduce the greenhouse gas emissions from its activity, Avinor, the owner and manager of most of the civilian airports in Norway, has a goal to increase the share of public transportation in ground access to/from its airports. To counteract against the excessive car usage in Norway (including ground access to civilian airports) the government plans to improve the accessibility of public transportation in the major cities, where an important part of this are investments in increased capacity on rail (Det Kongelige Samferdselsdepartement, 2012-2013). One of the investments included in this project is increasing the rail capacity on rail from Trondheim City Center to Trondheim Airport, Værnes, and thus increasing the public transportation share by encouraging passengers to use the new train service.

Trondheim is a city Sør-Trøndelag in Middle Norway. It has a population of 175 068 (SSB a) and is the third most populous city in Norway, although the fourth largest urban area. The city functions as the administrative center of Sør-Trøndelag county and is dominated by the Norwegian University of Science and Technology (NTNU), the Foundation for Scientific and Industrial Research (SINTEF), St. Olav University Hospital and other technology-oriented institutions. The city is served by Trondheim Airport, Værnes located about 30 km to the east from Trondheim City Center (Figure 2).

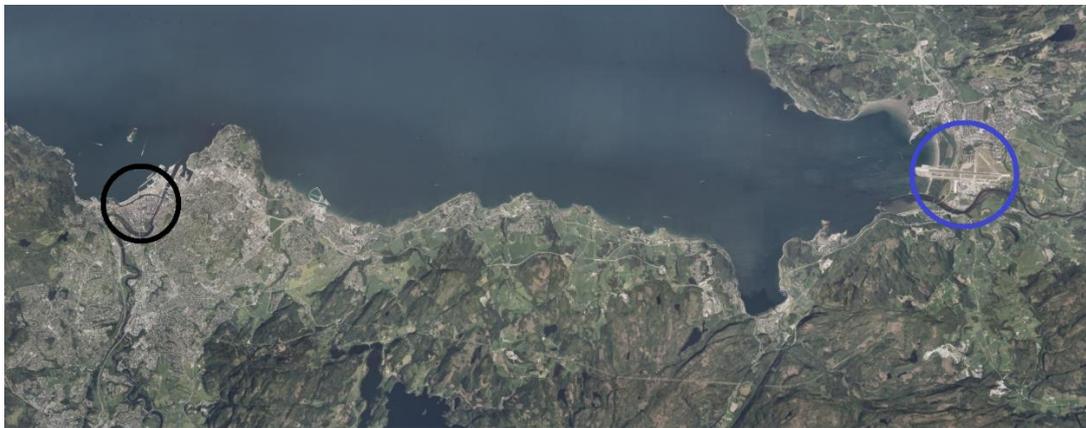


Figure 2: Location of Trondheim Airport, Værnes (blue ring) and Trondheim City Center (black ring)

Trondheim Airport, Værnes is one of the largest airports in terms of number of passengers on board at departure and arrival in total in Norway. This number was at 4 347 706 passengers in 2015 (SSB b), which puts Værnes Airport in 4<sup>th</sup> place on the list of Norway's busiest airports. In addition to today's traffic, it is predicted that the number of travelers to and from Værnes Airport is going to increase steadily over the next years. It was found that the majority of the traffic (2 mill. trips  $\approx$  60 %) was generated and attracted in Trondheim municipality (Denstadli et al. 2012). The airport is serviced by two airport express buses (Flybussen and Værnesekspresen), train and taxis. Both buses go through the City Center, but they have different routes on the way there. Flybussen's route goes then through the City Center, where the majority of the hotels are served. There are departures every 10 min. in both directions Monday - Friday, from 4:00 from Trondheim and from 7:20 from Værnes Airport. Værnesekspresen runs almost the same route as Flybussen. As opposed to Flybussen, the route goes through eastern parts of the city before reaching the City Center. Værnesekspresen adapts its departure times from Værnes Airport to the plane arrival and departure times (every 15 minutes in peak periods). Both buses need about 30 min. to reach the City Center when going from the airport.

NSB (Norwegian State Railways) trains have hourly departures between Trondheim and Værnes until 9:10 p.m. During the morning and afternoon rush hours the train departures every 30 minutes. The travel time to Trondheim Sentralstasjon (Trondheim Central Station) is 38 min. The current departure pattern and frequency make the train service unlikely to attract customers from the travel time oriented taxi and buss market in the City Center. The airport buses' geographical coverage has its

obvious strength in that they serve a large population area, and that passengers do not have to change to other means of transportation along the way. The way the airport buses' offer is designed today is still a reason to question whether or not this gives disproportionate travel time advantage to car and taxi (Denstadli et al. 2012: 38).

JBV (Norwegian National Rail Administration) in order to improve the capacity of the local rail network plans to develop transportation corridor Trondheim – Steinkjer, which includes i.a. construction of a high-speed, double track railway line between Trondheim City Center and the town of Stjørdal. The railway line would also connect Værnes Airport with Trondheim. It is estimated that the new railway line would improve the local train service significantly by decreasing the onboard travel time, increasing the departure frequency and improving the comfort standard (low floor modern trains would be used) (JBV 2013).

The foreign scientific papers presented in the state-of-the-art review present various research on modal split when accessing various airports in the world and how passengers' travel behavior changes when a new transportation infrastructure, which changes the available transportation services, is introduced. Because of the big future changes in the railway infrastructure in the corridor between the city of Trondheim and Værnes Airport a similar research would supply much useful information for both the local transportation authorities and the scientific community. Different similarities and/or differences between the foreign results may be found and analyzed.

The aim of this work is an attempt to examine the train service's attractiveness today and after the construction of the double track between Trondheim Sentralstasjon and Trondheim Airport, Værnes. Attractiveness of the train service's to the airport was defined as the train's modal share (probability of choosing the train service) compared to other means of transportation, that provide transportation services along the same route as the train. Based on the train's modal share it may be concluded afterwards how useful the development may be for the coverage of the local community's transportation needs. The competitiveness relationship between the airport express buses (Flybussen and Værnesekspressen) and the train on the route Trondheim Sentralstasjon – Værnes Airport was mathematically examined. This was accomplished by using a stated-preference survey, where different abilities of the two means of transportation were presented and varied in several combinations. Respondents were then tasked to select the alternative that he/she finds most attractive. This survey gave then an input for a utility function in a logit model, that illustrated mathematically the benefit observed in selecting the specific means of transportation.

This article begins with a state-of-the-art review introducing similar studies and presenting findings that were basis for this work. Several studies from both Norway and other countries are shortly presented and their results are described. The article continues with a description of the research method used in the study and the data set obtained from the respondents. After that the statistical results are presented mostly in form of figures and tables. The paper ends with a result discussion of both the utility models and other findings.

## State-of-the-art review

Several articles have dealt with ground access to airports and its modal split. After classification and discrete choice modelling conducted in relation to estimating capacity needs for relocated Athens International Airport (Psaraki & Abacoumkin 2002) it was found that passengers were going to be more likely to drive a car (drive and park) and less likely to be dropped off (no parking involved) when accessing the new airport, while lifts (offered a ride by a third party; short term parking involved) and taxi were going to be almost exactly equally attractive (similar modal split percentages) as before. The study included only those four means of transportation and the biggest difference was observed for

domestic business trips. The park and drive option rose by over 8 percentage points (37.09 % vs. 45.63 %), while drop-off and taxi fell by approximately 4 pp. (17.55 % vs. 13.53 % for drop-off and 41.72 % vs. 37.67 % for taxi). The airport ground access mode choice behavior of air passengers traveling overseas from Taiwan was investigated also in a study by Jou et al. (2010). A mixed logit model derived from revealed and stated-preference data was designed to determine the preferences of air passengers for the new airport ground access mode (mass rapid transit system - primarily highway transport: car and bus). An interesting result, that the study came to was that if the in-vehicle time of the high speed railway from the Taipei city center to the airport could be improved by e. g. 10 %, there was likely to be a about 10.84 % increase in the high speed railway's market share, holding all other influences fixed. On the other hand 1 % increase in the in-vehicle time in the mass rapid transit system was found to increase market share by 0.859 %, 0.854 %, 0.865 % respectively for self-driving, pickup, and taxi. Analysis of air passengers' behavior of airport access mode choice was also conducted in Korea, where choice models for airport access mode for the two biggest domestic airports in Korea (Gimpo Airport and Daegu Airport) were developed (Choo et al. 2013). Logistic regression models were then designed, where the types of airport access mode choice modelled were car and public transportation, car and bus, and car and subway. Modal split for each airport and five trip purposes (leisure, return, business, visit relatives/entertainment and other) was developed. A total summary of all the categories was also presented. It was found that the modal split for Gimpo Airport was more equal (27.4 % car, 15.9 % taxi, 31.7 % bus and 25.1 % subway) than for Daegu Airport (43.5 % car, 15.1 % taxi, 15.1 % bus and 7.6 % subway). It was shown that these differences were due to high car and taxi travel cost compared to the public transportation for Gimpo Airport.

Different studies, including those mentioned above, describe also factors that influence passengers' ground access choices. Akar (2013) examined the ground access mode choice decisions of passengers traveling to Columbus Airport in US. Based on respondents' attitudes towards car usage, interest in alternative transportation mode, their socio-demographic background and other factors, binary logit models were designed and used to analyze the passengers' interest in taking alternative means of transportation. The results showed that passengers on business trips, flying alone (or with fewer people), who had already tried to reduce their car usage in general were more likely to choose alternative modes of transportation when accessing the airport. In addition, the most important factors that influenced air passengers' ground access choices were found by asking the respondents if they were very important, important, somewhat important or not important. These, in descending importance for leisure trips, were time of current flight (32.0 % v. important, 40.8 % important), travel time (27.3 % v. important, 39.0 % important), flexibility in departure time (27.3 % v. important, 38.5 % important), comfort (23.6 % v. important, 36.6 % important) and the time of return flight (22.6 % v. important, 35.5 % important). Most important determinants of air passenger's choice in travelers in the New York metropolitan region were studied by Gupta et al. (2008). For nonbusiness trips they turned out to be average yield, access time, and access cost; but demographics and trip characteristics were also significant. The results show e.g. that lower-income groups preferred cheaper means of transportation as compared with higher-income groups and vice versa. Lower-income groups had a higher disutility associated with auto-park, rental cars or taxis, as compared with higher-income groups and they appeared to prefer public transportation modes (rail and bus). The results obtained in study in Taiwan (Jou et al. 2010) from mixed logit model indicated that while out-of-vehicle travel time and in-vehicle travel time were two important factors in affecting travelers' choice of ground access mode to the airport. Besides, passengers were asked to evaluate the importance of factors influencing the choice on airport access modes from very unimportant to very important. The amount of overall time-savings (84.3 % total for important and v. important), the user-friendly nature of the various means of transportation (88.9 %) and no transferring (84 %) were the most crucial attributes. Choo et al. (2013) conducted descriptive analyses to identify whether the key explanatory variables such as trip purpose, travel time, and travel cost were statistically different among ground access modes to the airports. The results from the model indicated that the airport access mode choice was significantly affected by

sociodemographic variables and travel characteristics, such as travel time, travel distance, trip purpose, age, gender, occupation and income. For example, elderly passengers were more likely to travel by car, because they felt uncomfortable in accessing and taking a subway. People with professional and technical jobs tended to choose car also, because of higher incomes and their relatively higher value of time. On the other hand, travel time was significant with a negative coefficient in almost all models. It was also found that bus was more competitive than a car with respect to time and cost for longer travel distance.

Factors influencing passengers' travel behavior to Norway's busiest airports were studied by Denstadli (2012). The study's goal was to identify factors that motivated to choose public transportation modes on trips to and from the busiest airports in Norway. The research was conducted using surveys, interviews with the transportation companies serving the airports and knowledge development based on similar international research projects. The respondents were asked what would have made them to choose public transportation services to the airports on a scale from 1 to 5 (1 – definitely not, 5 – definitely). In Værnes Airport case the respondents admitted that they would have been willing to change to public transportation if they did not have interchange during the trip (47 % of 4 and 5 answers), it would have been easier to get to airport bus stop (49 %) and if the total travel time by public transport was shorter (45 %). A positive response to reduced fares on buses and trains serving airports (27 % of 4 and 5 answers) and better information about public transport services when entering the arrivals hall was also discovered. It also turned out that only 39 % of passengers claimed that they were well familiar with the public transport services to/from Værnes Airport, while 35 % said they were some familiar and 27 % that they were not familiar what so ever. It is also important to note that based on different questions in the surveys conducted in relation to the project, several measures to increase the public transport share when accessing Værnes Airport were identified. These are mainly better train service and from the north, better train service from the area to the south of Trondheim and an airport express bus service between Trondheim City Center and the airport. The last one would have prioritized short travel time onboard, and was estimated to intercept a significant percentage of the taxi share of the marked between the City Center and the airport.

Based on the literature study "Skinnebonus - litteraturstudium" (Tørset & Meland 2002), describing the topic of the so called rail factor, the results of the study may be partly anticipated. The rail factor is a common attribute of all rail means of transportation (train, tram, light-rail etc.), but it is defined differently in the literature. Three different definitions of the rail factor are presented in the study:

- The onboard travel time factor: passengers are willing to travel longer with rail transportation modes
- The constant factor: the rail factor is a constant value which increases the utility of choosing rail modes in the logit model
- The modal split factor: rail modes attract more passengers than other public transportation modes

Several studies, which show that passengers are more willing to choose rail transport instead of bus in a binary choice model, were presented, although the numerical value of the tendency to choose rail modes is different from study to study. For example one of the studies presented in the report (Widlert 1992) shows that passengers travelling by bus would choose train more willingly than bus with the same travel time (31 % bus vs. 46 % train), but not if the travel time gets 20 % longer (76 % bus vs. 20 % train). Passengers travelling by car would on the other be much more willing to choose train in both cases (10 % bus vs 80 % train for this same travel time and 37 % bus and 47 % train for 20 % longer travel time). The rail factor, however, makes rail transportation modes more attractive than bus services regardless of chosen definition of the rail factor. Rail factor has to be determined in each case separately, since it is not a universal value.

## Research method

Stated-preference survey used in this research was experimental, orthogonal, full-factor design with conjoint analysis. This method has been chosen, because it is most often used as a basis for multinomial logit and discrete choice models (Bliemer & Rose 2010). Moreover, factorial designs are common stated-preference methodology in transportation research (Ryeng 1998: 15). Using experimental design means planning an experiment in such a way that an effective analysis of all relevant variables is ensured, and it implies the opportunity to study each independent variable effect on the dependent variable (main effects), simultaneously with any interaction effects. An interaction between two or more independent variables is meant by one interaction effect (Ryeng 1998: 15). On the other hand the orthogonality of an experimental design "relates to the correlation structure between the attributes of the design with designs in which all between attribute correlations are zero being said to be orthogonal. In other words, orthogonal designs ensure that the attribute levels are nicely spread over all choice tasks, and that attribute level combinations do not exhibit a certain (positively or negatively correlated) pattern" (Bliemer & Rose 2010: 3).

In this study the fully-factor design was used. In this type of research all possible combinations of all variables and levels can be found (Ryeng 1998: 15). It is also possible to reduce the extent of the survey by a so-called "fractional factor design" (all response options that can be derived from the "core" can be excluded) (Norheim 1990: 15). This is done because there is an upper limit to how many choice options a respondent can face before his/her concentration decreases. If the respondents are faced with many different choices, there is a certain risk that they get tired and answer contrary to what they actually would have chosen. In this research the full factor design is applied, since the number of options does not exceed sixteen, which is regarded as an acceptable number. An important disadvantage of the fractional factor design is that the lower number of combinations of variables and levels compromises the ability to estimate all interaction effects.

In this stated-preference survey train services with different attributes were compared with one bus service (actually two bus services, that were very similar to each other). It is very important to note that only the airport express bus service was compared with the train service, that is no other transportation modes were included in the stated-preference game. The reason for that was to investigate the relationship between only the most similar transportation services and furthermore keep the survey design very simple. The comparison of the train and bus service was done to find different combinations of factors that make the new train service more attractive (attracts more passengers) than the bus service. Therefore, only train service properties were changed, while factors that described the trip by bus were unchanged (these were based on the actual service quality, while the train service's attributes were based on JBV's forecast (JBV 2013)) in the survey. Only three factors were included in the study, i.e. ticket price, onboard travel time and departure frequency. So low number of variables is due to that the tasks in stated preference surveys should not be too complex. The answers can be unreliable if more than 2-3 variables vary at once (Ryeng 1998: 18). It was therefore necessary to limit the extent of the research. The three factors chosen for the study are called heavy factors, since they are what passengers put the greatest emphasis on when choosing means of transport. As mentioned, attributes of the bus service did not vary, while train service had three factors and each factor had two levels (high and low). This gave eight different options ( $2^3$ ). The attributes with their values used in the stated-preference game are presented in Table 1:

	Train low	Train high	Bus
Onboard travel time [min.]	20	30	30
Departure frequency [min.]	15	25	10
Ticket price [NOK]	50	150	130

Table 1: Attributes of bus and train trip used in the stated-preference survey with their respective values

In the stated-preference game the respondents were presented eight different hypothetical situations (train trip with different attributes vs. unchanged bus service) and asked to choose transportation service that would suit them most, if they were accessible during their trip from the airport to Trondheim. All of the attributes listed in Table 1 consider a trip to the City Center. Before answering the stated-preference questions, the respondents were informed that they needed to take into consideration possible changes to the onboard travel time (this relates only to the bus) and the ticket price if they were travelling to other parts of Trondheim than the City Center. It was also specified that the train went only to the City Center and did not stop on the way there. The respondents had four different answer options to choose from: certainly train, possibly train, possibly bus and certainly bus, that later were simplified to just «train» and «bus» when the data set was analyzed.

The central part of the survey was the stated-preference game. Its purpose was to determine the competitive relationship between the train and the airport express buses after the construction of double track, meaning the modal share after the investment. The competitiveness was studied on the distance between Trondheim Sentralstasjon and Værnes Airport. In addition to the stated-preference game, a number of additional multiple choice questions were also asked.

At the beginning the survey asked about the respondent's background, that is gender, age and the respondent's final destination point in Trondheim. The person was then asked about the trip he/she was undertaking, which includes questions about the number of luggage, type of transportation mode the respondent was actually choosing and type of trip the respondent was undertaking (business or leisure trip). The respondent was finally asked what he/she thought about the current train service between Trondheim Sentralstasjon and Værnes Airport. The questions focused on the reasons why the respondent took or did not take the train to the airport. If the person was planning to use the train, the respondent answered why he/she had chosen to do this. If the respondent was going to use another means of transportation the person was asked what kind of a change needed to take place, so that he/she would have chosen the train.

A utility model was then constructed based on the answers from the respondents. In the analysis four major variables were used: difference in onboard travel time, difference in egress time (time used to travel from the train station or the bus stop to the final destination), difference in departure frequency and difference in ticket price. The egress time was not included directly in the stated-preference game as a variable. It was included in the utility models though, since this was a part of the journey, which the respondents were asked to take into consideration to achieve the highest possible realism in the hypothetical situations. All of the variables were calculated by subtracting the attribute value for the train from the attribute value for the bus (e. g. ticket price bus – ticket price train). The differences were used to compare exactly both transportation services and find the most and the least favorable cases for the hypothetical train service. Other variables such as gender, age, leisure/business trip or the final destination district were used in miscellaneous more detailed analyses.

To produce the utility models the binary logistic regression function in SPSS program was used. The dependent variable in the logistic regression was the simplified choice between train and bus (instead of “certainly train”, “possibly train”, “possibly bus” and “certainly bus” as described above). The variables used were the four variables presented above (difference in onboard travel time, difference in egress time, difference in departure frequency and difference in ticket price). Depending on the model's focus, the data set was limited to certain field, e.g. only trips to the City Center were used by the logistic regression function.

## The data set

The survey was conducted in March 2016 at Værnes Airport inside the arrival hall. The respondents were most often passengers who had just arrived by plane to the airport and were about to take their trip to the city. This means that only people travelling from Værnes to Trondheim were asked. The final respondent group which answered all the questions in the survey was 291 people.

The respondent group corresponded well with the Norwegian demographics statistics. The percentage men and women participating in the survey were approximately the same as in the Norwegian society (52,9 % men and 47,1 % women in the study, and 50,4 % men and 49,6 % women in the whole society (SSB c)). On the other hand the age distribution was slightly different in the respondent group than in the society. There was a significant overrepresentation of younger age groups, such as 20-24, 30-34 and 35-39. This may be due to that Trondheim is a university city, that attracts many trips undertaken by young people. The small underrepresentation of older age groups may be due to changed travel pattern for people over 65 years old, who travel up to three times less than younger adult people (SSB d). The age distribution is presented in Table 2:

Age	Percentage in society (only age group of 15-84 included)	Percentage in the survey
15-19	7,85%	6,19%
20-24	8,23%	12,71%
25-29	8,71%	6,19%
30-34	8,41%	12,71%
35-39	8,25%	12,37%
40-44	8,89%	12,71%
45-49	9,04%	4,81%
50-54	8,26%	8,25%
55-59	7,63%	5,84%
60-64	6,99%	5,15%
65-69	6,71%	4,48%
70-74	5,07%	7,22%
75-79	3,48%	1,03%
80-84	2,50%	0,34%
<b>Total</b>	100,00%	100,00%

Table 2: Age distribution in the data set compared with age distribution in the Norwegian society.

73 % of the respondents were on a leisure trip, while only 27 % were on a business trip. The transportation mode chosen by the respondents was most often one of the airport buses (the survey did not make a distinction between Værnesekspresen and Flybussen). The modal split is shown in Figure 3. Almost half of the whole respondent group (42 % + 5 %) chose the bus service from the airport, while only 16 % (14 % + 2 %) chose today's train service. This means that the public transportation share from the airport to the city was at 63 %. The results in Figure 3 can be compared to the modal split information presented by Denstadli (2012) (Figure 1). The public transportation share was found there to be at 45 %, which was much lower than in this case. This high level was partly due to the high train share, which was over double as high as the one found by Denstadli. The airport bus share was also almost 10 percent points higher. A quite significant difference was also observed for car, parked, that turned out to be almost half the size of that found in 2012. The differences in the data sets can be explained by both the size of this study's respondent group, which may cause an underrepresentation of some group, as well as the distance in time between these two studies (four

years). Another possible explanation is difference in the time during the day at which the data collection was conducted, although there is no information how big this difference may have been.

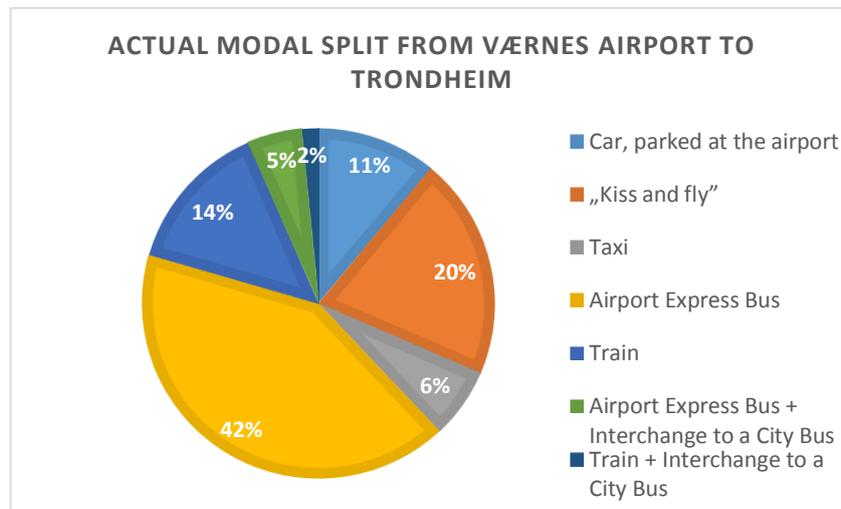


Figure 3: Actual modal split from Trondheim Airport, Værnes to Trondheim

It was also found that the biggest part of the respondent group was travelling to the City Center (Figure 4). Other part of Trondheim had significantly lower shares of the trips to the city. The percentage distribution can be compared with the map over Trondheim (Figure 4).

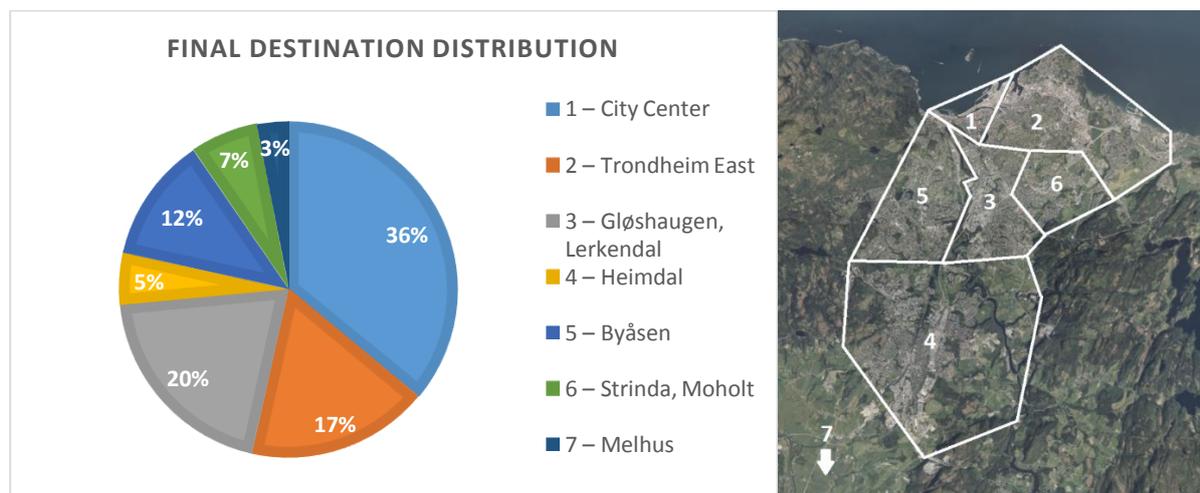


Figure 4: Final destination distribution and a map over Trondheim with districts assigned their respective numbers

## Results

### Utility models

It was found that only 66 % of the travelers to the city found the new possible train service relevant. This means that 34 % of the respondents was not willing to even consider choosing the new train service regardless of the service quality it would provide. The stated-preference part of the survey was then completed by only 192 respondents. Table 3 shows the frequency and percentage share for each answer option in the stated-preference game. Each respondent answered eight times (eight hypothetical situations), which makes total of 2 328 different answers included those who did not participate in the stated-preference game.

	Frequency	Share
<b>Certainly train</b>	468	20.1%
<b>Possibly train</b>	241	10.4%
<b>Possibly bus</b>	223	9.6%
<b>Certainly bus</b>	604	25.9%
<b>Did not answer</b>	792	34.0%
<b>Total</b>	2328	100.0%

Table 3: Frequency and percentage share for each answer option in the stated-preference survey included the respondents that did not participate

In table 4 the basic utility model, based on the whole data set, is presented.

	B	S.E.	Wald	Sig.	Exp(B)	N
<b>Δ onboard travel time</b>	,043	,009	21,635	,000	1,043	2328
<b>Δ egress time</b>	,133	,010	188,955	,000	1,142	
<b>Δ departure frequency</b>	,216	,013	260,244	,000	1,241	
<b>Δ ticket price</b>	,006	,001	20,079	,000	1,006	
<b>Constant</b>	2,658	,175	229,516	,000	14,274	

Table 4: The basic utility model, N – number of cases in analysis

which gives the following formula:

$$U_{Bus} = 2.658 + 0.043x_1 + 0.133x_2 + 0.216x_3 + 0.006x_4$$

where:

- $x_1$  - Δ onboard travel time
- $x_2$  - Δ egress time
- $x_3$  - Δ departure frequency
- $x_4$  - Δ ticket price

The utility functions produced this way gave the utility for choosing the bus service dependent on different attributes of the trip. To calculate the probability of choosing the bus the utility value was substituted into the logit model probability function:

$$P_{Bus} = \frac{1}{1 + e^{U_{Bus}}} \times 100 \%$$

where:

- $P_{Bus}$  – probability for choosing bus
- $U_{Bus}$  – utility value of choosing bus

It was further possible to develop more detailed models for each district in Trondheim. It was done by including only trips made to the particular district, which made the respondent group even smaller compared to the original one. Because of that, only three models were finally created, including those, that had the biggest data basis. Additional models were also created, where distinction between genders, journey type (leisure or business), number of luggage and means of transportation actually used on the trip was made. All models are summarized in Table 5, Table 6, Table 7, Table 8 and Table 9:

Final destination							
		B	S.E.	Wald	Sig.	Exp(B)	N
City Center	Δ onboard travel time	,073	,019	15,168	,000	1,076	736
	Δ egress time	,209	,021	99,960	,000	1,233	
	Δ departure frequency	,247	,021	139,328	,000	1,280	
	Δ ticket price	,007	,002	15,168	,000	1,007	
	Constant	3,159	,290	118,405	,000	23,546	
		B	S.E.	Wald	Sig.	Exp(B)	N
Trondheim East	Δ onboard travel time	,041	,026	2,428	,119	1,042	344
	Δ egress time	,165	,023	53,070	,000	1,179	
	Δ departure frequency	,201	,028	51,002	,000	1,223	
	Δ ticket price	,004	,003	2,428	,119	1,004	
	Constant	3,045	,395	59,500	,000	21,006	
		B	S.E.	Wald	Sig.	Exp(B)	N
Gløshaugen, Lerkendal	Δ onboard travel time	,095	,030	9,905	,002	1,100	320
	Δ egress time	-,011	,022	,256	,613	,989	
	Δ departure frequency	,246	,037	43,354	,000	1,279	
	Δ ticket price	,005	,003	3,102	,078	1,005	
	Constant	-1,470	,844	3,031	,082	,230	

Table 5: Utility models for three districts in Trondheim with the biggest data basis

Gender							
		B	S.E.	Wald	Sig.	Exp(B)	N
Only men	Δ onboard travel time	,053	,013	16,749	,000	1,054	792
	Δ egress time	,130	,013	101,702	,000	1,139	
	Δ departure frequency	,233	,019	147,946	,000	1,262	
	Δ ticket price	,006	,002	10,240	,001	1,006	
	Constant	2,892	,252	131,710	,000	18,036	
		B	S.E.	Wald	Sig.	Exp(B)	N
Only women	Δ onboard travel time	,031	,013	5,651	,017	1,032	744
	Δ egress time	,138	,015	87,958	,000	1,148	
	Δ departure frequency	,203	,019	113,135	,000	1,225	
	Δ ticket price	,006	,002	10,027	,002	1,006	
	Constant	2,471	,248	99,025	,000	11,835	

Table 6: Utility models for each gender

Journey type							
		B	S.E.	Wald	Sig.	Exp(B)	N
Only leisure journeys	Δ onboard travel time	,051	,011	21,972	,000	1,052	1 112
	Δ egress time	,136	,011	145,930	,000	1,145	
	Δ departure frequency	,206	,016	172,151	,000	1,229	
	Δ ticket price	,005	,001	11,067	,001	1,005	
	Constant	2,433	,203	144,129	,000	11,394	
		B	S.E.	Wald	Sig.	Exp(B)	N
Only business journeys	Δ onboard travel time	,033	,018	3,191	,074	1,033	424
	Δ egress time	,131	,020	44,275	,000	1,140	
	Δ departure frequency	,248	,026	89,081	,000	1,281	
	Δ ticket price	,008	,002	10,098	,001	1,008	
	Constant	3,243	,358	81,991	,000	25,618	

Table 7: Utility models for each journey type

Number of luggage							
		B	S.E.	Wald	Sig.	Exp(B)	N
No checked luggage	Δ onboard travel time	,019	,020	,931	,335	1,019	304
	Δ egress time	,108	,022	25,347	,000	1,115	
	Δ departure frequency	,195	,030	43,649	,000	1,216	
	Δ ticket price	,004	,003	2,317	,128	1,004	
	Constant	2,059	,371	30,877	,000	7,839	
		B	S.E.	Wald	Sig.	Exp(B)	N
1 piece of checked luggage	Δ onboard travel time	,049	,011	20,228	,000	1,050	1 104
	Δ egress time	,135	,011	145,898	,000	1,145	
	Δ departure frequency	,213	,016	181,020	,000	1,237	
	Δ ticket price	,006	,001	14,676	,000	1,006	
	Constant	2,675	,208	165,519	,000	14,510	
		B	S.E.	Wald	Sig.	Exp(B)	N
2 pieces of checked luggage	Δ onboard travel time	,031	,058	,281	,596	1,031	80
	Δ egress time	,191	,081	5,582	,018	1,210	
	Δ departure frequency	,289	,074	15,462	,000	1,336	
	Δ ticket price	,014	,006	4,879	,027	1,014	
	Constant	3,840	1,006	14,558	,000	46,534	

Table 8: Utility models dependent on number of checked luggage

Means of transportation actually used on the journey							
		B	S.E.	Wald	Sig.	Exp(B)	N
<b>Car, parked at the airport</b>	Δ onboard travel time	-,099	,107	,849	,357	,906	80
	Δ egress time	,193	,119	2,651	,104	1,213	
	Δ departure frequency	2,004	654,652	,000	,998	7,420	
	Δ ticket price	,021	,014	2,412	,120	1,022	
	Constant	9,206	3273,260	,000	,998	9958,918	
		B	S.E.	Wald	Sig.	Exp(B)	N
<b>Car passenger</b>	Δ onboard travel time	,110	,026	17,702	,000	1,117	232
	Δ egress time	,159	,029	29,410	,000	1,173	
	Δ departure frequency	,270	,039	47,104	,000	1,310	
	Δ ticket price	,006	,003	2,885	,089	1,006	
	Constant	2,269	,456	24,741	,000	9,669	
		B	S.E.	Wald	Sig.	Exp(B)	N
<b>Bus</b>	Δ onboard travel time	,023	,015	2,566	,109	1,024	728
	Δ egress time	,068	,014	22,558	,000	1,070	
	Δ departure frequency	,329	,026	162,958	,000	1,389	
	Δ ticket price	,008	,002	15,949	,000	1,008	
	Constant	2,417	,259	86,731	,000	11,209	
		B	S.E.	Wald	Sig.	Exp(B)	N
<b>Train</b>	Δ onboard travel time	,004	,040	,012	,913	1,004	328
	Δ egress time	,140	,055	6,591	,010	1,151	
	Δ departure frequency	,209	,056	13,718	,000	1,233	
	Δ ticket price	,016	,005	10,365	,001	1,016	
	Constant	4,863	,823	34,875	,000	129,408	

Table 9: Utility models for each means of transportation

### Model applications

Based on the utility models for the three districts presented in Table 5, a probability value of choosing the train could be obtained for those areas. In this case two most extreme situations for each district were put in the models in order obtain the lowest and highest possible probability values for choosing the train service to Trondheim Sentralstasjon and then continuing the journey by other transportation mode. Also the most equal situation, where the competitive transportation services were almost equal in quality, and a situation with today's train service were examined. The most train favorable situation describes the condition, when it was most convenient to choose the train instead of the airport express bus. On the other hand, the least train favorable situations describe the condition, when the passenger saves most time (both as onboard travel time and egress time) and money choosing the bus. The attributes were calculated by subtracting the attribute value for the train from the attribute value for the bus. The situations put in the models are presented in table 10:

<b>City Center</b>				
	Most train favorable	Least train favorable	Most equal	Actual (today's)
<b>Δ onboard travel time [min.]</b>	10	0	0	-5
<b>Average Δ egress time [min.]</b>	-5	-5	-5	-5
<b>Δ departure frequency [every min.]</b>	-5	-15	-5	-50
<b>Δ ticket price [NOK]</b>	80	-20	0	50
<b>Trondheim East</b>				
	Most train favorable	Least train favorable	Most equal	Actual (today's)
<b>Δ onboard travel time [min.]</b>	6	-4	0	-5
<b>Average Δ egress time [min.]</b>	-7,5	-7,5	-7,5	-7,5
<b>Δ departure frequency [every min.]</b>	-5	-15	-5	-50
<b>Δ ticket price [NOK]</b>	80	-20	0	50
<b>Gløshaugen, Lerkendal</b>				
	Most train favorable	Least train favorable	Most equal	Actual (today's)
<b>Δ onboard travel time [min.]</b>	30	15	0	-5
<b>Average Δ egress time [min.]</b>	-25	-25	-25	-25
<b>Δ departure frequency [every min.]</b>	-5	-15	-5	-50
<b>Δ ticket price [NOK]</b>	80	-20	0	50

Table 10: Attributes for each situation used to calculate the probability values

Two examples with most extreme values were investigated. Those extreme situations were most and least train favorable combinations of variable values (Table 10) corresponding with the attributes for the train service shown in Table 1, where the most favorable values are placed in the column “train low” and the least favorable in “train high”. Extreme differences were found after modeling those situations. Very high values were noticed for the most train favorable situation (90 %, 80 % and 70 % for the City Center, Trondheim East and Gløshaugen, Lerkendal respectively). On the other hand the probability for travelling by train decreased to quite small numbers (15 %, 19 % and 3 % for the City Center, Trondheim East and Gløshaugen, Lerkendal respectively).

Further the most equal situation was examined. This included the same onboard travel time and ticket price. The departure frequencies for the train and the bus were also set to be very similar, but not equal, since 10 min. departure frequency for train would be unrealistic on this route (JBV 2013). The obtained results for the City Center and Trondheim East (71 % and 69 % respectively) were very similar to those obtained in the most train favorable situation. The Gløshaugen, Lerkendal value, on the other hand, was found to be much lower than the other ones and it was much closer to the respective value from the least train favorable situation (8 %).

Lastly, today’s train service attributes were inserted into the model in order to compare its output with the statistics on ground access modal split between Værnes and Trondheim (Figure 1). It was found that by substituting 38 min. onboard travel time, 60 min. departure frequency and 80 NOK ticket price, which are characteristic for the current train service, the probability for choosing the train service decreased to less than 0,1 % for the City Center and Trondheim East, whilst it was approximately 0 % for Gløshaugen, Lerkendal.

In every situation the difference in the egress time was an average value, that is each egress time value multiplied by the respective number of respondents and divided by the total number of respondents for the district. By doing so, the situations got much more representative than if only the most extreme values for difference in egress time were used, which may be related to very few respondents.

Figure 5 presents the probability results for choosing the train service obtained from substituting values from Table 10 into the utility functions obtained from Table 5:



Figure 5: Probability distribution for choosing the train service assuming most train favorable situation, least train favorable situation, most equal situation and today's situation respectively

Frequency analyses

Based on the obtained data set many other analyses of the passengers' travel behavior have been conducted. Only the most significant results are presented here. Table 11 shows the respondents' answers regarding what they valued most on an average trip to an airport in general (that is regardless what airport this was). It is important to note that only two most important factors could be chosen from among all the options presented. 34 % of 291 respondents did not answer, since they did not participate in the stated-preference game (had previously answered that the train service was irrelevant for them), which was a necessary condition to answer this question.

Share agreed				
Statement	All (N=193)	City Center (N=92)	Trondheim East (N=43)	Gløshaugen, Lerkendal (N=40)
Total travel time	86%	84%	74%	100%
Few (preferably no) interchanges	33%	47%	28%	18%
Enough time between interchanges	8%	5%	14%	10%
Punctuality	6%	9%	5%	3%
Frequent departures	44%	27%	47%	63%
Comfort	22%	24%	33%	10%
Short distance to the station/bus stop	6%	7%	2%	10%

Table 11: Most important attributes of an airport ground access trip. “What is most important for you when travelling to/from an airport (despite of the ticket price)? Choose to most important trip attributes”.

It can be clearly seen that the most popular option is “total travel time”, which includes all of the time spent on travelling from the final destination to the airport or vice versa. “Few (preferably no) interchanges” and „frequent departures” were also quite popular answers among the respondents. It can be seen that the answers for Gløshaugen, Lerkendal were quite different from the other ones. The share agreed for both total travel time and frequent departures was significantly higher than in the other districts.

It was also examined why the future train service would not be relevant for some passengers anyway. The reasons given by those respondents who did not participate in the stated-preference game are presented in Table 12. The respondents were able to choose multiple answers in the question “Why is it irrelevant for you travel to/from Værnes Airport by train?”:

Share agreed				
Statement	All (N=128)	City Center (N=19)	Trondheim East (N=16)	Gløshaugen, Lerkendal (N=32)
The station is too far away	95%	79%	94%	94%
The trains departure frequency is too low	41%	42%	63%	47%
The city buses' departure frequencies are too low	44%	26%	63%	63%
The interchange costs too much	11%	16%	13%	16%
It is necessary to interchange	49%	47%	63%	59%
The city bus connections are too bad/few	58%	32%	81%	66%

Table 12: Reasons why some respondents do not see the future train service relevant for them. “Why is the train service irrelevant for you?”

## Results discussion

Although the data set used in the study was quite small in some models, the respondents did represent passengers travelling from Værnes Airport to Trondheim quite well in terms of age, gender and used transportation mode. A clear trend can be seen in the obtained results concerning the probability of choosing the train service to different parts of the city. Both the most and least favorable train situation presented in Figure 5 relate only to the most extreme conditions. This means that the actual, mean probability of choosing the train service, while travelling to each district will lie somewhere between

those values. The hypothetical situation closest to the possible future probability for choosing the train service, which was achieved by model application, was the most equal situation. This situation favored neither the train nor the bus and allows to compare almost identical transportation services. This showed that the new train service had a very high chance for effective competitiveness against the bus service, that is to take over many passengers from different transportation modes, but mainly the bus. This would bring a significant change in the ground access modal split to/from Værnes Airport, by increasing the overall train service share way above today's 7 % (Figure 1) or even 16 % (Figure 3).

It can be also observed that the probability values in the most equal situation, where the attributions for the train and bus trip are very similar to each other, were closer to the most train favorable situation, than to the least train favorable situation. This supports the rail factor concept (Tørset & Meland 2002), which says that rail modes attract more passengers than other public transportation modes, since the majority of the passengers would choose the train service over the bus service, when their attributes are very similar.

Farther the final destination was from Trondheim Sentralstasjon, the probability for travelling by the train got lower. The most possible explanation to this is the fact that passengers need to interchange to either a taxi or a city bus, which is challenging at the train station, since it is not an important public transportation node in the city. Only a few bus lines with few hourly departures service Trondheim Sentralstasjon, while the biggest public transport node, Sentrumsterminalen (The City Center bus terminal) is located about 1 km away walking from the station. This makes any possible interchange unattractive, which was supported by the respondents answers concerning reason why they do not find the train service relevant (Table 12). Other important factor was the distance from the train station itself. Many parts of the city lie simply too far away from Trondheim Sentralstasjon, which often makes the total travel time to the final destination too long (Table 12). This may be also seen in the ratio between the coefficients for onboard travel time and egress time. The difference in the egress time between the two transportation modes was most often valued much more than the difference in the onboard travel time, which means that the respondents assign much bigger value to the time used on accessing the bus or the train. This ratio had most often a value of approximately 3 or 4. This makes even a slight change in the egress time having a big impact on the probability of choosing the train service. This corresponds quite well with findings that no interchange and total travel time (overall time-savings) are the most crucial properties of the trips (Jou et al. 2010, Denstadli 2012), as long egress time to bus or train means most often changing to a city bus or other means of transportation. It can be observed e. g. that egress time in relation to onboard time is much more important for women than for men and for passenger on business trips than for passengers on leisure trips.

The variable constant for departure frequency turned out to have the highest value in every model, which clearly underlines its importance, since even a small change in the departure frequency had a significant effect of the total utility of choosing the transportation mode. This corresponds well with the respondents' answers about two most important attributes of a trip from airport (Table 11). On the other hand the ticket price had the lowest value. This meant that even if high ticket prices were substituted into the utility function, the ticket price product had a very low importance comparing to other attributes. This may be explained by general high time-valuing in Norway (Østli et al. 2015). The monetary value of time for the model was not calculated, since it was not included in the scope of this study. Anyhow, this relatively low importance of the ticket price was somewhat similar to the observation made by Denstadli (2012), where a positive response to reduced fares on buses and trains serving airports were found, but simultaneously it had not a very significant effect on choosing transportation mode in airport ground access.

The model was also tested with today's train service attributes and compared with the modal split already observed at the airport (Figure 1 and Figure 3). The model results indicate that there should

be approximately no trips made by the train to the city. A conclusion drawn based on this fact could be that the utility model was very inaccurate, since it did not model the today's modal share of the train even approximately. This error may although be explained by the fact that in this case the model worked outside its area, that is attributes which were substituted into the utility function differed a lot from those used in the hypothetical situations in the stated-preference game. This contributed to the fact that the results were very hypothetical and may not correspond with the actual modal split. This explanation is supported by the fact that the today's modal share of the train service was found to be over twice the size of the one found by Denstadli. This excludes the possibility that the respondents' answers obtained through the survey underrepresent the actual modal share of the train service in the airport ground access.

## Conclusion

In this study the future competitiveness between airport express bus and train service on route between city of Trondheim and Trondheim Airport, Værnes was investigated. Only those two transportation modes were researched, since they are very similar public transportation services, which are going to become very serious competitors after a double track railway line is going to be built between Trondheim City Center and Værnes Airport. A questionnaire consisted of both multiple choice questions covering respondents' background and their opinions on today's and future train service, and a stated-preference game was used to collect data among plane passengers at the arrival hall at Værnes Airport. The results of the stated-preference game showed that the future train service from the City Center to the airport will most probably take over many passengers travelling by bus today, because of the train's high modal share. By setting up utility models for the most trip attractive districts in Trondheim it was found that the train service will be very popular in the City Center and in Trondheim East district, even if both transportation services had very similar attributes (onboard travel time, departure frequency and ticket price). On the other hand, in the district Gløshaugen, Lerkendal, that was also examined, the train service will be chosen much less often, most probably because of the long egress time when travelling by the train via the City Center.

Egress time (the time used on reaching the final destination after leaving the bus or the train) was found to have the biggest impact on the probability of choosing the future train service. A clear correlation between a long average egress time and comparatively very low probability for choosing the train service was found. The transportation service's departure frequency had also a significant impact on the overall utility value. It could be seen that, today's train service's attributes (i.a. 60 min. departure frequency) substituted into the utility model gave an extremely low probability for choosing the train.

In terms of important factors influencing choice of the train service the distance from the train station to the final destination, city bus connection to/from the train station and the need to interchange to other means of transportation at the train station were found to have the biggest importance for the passengers. Furthermore the total travel time, frequent departures and few (preferably no interchanges) were found to be the most important factors at airport ground access trip in general. Those results suit very well with the findings that egress time has the biggest impact on the probability of choosing the train service.

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# Appendices



## Appendix 1 – The first version of the survey (fall 2015)

1. Du er:

- Kvinne
- Mann

2. Hvor gammel er du?

.....

3. Du er på:

- Forretningsreise
- Fritidsreise

4. Hvor mange stykker innsjekket bagasje har du med deg/pleier du å ha med deg?

- Kun håndbagasje
- 1 koffert
- 2 kofferter
- Flere enn 2 kofferter

5. Hvor skal du til/kommer du fra?

- Trondheim sentrum (inkl. Ila, Møllenberg)
- Trondheim øst (Lade, Strindheim, Jacobsli, Ranheim)
- Lerkendal, Singsaker, Berg, Nardo, Tempe
- Heimdal (inkl. Tiller, Kolstad, Flatåsen, Katterm)
- Byåsen (inkl. Sverresborg, Uгла, Hallset, Selsbakk)
- Strinda (inkl. Moholt, Tyholt, Risvollan, Angeltrøa)
- Melhus
- Annet sted i Trondheim (vennligst spesifiser): .....

6. Hvordan kom du til Værnes/drar du hjem?

- Kjørte bil selv, parkerte på flyplassen
- Ble kjørt, «kiss and fly»
- Drosje

- Flybussen
- Værnesekspresen
- Toget
- Kombinasjon av flere: .....
- Annet: .....

7. **Hvis du valgte tog:** vennligst kryss av de påstandene som best beskriver hvorfor du valgte tog til flyplassen:

- Det er raskt
- Slipper å bytte transportmiddel underveis
- Det er billig
- Det er komfortabelt
- Det er lite forsinkelser
- Det er fleksibelt
- Annet: .....

8. **Hvis du ikke valgte tog:** hvilken endring må til for at du skal velge tog (du kan velge flere):

- Ingen, det er uaktuelt å reise med tog
- Kortere reise tid
- Flere avganger
- Bedre punktlighet
- Andre avgangstider
- Bedre korrespondanse med andre transportmidler
- Lavere billettpris
- Bedre komfort
- Flere sitteplasser
- Bedre muligheter til å jobbe underveis
- Lettere å komme til/fra stasjonen

9. Hva er viktigst for deg ved en reise til/fra flyplass (bortsett fra billettprisen)? Ranger fra viktigst til minst viktig:

- ..... Den totale reisetiden
- ..... Få bytter ( gjerne ingen)
- ..... Gode byttetider (kort ventetid mellom de ulike transportmidler)

- ..... Punktlighet
- ..... Komfort
- ..... Kort avstand fra/til stasjonen til/fra reisemålet

Hvor lang kan den maks. være: .....

10. Tenk deg en reise fra Værnes til Trondheim S. Hvilken reisemåte ville du valgt?

**Situasjon 1**

Transportmiddel	Tog	Flybuss
Avgangsfrekvens	15 min.	10 min.
Reisetid ombord	20 min.	30 min.
Billettpris	120 kr	130 kr

**Situasjon 2**

Transportmiddel	Tog	Flybuss
Avgangsfrekvens	25 min.	10 min.
Reisetid ombord	20 min.	30 min.
Billettpris	120 kr	130 kr

**Situasjon 3**

Transportmiddel	Tog	Flybuss
Avgangsfrekvens	15 min.	10 min.
Reisetid ombord	30 min.	30 min.
Billettpris	120 kr	130 kr

**Situasjon 4**

Transportmiddel	Tog	Flybuss
Avgangsfrekvens	25 min.	10 min.
Reisetid ombord	30 min.	30 min.
Billettpris	120 kr	130 kr

**Situasjon 5**

Transportmiddel	Tog	Flybuss
Avgangsfrekvens	15 min.	10 min.
Reisetid ombord	20 min.	30 min.
Billettpris	90 kr	130 kr

**Situasjon 6**

Transportmiddel	Tog	Flybuss
Avgangsfrekvens	25 min.	10 min.
Reisetid ombord	20 min.	30 min.
Billettpris	90 kr	130 kr

### Situasjon 7

Transportmiddel	Tog	Flybuss
Avgangsfrekvens	15 min.	10 min.
Reisetid ombord	30 min.	30 min.
Billettpris	90 kr	130 kr

### Situasjon 8

Transportmiddel	Tog	Flybuss
Avgangsfrekvens	25 min.	10 min.
Reisetid ombord	30 min.	30 min.
Billettpris	90 kr	130 kr

11. Hva gjør eventuelt at du ikke ønsker å ta tog fra Værnes til Trondheim S?

.....

12. Hvis reisemålet ditt ikke var i Trondheim sentrum: Tenk deg at toget mellom Værnes og Trondheim S kjører hver 15 min., og at reisetiden er 20 min. Hvor sannsynlig er at du velger å ta toget til Trondheim S, og deretter bytter til et annet transportmiddel (buss eller drosje)?

- Veldig sannsynlig
- Ganske sannsynlig
- Ganske usannsynlig
- Veldig usannsynlig
- Vet ikke

13. Hva gjør at du er skeptisk mot å ta tog fra Værnes til Trondheim S, og så bytte til et annet transportmiddel?

- Reisemålet mitt ligger for langt unna Trondheim S (den totale reisetiden blir for lang)
- Frekvensen på toget er for lav
- Frekvensen på kollektivtilbudet er for lav
- Å reise med kollektivtransport/drosje i Trondheim koster for mye
- Det er for tungvint med bytte (flytte bagasjen osv.)
- For få busslinjer kjører rett ved Trondheim S
- Annet: .....

# Appendix 2 – The final version of the survey (1<sup>th</sup> of March)

## Del 1

1. Du er:

- Kvinne
- Mann

2. Hvor gammel er du?

.....

3. På hva slags type reise er du på? Forretningsreise er alle typer reiser knyttet til din jobb, mens fritidsreiser er alle andre typer reiser. NB! Å komme tilbake fra ferien til studiestedet ditt telles som en fritidsreise.

- Forretningsreise
- Fritidsreise

4. Hvor mange stykker innsjekket kolli har du med deg?

- Ingen, kun håndbagasje
- 1 stykke kolli
- 2 stykker kolli
- Flere enn 2 stykker kolli

5. Hvor skal du til i Trondheim?

- Trondheim sentrum (inkl. Ila, Møllenberg)
- Trondheim øst (Lade, Strindheim, Jacobsli, Ranheim)
- Gløshaugen, Lerkendal, Singsaker, Berg, Nardo, Tempe

Dato:

Tidspunkt:

Sted:

Intervjuer:

- Heimdal (inkl. Tiller, Kolstad, Flatåsen, Kattem)
- Byåsen (inkl. Sverresborg, Uгла, Hallset, Selsbakk)
- Strinda (inkl. Moholt, Tyholt, Risvollan, Angeltrøa)
- Melhus
- Annet sted i Trondheim (vennligst spesifiser): .....

6. Hvordan drar du til reisens endepunkt?

- Med egen bil, parkering på flyplassen
- Som passasjer i bil, «kiss and fly»
- Drosje
- Flybuss (Flybussen eller Værnesekspressen)
- Tog
- Kombinasjon av flere: .....
- Annet: .....

7. **Hvis du skal ta tog:** vennligst kryss av de påstandene som best beskriver hvorfor du valgte tog til flyplassen (sett ett eller flere kryss):

- Det er raskt
- Det er billig
- Det er komfortabelt
- Det er lite forsinkelser
- Det er fleksibelt
- Annet: .....

8. **Hvis du ikke skal ta tog:** hvilken endring må til for at du skal velge tog (sett ett eller flere kryss):

- Ingen, det er uaktuelt å reise med tog
- Kortere reise tid

- Flere avganger
- Bedre punktlighet
- Andre avgangstider
- Bedre korrespondanse med andre transportmidler
- Lavere billettpris
- Bedre komfort
- Flere sitteplasser
- Bedre muligheter til å jobbe underveis
- Lettere å komme til/fra stasjonen

**NB! Gå over til Del 3 (side 8) hvis du svarte «Ingen, det er uaktuelt å reise med tog» i forrige spørsmål.**

9. Hva er viktigst for deg ved en reise til/fra flyplass (bortsett fra billettprisen)? Velg to viktigste reiseegenskapene.

- Den totale reisetiden
- Få bytter ( gjerne ingen)
- Gode byttetider (kort ventetid mellom de ulike transportmidler)
- Punktlighet
- Hyppige avganger
- Komfort
- Kort avstand fra/til stasjonen til/fra reisemålet

Hvor lang kan den maks være (i min): .....

## Del 2

Du vil nå bli presentert for 8 ulike hypotetiske situasjoner:

10. Tenk deg at du skal gjennomføre den samme reisen som nå, men at du kun har mulighet til å velge mellom tog og flybuss. Du kan gå av og på flybussen der du vanligvis gjør det. Toget kjører direkte mellom Trondheim S og Værnes uten stopp. Hvilket reisemiddel ville du valgt i hver situasjon? **NB!** Husk å ta hensyn til andre forhold ved reisen som kan være viktige for deg. Dette kan være f. eks. nødvendig bytte, avstand mellom togstasjonen og avgangshallen på Værnes eller avstanden fra besøksstedet/bostedet ditt til bussholdeplassen din.

Transportmiddel	Situasjon 1	
	Tog	Flybuss
Avgangsfrekvens	15 min.	10 min.
Reisetid Trondheim S - Værnes	20 min.	30 min.
Billettpris	150 kr	130 kr

I situasjon 1 velger jeg:

- Helt sikkert tog
- Sannsynligvis tog
- Sannsynligvis flybuss
- Helt sikkert flybuss

Transportmiddel	Situasjon 2	
	Tog	Flybuss
Avgangsfrekvens	25 min.	10 min.
Reisetid Trondheim S - Værnes	20 min.	30 min.
Billettpris	150 kr	130 kr

I situasjon 2 velger jeg:

- Helt sikkert tog
- Sannsynligvis tog
- Sannsynligvis flybuss
- Helt sikkert flybuss

Transportmiddel	Situasjon 3	
	Tog	Flybuss
Avgangsfrekvens	15 min.	10 min.
Reisetid Trondheim S - Værnes	30 min.	30 min.
Billettpris	150 kr	130 kr

I situasjon 3 velger jeg:

- Helt sikkert tog
- Sannsynligvis tog
- Sannsynligvis flybuss
- Helt sikkert flybuss

Situasjon 4		
	Tog	Flybuss
Transportmiddel		
Avgangsfrekvens	25 min.	10 min.
Reisetid Trondheim S - Værnes	30 min.	30 min.
Billettpris	150 kr	130 kr

I situasjon 4 velger jeg:

- Helt sikkert tog
- Sannsynligvis tog
- Sannsynligvis flybuss
- Helt sikkert flybuss

Situasjon 5		
	Tog	Flybuss
Transportmiddel		
Avgangsfrekvens	15 min.	10 min.
Reisetid Trondheim S - Værnes	20 min.	30 min.
Billettpris	50 kr	130 kr

I situasjon 5 velger jeg:

- Helt sikkert tog
- Sannsynligvis tog
- Sannsynligvis flybuss
- Helt sikkert flybuss

	Situasjon 6	
	Tog	Flybuss
Transportmiddel		
Avgangsfrekvens	25 min.	10 min.
Reisetid Trondheim S - Værnes	20 min.	30 min.
Billettpris	50 kr	130 kr

I situasjon 6 velger jeg:

- Helt sikkert tog
- Sannsynligvis tog
- Sannsynligvis flybuss
- Helt sikkert flybuss

	Situasjon 7	
	Tog	Flybuss
Transportmiddel		
Avgangsfrekvens	15 min.	10 min.
Reisetid Trondheim S - Værnes	30 min.	30 min.
Billettpris	50 kr	130 kr

I situasjon 7 velger jeg:

- Helt sikkert tog
- Sannsynligvis tog
- Sannsynligvis flybuss
- Helt sikkert flybuss

Situasjon 8		
	Tog	Flybuss
Transportmiddel		
Avgangsfrekvens	25 min.	10 min.
Reisetid Trondheim S - Værnes	30 min.	30 min.
Billettpris	50 kr	130 kr

I situasjon 8 velger jeg:

- Helt sikkert tog
- Sannsynligvis tog
- Sannsynligvis flybuss
- Helt sikkert flybuss

## Del 3

11. Hvor lang tid tror du du vil bruke på å reise mellom nærmeste holdeplass der flybussen stopper og reisens endepunkt?

- Under 5 min.
- 5 – 10 min.
- 10 – 20 min.
- 20 – 30 min.
- Over 30 min.

12. Hvor lang tid tror du du vil bruke på å reise mellom Trondheim S og reisens endepunkt?

- Under 5 min.
- 5 – 10 min.
- 10 – 20 min.
- 20 – 30 min.
- Over 30 min.

13. Hvis du svarte «Ingen, det er uaktuelt å reise med tog» i spørsmål 8 eller ikke valgte tog i noen av de 8 hypotetiske situasjonene: hvorfor er det uaktuelt for deg å reise med tog (sett ett eller flere kryss)?

- Reisemålet mitt ligger for langt unna Trondheim S (den totale reisetiden blir for lang)
- Frekvensen på toget er for lav
- Frekvensen på kollektivtilbudet er for lav
- Å reise med kollektivtransport/drosje i Trondheim koster for mye
- Det er for tungvint med bytte (flytte bagasjen osv.)
- Det er for dårlig forbindelse til Trondheims busslinjer fra Trondheim S
- Annet: .....

14. Til slutt: er det noen andre forhold/ting som ikke ble nevnt, men som er viktig for deg ved valg av reisemiddel på en flyplassreise i Trondheim?

.....

.....

.....

.....

**Tusen takk for deltakelse!**



## Appendix 3 – The utility models

The general model						
	B	S.E.	Wald	Sig.	Exp(B)	N
<b>Δ onboard travel time</b>	,043	,009	21,635	,000	1,043	2328
<b>Δ egress time</b>	,133	,010	188,955	,000	1,142	
<b>Δ departure frequency</b>	,216	,013	260,244	,000	1,241	
<b>Δ ticket price</b>	,006	,001	20,079	,000	1,006	
<b>Constant</b>	2,658	,175	229,516	,000	14,274	

Table A3-1: The general utility model

Final destination							
		B	S.E.	Wald	Sig.	Exp(B)	N
<b>City Center</b>	Δ onboard travel time	,073	,019	15,168	,000	1,076	736
	Δ egress time	,209	,021	99,960	,000	1,233	
	Δ departure frequency	,247	,021	139,328	,000	1,280	
	Δ ticket price	,007	,002	15,168	,000	1,007	
	Constant	3,159	,290	118,405	,000	23,546	
		<b>B</b>	<b>S.E.</b>	<b>Wald</b>	<b>Sig.</b>	<b>Exp(B)</b>	<b>N</b>
<b>Trondheim East</b>	Δ onboard travel time	,041	,026	2,428	,119	1,042	344
	Δ egress time	,165	,023	53,070	,000	1,179	
	Δ departure frequency	,201	,028	51,002	,000	1,223	
	Δ ticket price	,004	,003	2,428	,119	1,004	
	Constant	3,045	,395	59,500	,000	21,006	
		<b>B</b>	<b>S.E.</b>	<b>Wald</b>	<b>Sig.</b>	<b>Exp(B)</b>	<b>N</b>
<b>Gløshaugen, Lerkendal</b>	Δ onboard travel time	,095	,030	9,905	,002	1,100	320
	Δ egress time	-,011	,022	,256	,613	,989	
	Δ departure frequency	,246	,037	43,354	,000	1,279	
	Δ ticket price	,005	,003	3,102	,078	1,005	
	Constant	-1,470	,844	3,031	,082	,230	

Table A3-2: Utility models for three districts in Trondheim with the biggest data basis

Gender							
		B	S.E.	Wald	Sig.	Exp(B)	N
<b>Only men</b>	Δ onboard travel time	,053	,013	16,749	,000	1,054	792
	Δ egress time	,130	,013	101,702	,000	1,139	
	Δ departure frequency	,233	,019	147,946	,000	1,262	
	Δ ticket price	,006	,002	10,240	,001	1,006	
	Constant	2,892	,252	131,710	,000	18,036	
		B	S.E.	Wald	Sig.	Exp(B)	N
<b>Only women</b>	Δ onboard travel time	,031	,013	5,651	,017	1,032	744
	Δ egress time	,138	,015	87,958	,000	1,148	
	Δ departure frequency	,203	,019	113,135	,000	1,225	
	Δ ticket price	,006	,002	10,027	,002	1,006	
	Constant	2,471	,248	99,025	,000	11,835	

Table A3-3: Utility models for each gender

Journey type							
		B	S.E.	Wald	Sig.	Exp(B)	N
<b>Only leisure journeys</b>	Δ onboard travel time	,051	,011	21,972	,000	1,052	1112
	Δ egress time	,136	,011	145,930	,000	1,145	
	Δ departure frequency	,206	,016	172,151	,000	1,229	
	Δ ticket price	,005	,001	11,067	,001	1,005	
	Constant	2,433	,203	144,129	,000	11,394	
		B	S.E.	Wald	Sig.	Exp(B)	N
<b>Only business journeys</b>	Δ onboard travel time	,033	,018	3,191	,074	1,033	424
	Δ egress time	,131	,020	44,275	,000	1,140	
	Δ departure frequency	,248	,026	89,081	,000	1,281	
	Δ ticket price	,008	,002	10,098	,001	1,008	
	Constant	3,243	,358	81,991	,000	25,618	

Table A3-4: Utility models for each journey type

Number of luggage							
		B	S.E.	Wald	Sig.	Exp(B)	N
<b>No checked luggage</b>	Δ onboard travel time	,019	,020	,931	,335	1,019	304
	Δ egress time	,108	,022	25,347	,000	1,115	
	Δ departure frequency	,195	,030	43,649	,000	1,216	
	Δ ticket price	,004	,003	2,317	,128	1,004	
	Constant	2,059	,371	30,877	,000	7,839	
		B	S.E.	Wald	Sig.	Exp(B)	N
<b>1 piece of checked luggage</b>	Δ onboard travel time	,049	,011	20,228	,000	1,050	1104
	Δ egress time	,135	,011	145,898	,000	1,145	
	Δ departure frequency	,213	,016	181,020	,000	1,237	
	Δ ticket price	,006	,001	14,676	,000	1,006	
	Constant	2,675	,208	165,519	,000	14,510	
		B	S.E.	Wald	Sig.	Exp(B)	N
<b>2 pieces of checked luggage</b>	Δ onboard travel time	,031	,058	,281	,596	1,031	80
	Δ egress time	,191	,081	5,582	,018	1,210	
	Δ departure frequency	,289	,074	15,462	,000	1,336	
	Δ ticket price	,014	,006	4,879	,027	1,014	
	Constant	3,840	1,006	14,558	,000	46,534	

Table A3-5: Utility models dependent on number of checked luggage

Means of transportation actually used on the journey							
		B	S.E.	Wald	Sig.	Exp(B)	N
<b>Car, parked at the airport</b>	Δ onboard travel time	-,099	,107	,849	,357	,906	80
	Δ egress time	,193	,119	2,651	,104	1,213	
	Δ departure frequency	2,004	654,652	,000	,998	7,420	
	Δ ticket price	,021	,014	2,412	,120	1,022	
	Constant	9,206	3273,260	,000	,998	9958,918	
		B	S.E.	Wald	Sig.	Exp(B)	N
<b>Car passenger</b>	Δ onboard travel time	,110	,026	17,702	,000	1,117	232
	Δ egress time	,159	,029	29,410	,000	1,173	
	Δ departure frequency	,270	,039	47,104	,000	1,310	
	Δ ticket price	,006	,003	2,885	,089	1,006	
	Constant	2,269	,456	24,741	,000	9,669	
		B	S.E.	Wald	Sig.	Exp(B)	N
<b>Bus</b>	Δ onboard travel time	,023	,015	2,566	,109	1,024	728
	Δ egress time	,068	,014	22,558	,000	1,070	
	Δ departure frequency	,329	,026	162,958	,000	1,389	
	Δ ticket price	,008	,002	15,949	,000	1,008	
	Constant	2,417	,259	86,731	,000	11,209	
		B	S.E.	Wald	Sig.	Exp(B)	N
<b>Train</b>	Δ onboard travel time	,004	,040	,012	,913	1,004	328
	Δ egress time	,140	,055	6,591	,010	1,151	
	Δ departure frequency	,209	,056	13,718	,000	1,233	
	Δ ticket price	,016	,005	10,365	,001	1,016	
	Constant	4,863	,823	34,875	,000	129,408	

Table A3-6: Utility models for each means of transportation

# Appendix 4 - Probability distribution for choosing the train service



Figure A4-1: Probability distribution for choosing the train service assuming most train favorable situation, least train favorable situation, most equal situation and today's situation respectively