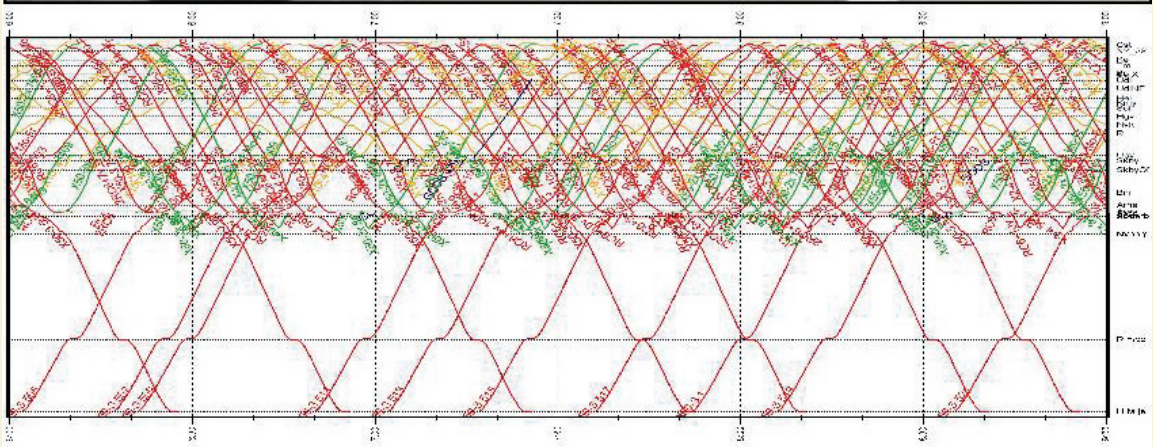
Evaluation of route alternatives for a new railway line to Norrtälje/ Kapellskär from a passenger traffic perspective

LAURA MORENO DEL CAMPO



KTH Architecture and the Built Environment

Master of Science Thesis
Stockholm, Sweden 2008

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TEC-MT 08-005

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Master thesis

April 2008

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Division of Transportation and Logistics
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Contents

Foreword

This thesis is the result of my research work as part of my career for becoming a Civil Engineer. The project was run from September 2007 until April 2008 at the Division of Transportation and Logistics of the Royal Institute of Technology (KTH) Railway Group, in Stockholm.

I would like to express my sincere gratitude to my supervisor, Gerhard Troche, for his encouragement, patience and excellent guidance, as well as the rest of the research team including Anders Lindahl, for their advices, help, rich comments and inspiration during my work at the Railway Group, which proved invaluable for teaching an engineer to be a researcher.

I would also like to express my gratitude to Banverket and the Stockholm's Hamnar (Stockholm's Port Authorities) for offering me the possibility to have an interview with them and also give me valuable information.

Finally, I would like to thank my family, specially my parents and my brother, who have supported me through my stay in Sweden, my friends and my home university Universidad de Castilla-La Mancha (UCLM), for making it possible and easier my stay in Stockholm.

Stockholm, April 2008.

Laura Moreno del Campo

Summary

Passenger rail services are a key part of Stockholm's transportation system, and are growing in importance year after year. Considerable sums of money have been invested in improvements to the Swedish rail network since the 1990's.

In this Project a new passenger railway line is proposed chosen out of four route alternatives on the northern part of the Stockholm area. The purpose is to study and evaluate alternative corridors in the Stockholm region to/from Norrtälje - the port of Kapellskär, and how a future rail passenger service on these alternative corridors would look like.

This area is nowadays served by bus services, but as long as all this zone keeps growing in population rate, better public transportation services are needed, since many people living in the study area have their workplaces in Stockholm and need to use public transportation every day to reach their workplaces. Along this Project, some future plans of well known companies are also explained related to the development of new passenger train services in the area.

Along the text, the four proposals are explained and analysed from a passenger traffic perspective, in order to choose the best alternative at the end of the Project.

Many calculations are made in order to prove that a new passenger railway line in the Stockholm area would improve the public transportation system existing nowadays and it is actually needed to do so.

In this Project it is also explained how it would also be interesting to introduce a new freight railway line operating along the same infrastructure as the new passenger trains.

As a conclusion, the best alternative from the passenger and freight traffic perspective is selected, as well as the best alternative just from the passenger traffic perspective.

At the end besides defining the solution, some recommendations related to the Project are given.

1 Introduction

In this first chapter a description of this Project is made by defining first the delimitation of the study area and after the background of the project with all the boundary conditions and the present situation. Next, the goals of the Project are defined as well as the methodology followed to get to the final solution of the Project.

(Note: all the tables and figures are named starting with their chapter number).

1.1 Background and delimitation

The study zone of this Project corresponds to the Northern region of Stockholm, Sweden: Roslagen area, including Stockholm and the towns of Norrtälje, Rimbo, Märsta/Arlanda and Uppsala among others.

This Project also takes into account the port of Kapellskär, an important port about 60 km north of Stockholm which has been becoming more important in the last years since the port of Stockholm is getting congested and insufficient. The port of Kapellskär has frequent ferry connections for both goods and passengers to Finland, Russia, Estonia, Latvia and Lithuania among other countries. It is located by the Baltic Sea, in Norrtälje Municipality, Stockholm County. The harbour is owned by Ports of Stockholm. *(See figure 1.1.1).*

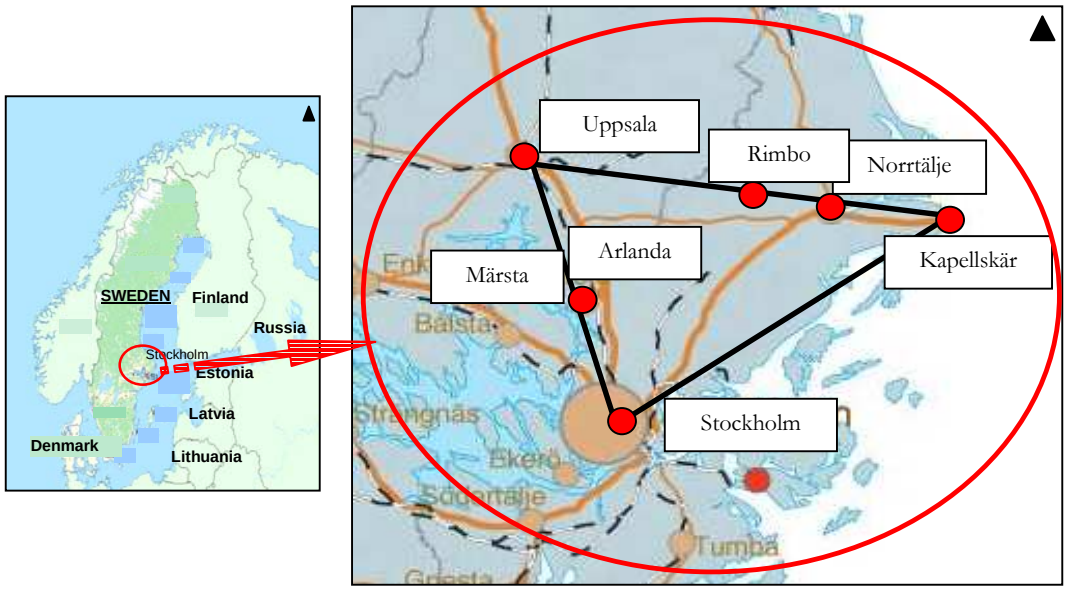

Figure 1.1.1: Study area.

Stockholm is the largest city of Sweden (1,252,020 inhabitants, December 2005). Its strategic localisation on several islands forming an archipelago on the east coast of Sweden has been historically important.

As it is said before, Arlanda is one of the points that also belong to this Project, and this location is where one of the three airports of Stockholm city is located (about 42 km North of Stockholm). It is the largest airport in Sweden for international flights, and it serves both passengers and freight service. It is also one of the three major hubs of the Scandinavian Airlines System. The connection between Arlanda airport and Stockholm is by the means of road traffic, and also by train traffic with both a high-speed train line (Arlanda Express) and a conventional train line, both sharing the same tracks. The railway line that goes to Arlanda is very congested nowadays, and one of the main reasons is because trains go via tunnel in the surroundings of Arlanda airport, which makes it impossible to expand the railway lines by adding more tracks.

Märsta (22,548 inhabitants, December 2005) is a suburb of Metropolitan Stockholm. The town is best known for its airport, Arlanda.

Uppsala (128,409 inhabitants, December 2005) is the second most important city in the study area after Stockholm, and it is the fourth largest city of Sweden. It is located about 70 km North of Stockholm (more data in the next chapter).

Norrtälje (16,263 inhabitants, December 2005) is a town in the Swedish province of Uppland and the seat of the Norrtälje Municipality, Stockholm County.

Rimbo (4,606 inhabitants, December 2005) is a locality in the Norrtälje Municipality. It is located about 20 km west of Norrtälje.

This Northern sector is the fastest growing portion of region in the Stockholm County. The population rate has been doubled in the last twenty years and the number of job positions is willing to increase up to 50% towards year 2030[1]. Among the North-eastern part of the municipality there has been a large expansion and development. According to the existing data, it is planned to build more than 100,000 new housings within the region towards year 2030 and in accordance with the supposed regional development plan RUFS 2001, shall Täby-Arninge develop to a regional part nucleus. One more important data is that most of the people living in this Northern sector have their workplaces in Stockholm and Uppsala, since these two are the main cities in the area.

Related to the public transportation system in Stockholm, passenger railway transport has increased 10% in the last years[2], and several new lines have been built or older lines modernized to cope with speeds up to 200 km/h. A problem with all this modernization is that there exists capacity problems in the Stockholm rail transport system, even after the new City Line is built in Stockholm (a new 6 km rail tunnel under central Stockholm). One of the reasons of these capacity problems is due to the morphology of the city of Stockholm and its numerous islands forming an archipelago, which make it difficult to expand the existing railway tracks because there is no physical space for this.

[1] *Source: Banverket, WSP-Pilot study of Roslagspilen, May 2007.*
[2] *Source: Banverket.*

The existing passenger transportation system in the study area is by the use of six different lines of buses connecting towns, and three railway lines:

- One going from Stockholm to Uppsala passing by Märsta and Arlanda, which is the main railway line that connects Stockholm with the North;
- And the other two railway lines (Roslagsbanan) serve the southern part of the study area going from Stockholm to Kårsta (one branch), and to Åkersberga (the other branch: the Österskär branch). Both lines pass by Täby.

(See figure 2.1.1, and Appendix I: Present situation buses timetables).

There are plans from Banverket to build one more railway line by the year 2030: Roslagspilen-line, a new railway line for passenger traffic that would serve the south-east and east of the study area by linking Stockholm with Norrtälje. This line would start in Solna and would pass by Danderyd, Täby, Arninge, Täljö, Åkersberga, Roslags-Kulla, Bergshamra, and Norrtälje[3]. *(See figure 1.1.2).*

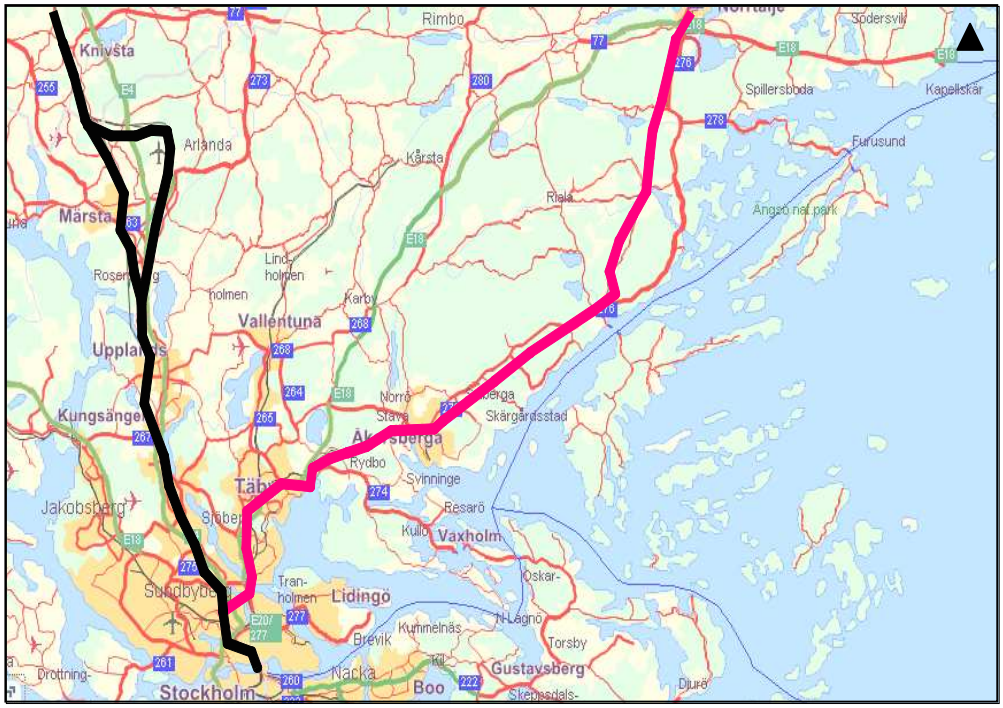

Figure 1.1.2: Roslagspilen-line (showed in pink colour). New railway line planned by Banverket for the year 2030.

And next, to end up with this section, some benefits of passenger rail are explained:

- Passenger rail service provides a quality transportation service as an alternative to automobile travel. It serves a big market, offering better fares and service levels higher than intercity bus.
- Short distance passenger rail services serve passengers who are travelling for either business or pleasure.
- Travellers are offered a time-competitive alternative.

[3] *Source: Banverket, WSP-Pilot study of Roslagspilen, May 2007.*

- This service may generate business and tourist related activity in the regions served.
- Rail service is also somewhat unique among intercity transportation modes in its ability to serve the central downtown areas of cities. Rail provides direct access into the heart of downtown cities. This can be an advantage over other modes, as access to downtown areas often requires using congested highways (either from an airport, by riding a bus, or by driving a car)[4].

1.2 Goal

The aim of this project is to carry out a study and evaluate alternative corridors in the Stockholm region to/from Norrtälje - the port of Kapellskär, and how a future rail passenger service on these alternative corridors would look like.

The alternative corridors consist of a new railway line from Norrtälje - the port of Kapellskär, northeast of Stockholm, to Stockholm or a point along the Stockholm-Uppsala railway line; from a Passenger Traffic perspective in order to:

- to serve Roslagen area with regional passenger train services in order to facilitate daily commuting so that people living in the region can live and work in different places,
- to improve the Public Transport system of the Greater Stockholm region,
- to give a rail access to the port of Kapellskär,
- to find a solution for a saturated system and increase its efficiency, since there are capacity problems in Stockholm because of the developing of the city and the transport system,
- to spread the economic growth from Greater Stockholm to the surrounding area through improved accessibility.

Along this Project several corridor alternatives are developed and studied, and at the end one of the alternatives has been chosen as the best alternative attending to different criteria that is also explained.

The selected corridor will be run by regional high-speed trains Regina type running at an average speed of 180-200 km/h, and the infrastructure will be double-tracks standard gauge (1,435 mm).

[4] *Source:* http://ntl.bts.gov/DOCS/iprt.html*, Intercity Passenger Rail Transportation - Overview and Presentation of Alternative Policies for Intercity Passenger Rail Transporation.*

1.3 Methodology

The methods used for carrying out this project and for obtaining information are:

1. The first step consists of a Search of information (Preliminary study):
   - Interviews with relevant companies related to the Roslagen area's transport from which information about passenger and freight transportation system in the area is obtained. These companies are Banverket: Swedish Rail Administration, SL, Port Authorities of Stockholm (Stockholm's Hamnar), and Cargo Net: freight railway company;
   - Interviews with travellers so that information about travelling preferences is obtained, as well as information about travelling times;
   - The use of the existing literature and data, in order to search information about population, maps, existing infrastructure, working places, etc.;
   - Existing information about passenger transportation in the area: timetables, historical data, etc.
   - Statistics and market analysis.

2. The second step consists of a study of all the possible corridor alternatives:
   - With the aid of maps, aerial photographs, pictures, visits to the study area;
   - Study of the emplacement of the new train stations;
   - Possible infrastructure for the simulation.

3. The third step corresponds to the simulation and creation of timetables for each alternative with the RailSys® program.

4. The last step is to choose the best alternative from a Passenger traffic perspective, as well as making recommendations in case of a combination of Passenger traffic-freight traffic, and also in the case of just freight traffic. Some conclusions are also obtained.

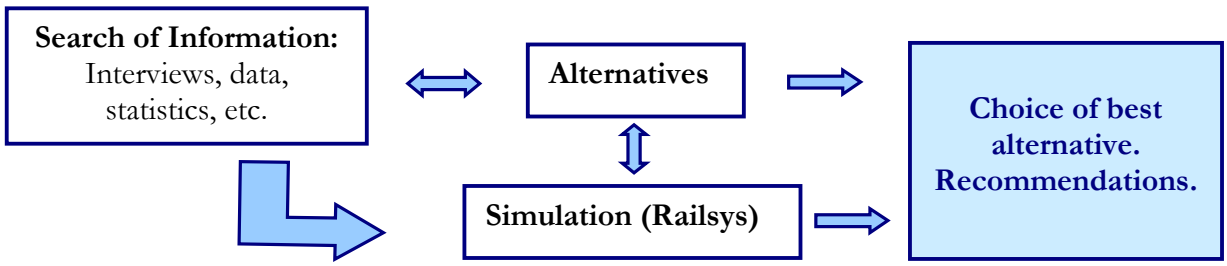

Figure 1.3.1: Methodology diagram.

2 Market analysis

In this chapter the present public transport situation in the study area is defined by all modes of transport, including the existing traffic with Finland by passenger ferries. It is also defined the population of the main localities in the area, and a study of the public transport travel demand in the area is carried out (capacity), being the bus the chosen mode, since the only transport mode that connects the main localities in the study area is the bus. At the end of the chapter, in order to analyze the market effects in the future of the new train line, a similar case study is used to compare its market effects with the ones this Project's proposal is likely to have in the future.

2.1 Today's Public transport network

The present situation related to the existing public passenger transportation system in the study area is:

- Six different bus lines connecting towns,
- Three railway lines:
  - One going from Stockholm to Uppsala passing by Märsta and Arlanda airport, which is the main railway line that connects Stockholm with the North;
  - And the other two railway lines are called the narrow-gauge Roslagsbanan train line. They serve the southern part of the study area going from Stockholm to Kårsta and to Åkersberga respectively, passing by Täby.

(See figure 2.1.1, 2.1.2, Table 2.1.1, and Appendix I: Present situation buses timetables).

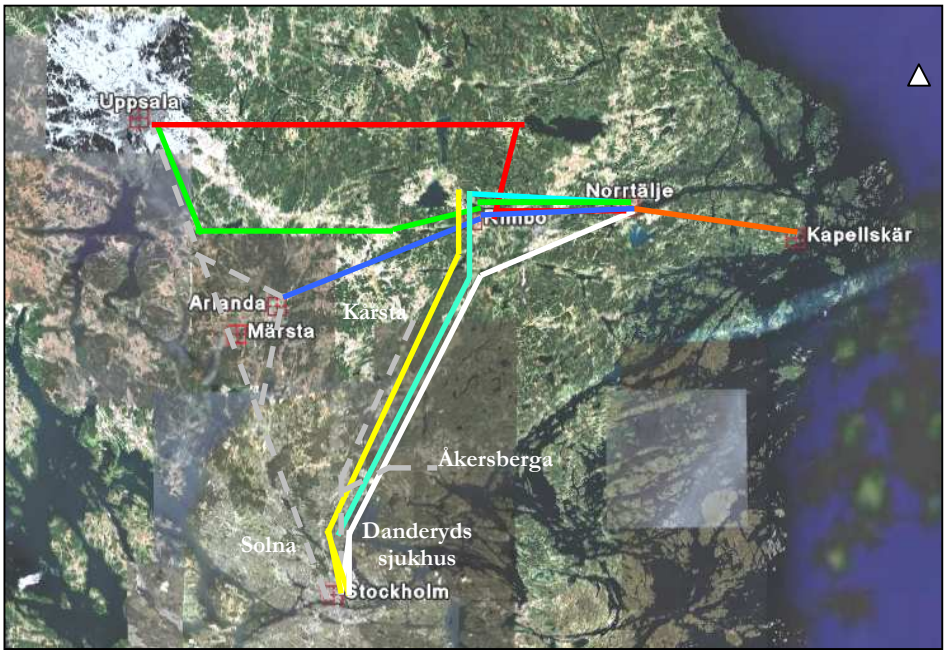

Figure 2.1.1: Existing passenger transportation system in the study area.

BUS LINES:

676 625 UL 807 631

647 639 UL 809

676: Norrtälje – Stockholm

647: Norrtälje – Rimbo – Arlanda

639: Stockholm – Rimbo

625: Danderyds sjukhus – Rimbo – Norrtälje

631: Norrtälje – Kapellskär

UL 807: Norrtälje – Rimbo – Uppsala

UL 809: Norrtälje - Uppsala

From the routes of the bus lines it can be seen that the most important towns in the study area (Roslagen area), are Norrtälje, Rimbo, Arlanda airport/Märsta and Uppsala, since all the bus lines pass by at least one of those localities. This is because they are the localities with bigger populations and from where many workers go to Stockholm to work. These localities therefore are the most interesting points to link with Stockholm, since they are the main trip generators in the study area.

Since Arlanda/Märsta and Uppsala are already connected to Stockholm via train line, the two localities remaining that would be interesting to link with Stockholm are Rimbo and Norrtälje. One more reason that makes these two localities important is the fact that they are suitable localities for also connecting bus lines to the new train lines, since most of the bus lines stop at those points. By connecting the bus lines to the train lines, the possibility to also connect to the already existing railway line Stockholm – Uppsala (a very used line nowadays) is possible.

In *Table 2.1.1.* it is shown an abstract of the tables in Appendix I, where it can be seen the origins and destinations of all the bus lines in the study area and how long it takes to get from one origin to its destination (present travel times).

The origins and destinations that have more than one option (more than one bus line for the same route) are also shown in the table, and the bus line number in red-colour corresponds to the bus line that takes the shortest time to travel from the origin to the destination, therefore, it is the bus line that travellers would prefer for going from one point to another, the most used bus line.

	BUS LINE	SHORTEST FREQUENCY (minutes)	DURATION
Stockholm - Norrtälje	676	5	60-62´
Norrtälje - Stockholm	676	5	60-62´
Rimbo - Arlanda	647	30	45´
Arlanda - Rimbo	647	60	60´
Norrtälje - Arlanda	647	30	80´
Arlanda - Norrtälje	647	60	80´
Stockholm - Rimbo	639	30	60´
Rimbo - Stockholm	639	20	60´
Rimbo - Danderyds sjukhus	639, 625	10	40´
Danderyds sjukhus - Rimbo	639, 625	11	50´
Norrtälje - Uppsala	UL807, UL809	30	1 hour and 25´
Uppsala - Norrtälje	UL807, UL809	25	1 hour and 25´
Rimbo - Uppsala	UL807	30	60´
Uppsala - Rimbo	UL807	30	60´
Norrtälje - Kapellskär	631	80	50´
Kapellskär - Norrtälje	631	90	50´

Table 2.1.1: Origins-destinations.

It can be observed from the table above that the highest frequency of buses is for the line Stockholm-Norrtälje, Norrtälje-Stockholm, which is one of the bus lines with more demand (*see chapter 2.3*). In the other hand, the lowest frequency corresponds to the line Kapellskär-Norrtälje, which is a line with a very low demand (*see Appendix I*).

About the three existing railway lines, the line that goes from Stockholm to Uppsala passing by Märsta and Arlanda airport, is a double-track standard gauge (1,435 mm) line operated by both regional trains and high-speed trains X3 until Arlanda airport (not passing by Märsta) (*See figure 2.1.3*). The high-speed line (a 20 km link) was opened in November 1999, when the railway line from Ulriksdal to Skavstaby was widened from two to four tracks in order to allow high-speed trains Arlanda Express to operate. This link comprises three stations, all underground, and 7 km of tunnels. It takes 20 min. to travel from Stockholm to Arlanda airport.

The rest of the line (Arlanda-Uppsala) is only used by regional trains and long distance trains.

The speeds of the trains are 200 km/h for the high-speed trains, and 140-160 km/h for regional trains.

The other two railway lines (Roslagsbanan) consist of two different branches that serve the southern part of the study area going from Stockholm to Kårsta (one

branch), and from Stockholm to Åkersberga (the other branch: the Österskär branch), both passing by Täby.

Both train lines are very curvy, single-track, narrow gauge; and both lines also pass by very densely populated areas. Just regional trains operate them.

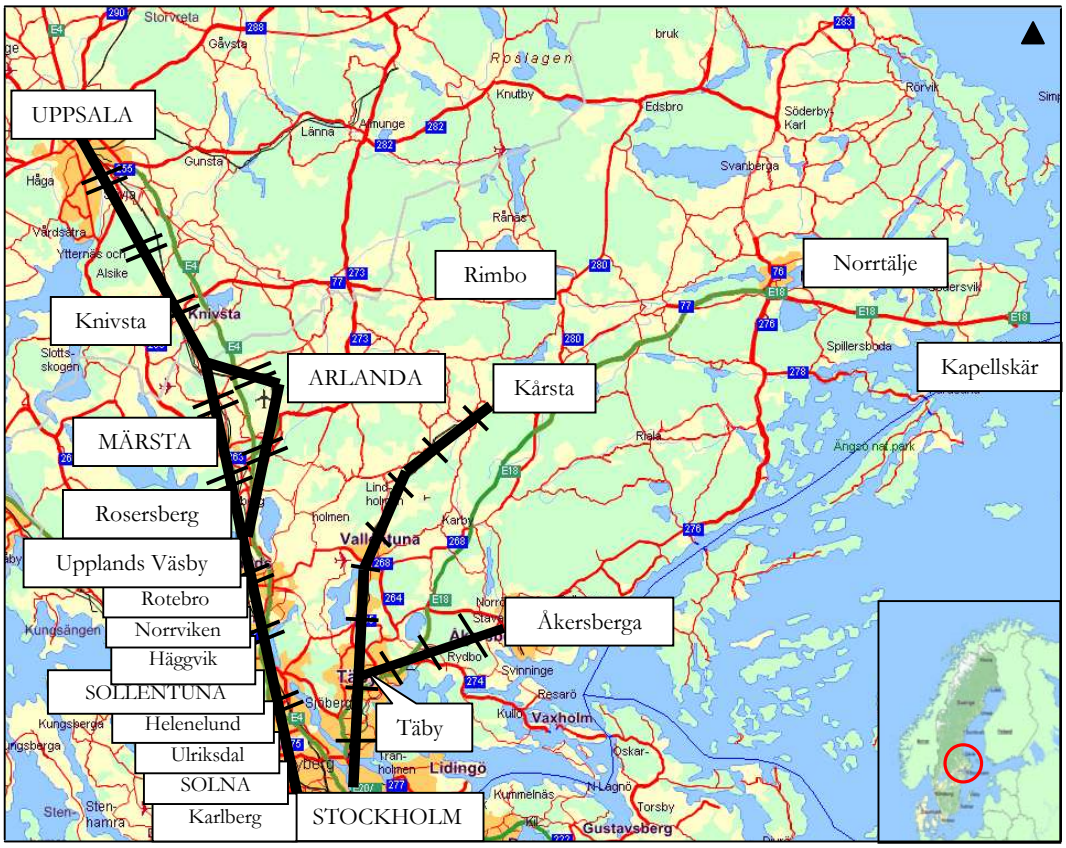

Figure 2.1.2: Existing railway lines in the study area.

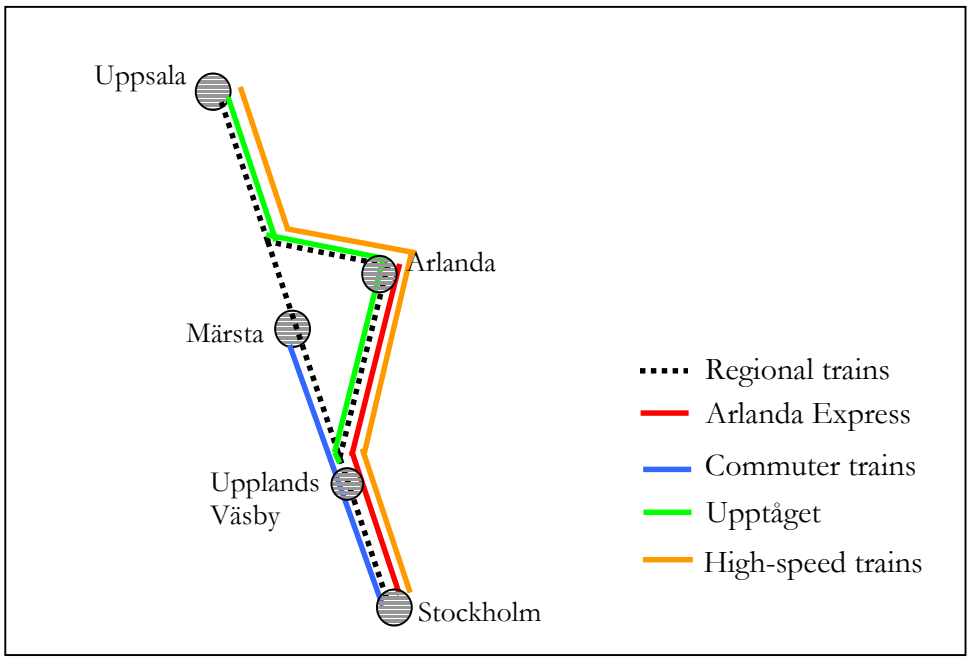

Figure 2.1.3: Sketch of the railway line Stockholm-Uppsala.

2.2 Traffic with Finland

The only traffic with Finland related to passenger traffic is by the means of ferry passenger traffic by sea (cruises). Sweden and Finland are both in the Baltic Sea and Gulf of Bothnia (in Scandinavia), both seas separated by Åland Islands (Finland), and the distance by sea between Sweden and Finland is around 300 km.

Figure 2.2.1: Map of Scandinavia.

The ferry passenger traffic between Sweden and Finland is operated by different companies that travel from Stockholm and the port of Kapellskär (Sweden) to Turku, Helsinki, Naantali and Mariehamn (all in Finland) (*See figure 2.2.2*).

Turku has a population of 175,354 (as of 2006). Because of its good location, the Port of Turku is the second busiest seaport in Finland with around 3.7 million passengers per year.

Helsinki is the capital city of Finland, with a population of 560,994 (as of 2005). The port of Helsinki is the most important port in Finland.

Mariehamn is the capital city of Åland islands (Finnish property). It has a population of 10,822 (as of 2006). Its harbour is an important international harbour with daily traffic to Sweden and mainland Finland. It is a tourist destination and a powerful incentive for Baltic ferries to stop at because, with respect to indirect taxation, Åland is not part of the EU system and so duty-free goods can be sold onboard.

Naantali is a city in south-western Finland, known as one of the most important tourist centres in the country. The small city, with a population of 14,081 (as of

2007), is located 15 kilometres west of Turku. The seaport of Naantali is the third largest in Finland in terms of goods traffic.

The navigation companies that travel between Sweden and Finland are:

- **Silja LINE**: the label name for the passenger and freight service achievements of the Finnish shipping company *Silja Oy off*. This navigation company operates at present a fleet of 11 ships in the Baltic Sea, and has boats for the combined freight-and passenger traffic, and also high-speed ferries in passenger traffic. In 2006 the Estonian ferry operator Tallink Group acquired Silja LINE in the business between Finland and Sweden.

  Each cruise ferry in the route Sweden - Finland has space for 3,013 passengers at the maximum. The number of passengers in 06/07 between Finland and Sweden for the Tallink Group was 2,156,202[5].

  Silja LINE serves the following routes in the cruise traffic Sweden-Finland:

  - Stockholm (Sweden) - Mariehamn (Finland) – Helsinki (Finland)
  - Stockholm (Sweden) - Mariehamn (Finland) - Turku (Finland)
  - Kapellskär (Sweden) - Turku (Finland). From September until April.

- **Viking LINE:** a Finnish shipping company that operates a fleet of ferries and cruise ferries between Finland, the Åland Islands, Sweden and Estonia.

  Viking LINE serves the following routes in the cruise traffic Sweden-Finland:

  - Stockholm (Sweden) - Mariehamn (Finland) - Helsinki (Finland)
  - Stockholm (Sweden) - Mariehamn (Finland) - Turku (Finland)
  - Kapellskär (Sweden) - Mariehamn (Finland)
  - Stockholm (Sweden) - Mariehamn (Finland).

- **Finnlines:** a Finnish passenger cruising company that works on the route Kapellskär (Sweden) - Naantali (Finland).

(*See figure 2.2.2*)

Figure 2.2.2: Ferry traffic with Finland.

[5] *Source: Tallink.*

2.3 Population and travel demand

In this section the study of the existing passenger demand and capacity is carried out for the most important localities in the study area.

The first thing to define is the population in those localities and municipalities. It has also been defined the share of population of each population centre with regard to the municipality the population centre belongs to:

MUNICIPALITY	POPULATION CENTRE	POPULATION 2005-12-31	SHARE OF POPULATION
Järfälla	Stockholm	61,574	99,7%
Huddinge	Stockholm	86,802	97,8%
Botkyrka	Stockholm	50,613	66,1%
Haninge	Stockholm	41,785	58,2%
Tyresö	Stockholm	37,947	92,3%
Danderyd	Stockholm	24,889	82,3%
Sollentuna	Stockholm	55,023	92,7%
Stockholm	Stockholm	770,889	100%
Nacka	Stockholm	28,08	35,0%
Sundbyberg	Stockholm	34,016	100%
Solna	Stockholm	60,402	99,7%
STOCKHOLM URBAN AREA:		**1,252,020**	**100%**
Norrtälje	**NORRTÄLJE**	**16,263**	**29,8%**
Norrtälje	**RIMBO**	**4,606**	**8,4%**
Norrtälje	Hallstavik	4,530	8,3%
Norrtälje	Rest of towns smaller than 1,000 inhabitants	29,197	53,5%
Norrtälje	TOTAL	54,596	100%
Sigtuna	**MÄRSTA**	**22,548**	**61,4%**
Sigtuna	Rest of towns smaller than 8,000 inhabitants	14,163	38,6%
Sigtuna	TOTAL	36,711	100%
Uppsala	**UPPSALA**	**128,409**	**70,1%**
Uppsala	Rest of towns smaller between 10,000-1,000 inhabitants	23,507	12,8%
Uppsala	Rest of towns smaller than 1,000 inhabitants	31,392	17,1%
Uppsala	TOTAL	183,308	100%

Table 2.3.1: Populations.[6]

[6] *SCB (Statistiska Centralbyrån). Statistics Sweden.*

The population of Kapellskär does not exist because it is not a town but a port. The existing data is that during the summer high season, the port employs nearly 200 people.

By attending at the share of population, one conclusion that can be drawn is that in the case a new train station is situated in the town of Norrtälje (for instance), this train station will serve the 29.8% of the whole municipality of Norrtälje, but this town is the largest in its municipality, so it makes sense to situate the train station here while the rest of the people living in the same municipality will have to travel to Norrtälje for taking the train.

The same happens in the case a new train station is situated in Rimbo: 8.4% of the population of the municipality of Norrtälje will be served. It is interesting to localize a new train station in both Norrtälje and Rimbo, because this way the 38.2% of the population of the municipality of Norrtälje will be served, and it will be easier for the rest of the people living in this municipality to travel either to Rimbo or to Norrtälje to take the train.

Next, with the aid of the data in Appendix I, the capacity of the existing passenger bus lines is analyzed. Demand and capacity are different concepts, but since there is not existing data about the demand (i.e. number of passengers), the requirements for capacity have been derived from today's capacity of the bus lines, assuming that the capacity of the bus lines correlates to the demand (this assumption is accurate during the dimensioning peak hours). This is, therefore, an approximate method.

The bus lines of which capacity needs to be calculated are the ones related to the most important localities in the study area (Stockholm, Uppsala, Norrtälje, Rimbo, and Märsta/Arlanda), but since the two main trip generators to Stockholm are Norrtälje and Rimbo, only the bus lines that link any of those two localities with Stockholm have been analyzed.

The bus lines of which capacity has been calculated are:

- Norrtälje – Stockholm: bus line 676
- Stockholm – Norrtälje: bus line 676
- Rimbo – Stockholm: bus line 639
- Stockholm – Rimbo: bus line 639
- Norrtälje – Kapellskär: bus line 631 (this line is analyzed in order to study if there is enough passenger traffic base nowadays)
- Kapellskär – Norrtälje: bus line 631.

(See figure 2.1.1)

Those origins and destinations have been studied because there is a higher number of passengers who travel from Rimbo and Norrtälje to Stockholm, than from Uppsala or any other origin to that destination, it means, most of the passengers that depart from Rimbo and Norrtälje have as their destination Stockholm and vice versa, this is why these four lines' capacity (the highest capacity), are the capacities that the best train alternative needs to meet among other factors in order to improve the existing passenger transportation system in the study area.

In *Figure AI.8* and *Figure AI.9* in Appendix I, it is showed all the localities that are nowadays connected by bus to Rimbo and to Norrtälje, but the highest passenger traffic flow is from Norrtälje and Rimbo to Stockholm, and vice versa.

For calculating the existing capacity in those four bus lines, the data that has been used is the number of seats of each line's buses, and the number of buses per hour on each line, so that the capacity is obtained for different times making it possible to plot a capacity curve for each bus line:

$$Capacity/\ hour = n^o\ seats * n^o\ buses/hour \qquad \textit{(Equation 2.1.1)}$$

The number of seats (passengers) is 59 seats for each bus, and the number of buses per hour is obtained with the data in Appendix I. By doing the calculation in this way, it is assumed that the buses are always totally full of passengers every time they travel from an origin to a destination. The calculation of the passenger demand (or capacity) has been done for weekdays (Monday to Friday) and not for the weekends, since during the weekdays, the demand is higher than in the weekends.

For the line Norrtälje-Stockholm (bus line 676), the number of buses per hour is obtained from *Figure AI.2* in Appendix I. The results obtained are in *Figure 2.3.1*.

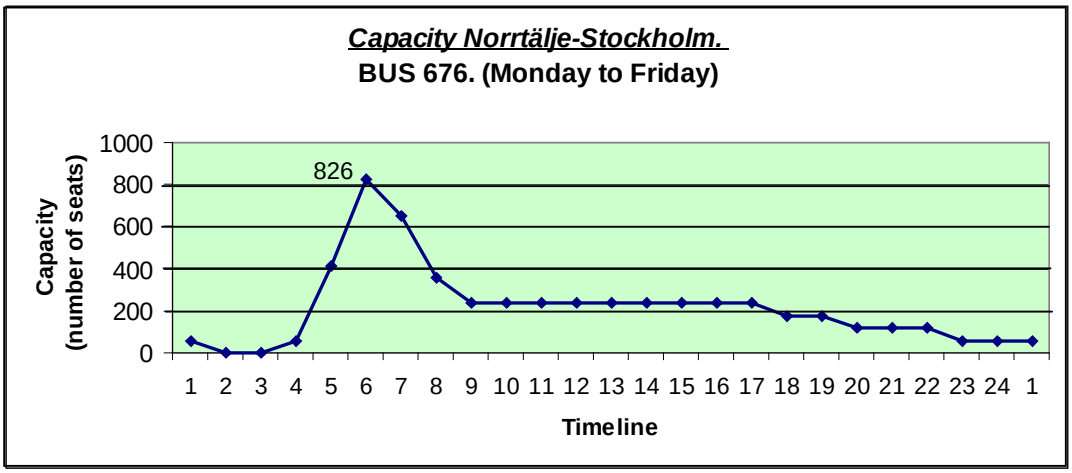

Figure 2.3.1: Capacity in bus line 676 Norrtälje - Stockholm.

(Note: the times used for calculating the buses' capacities are the departure times).

From the graph above and *Table AII.1* in Appendix II it is shown that the highest demand (capacity) for the bus line 676 in the direction Norrtälje – Stockholm, is 826 passengers, and this occurs from 06:00 to 07:00 in the morning (peak hour) which is when there are more buses in that line (14 buses in 1 hour), and the frequency between buses is the highest (5 minutes).

Some conclusions that can be drawn from the demand calculation is that the highest demand from Norrtälje to Stockholm from Monday to Friday is in the interval 06:00-07:00 hours which is the time when there are more people travelling from Norrtälje to Stockholm. The explanation to this is that at that time is when people from Norrtälje who work in Stockholm go to work in the morning. It can also be seen

from *Table AII.1* in Appendix II, that the total capacity in one weekday of the bus line 676 in this direction is around 5,300 numbers of seats /day.

For the line Stockholm - Norrtälje (bus line 676), the number of buses per hour is obtained from *Figure AI.5* in Appendix I. The results obtained are in *Figure 2.3.2.*

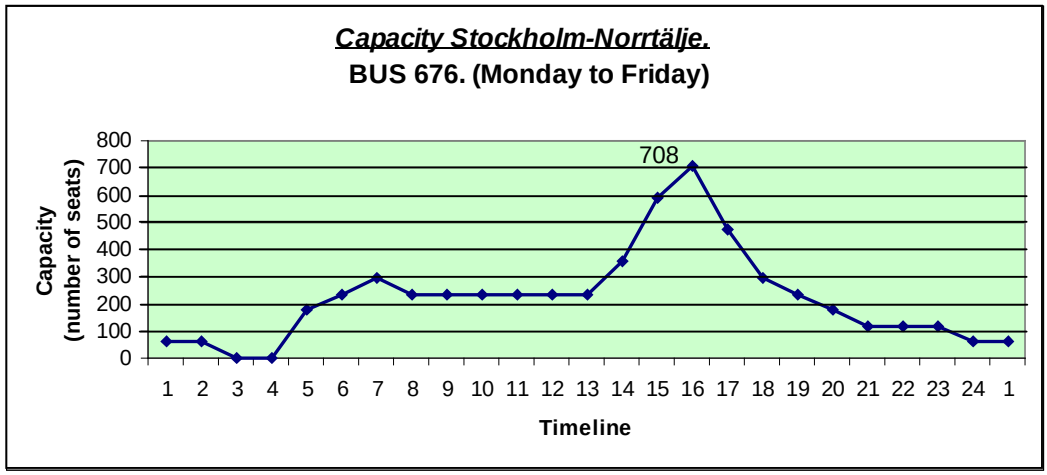

Figure 2.3.2: Capacity in bus line 676 Stockholm - Norrtälje.

(Note: the times used for calculating the buses' capacities are the departure times).

From the graph above and *Table AII.2* in Appendix II it is shown that the highest demand (capacity) for the bus line 676 in the direction Stockholm - Norrtälje, is 708 passengers, and this occurs from 16:00 to 17:00 in the afternoon (peak hour), which is the time when there are more buses in that line (12 buses per hour), and the frequency between buses is the highest (5 minutes).

Some conclusions that can be drawn from the demand calculation is that the highest demand from Stockholm to Norrtälje from Monday to Friday is in the interval 16:00-17:00 hours which is the time when there are more people travelling from Stockholm to Norrtälje. The explanation to this is that at that time is when people from Norrtälje who work in Stockholm go back home in the afternoon after work. It can also be seen from ***Table AII.2*** in Appendix II, that the total capacity in one weekday of the bus line 676 in this direction is around 5,500 numbers of seats/day.

Comparing both graphs *"Capacity Norrtälje-Stockholm" (figure 2.3.1)* and *"Capacity Stockholm-Norrtälje"* (*figure 2.3.2*) it can be seen that in the first graph *(Figure 2.3.1)*, the peak of the graph takes place in the morning at once, while in the second graph *(Figure 2.3.2)*, the peak occurs in the afternoon and it is more spread out along the time. The reason to this is because during the morning, the times when passengers from Norrtälje start to work in Stockholm or school starting time is similar (07:00 – 08:00), but during the afternoon, different passengers from Norrtälje finish their work at different times in Stockholm, plus the fact that many people stay in the capital city for doing other activities after work in the evening that also take time (shopping, meetings, etc.) before returning to their towns. This explanation is the reason why the graph of going-back-home from work *(Figure 2.3.2)* has its peak more spread out along the time. This is a theoretical fact, but it is confirmed by the obtained data.

For the line Rimbo-Stockholm (bus line 639), the number of buses per hour is obtained from *Figure AI.5* in Appendix I. The results obtained are in *Figure 2.3.3*.

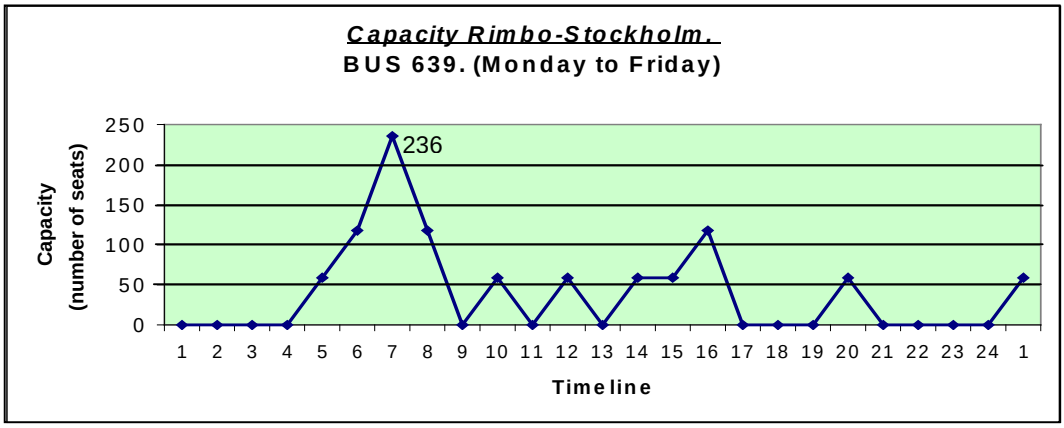

Figure 2.3.3: Capacity in bus line 639 Rimbo-Stockholm.

(Note: the times used for calculating the buses' capacities are the departure times).

From the graph above and *Table AII.4* in Appendix II it is shown that the highest demand (capacity) for the bus line 639 in the direction Rimbo – Stockholm, is 236 passengers, and this occurs from 07:00 to 08:00 in the morning (peak hour) which is when there are more buses in that line (4 buses in 1 hour), and the frequency between buses is the highest (20 minutes).

Some conclusions that can be drawn from the demand calculation is that the highest demand from Rimbo to Stockholm from Monday to Friday is in the interval 07:00-08:00 hours which is the time when there are more people travelling from Rimbo to Stockholm. The explanation to this is that at that time is when people from Rimbo who work in Stockholm go to work in the morning. There are also several peaks during the rest of the day, and this happens because in some hours there are no buses (like in the intervals 09:00-10:00, 11:00-12:00, 13:00-14:00) *(See Figure AI.22* in Appendix I), and so when there is one bus during the next hour, a peak is made. It can also be seen from *Table AII.4* in Appendix II, that the total capacity in one weekday of the bus line 639 in this direction is around 940 numbers of seats/day.

For the line Stockholm- Rimbo (bus line 639), the number of buses per hour is obtained from *Figure AI.4* in Appendix I. The results obtained are in *Figure 2.3.4*.

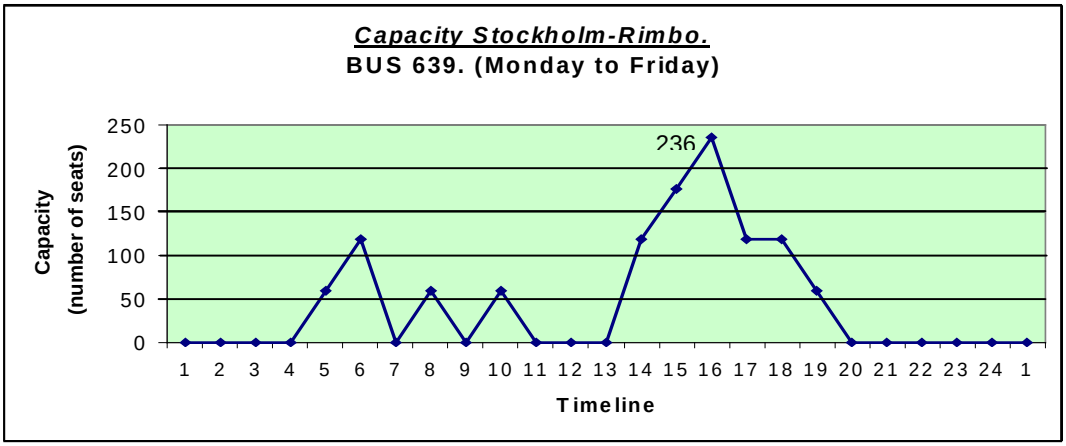

Figure 2.3.4: Capacity in bus line 676 Stockholm - Rimbo.

(Note: the times used for calculating the buses' capacities are the departure times).

From the graph above and *Table AII.3* in Appendix II it is shown that the highest demand (capacity) for the bus line 639 in the direction Stockholm - Rimbo, is 236 passengers, and this occurs from 16:00 to 17:00 in the afternoon (peak hour) which is when there are more buses in that line (4 buses in 1 hour), and the frequency between buses is the highest (15 minutes).

Some conclusions that can be drawn from the demand calculation are that the highest demand from Stockholm to Rimbo from Monday to Friday is in the interval 16:00-17:00 hours which is the time when there are more people travelling from Stockholm to Rimbo. The explanation to this is that at that time is when people from Rimbo who work in Stockholm go back home after work. It can also be seen from *Table AII.3* in Appendix II, that the total capacity in one weekday of the bus line 639 in this direction is around 1,100 numbers of seats/day.

Comparing both graphs *"Capacity Rimbo-Stockholm" (figure 2.3.3)* and *"Capacity Stockholm-Rimbo"* (*figure 2.3.4*) the same effect as in the bus line 676' graphs occurs: it can be seen that in the first graph *(Figure 2.3.3)*, the peak of the graph takes place in the morning at once, while in the second graph *(Figure 2.3.4)*, the peak occurs in the afternoon and it is more spread out along the time.

About the demand in the lines Norrtälje – Kapellskär and Kapellskär – Norrtälje, those are bus lines with low capacity and low number of buses *(see Figure 2.3.5 and Appendix I)*. This is because only the people that work in the port and some of the people that depart from any passenger ferry go to Kapellskär by bus. This fact makes it unlikely that a prolongation of the new train line until the port of Kapellskär is interesting from a passenger traffic perspective since the existing passenger traffic is very low. More studies have been carried out with more conclusions about this line in the simulation chapter (*chapter 5*) and next, the demand in those bus lines has been studied.

For the line Norrtälje-Kapellskär (bus line 631), the number of buses per hour is obtained from *Figure AI.38* in Appendix I. The results obtained are in *Figure 2.3.5*.

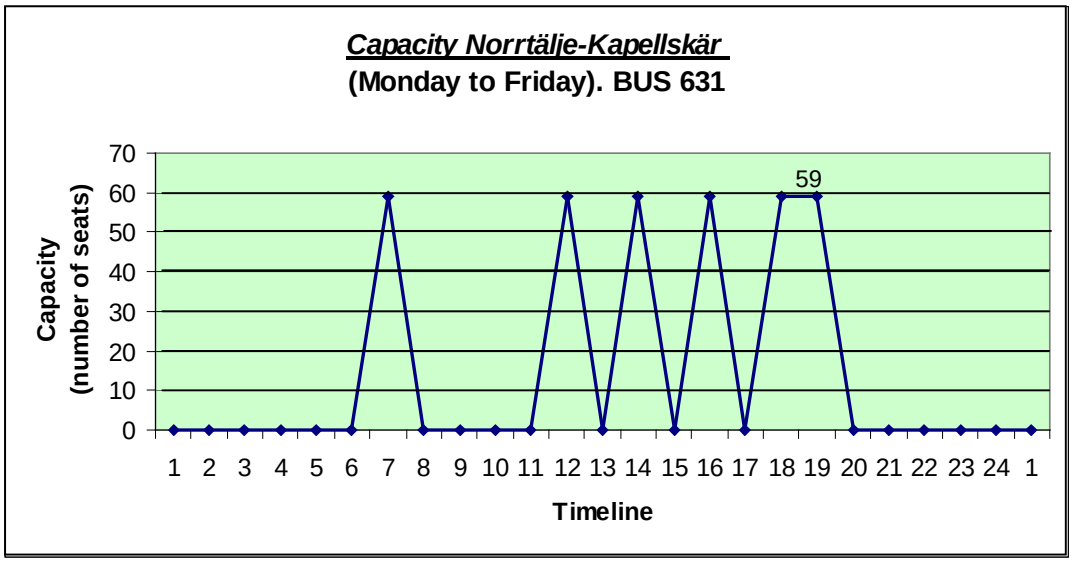

Figure 2.3.5: Capacity in bus line 631 Norrtälje - Kapellskär.

(Note: the times used for calculating the buses' capacities are the departure times).

From the graph above and *Table AII.5* in Appendix II it is shown that the highest demand (capacity) for the bus line 631 in the direction Norrtälje – Kapellskär, is 59 passengers, it means, 1 bus, and this occurs in different intervals of time: from 07:00 to 08:00, from 12:00-13:00, from 14:00-15:00, from 16:00-17:00, and from 18:00-20:00 (peak hours) which is when there is only one bus in that line (1 bus in 1 hour), and the frequency between buses is the highest (80 minutes in the interval 18:00-20:00).

Some conclusions that can be drawn from the demand calculation is that the highest demand from Norrtälje to Kapellskär from Monday to Friday is exactly the same in various intervals of time along the day, starting from 07:00-08:00 and with just one bus running every 150 minutes (an average time). The starting time corresponds to the time when the port workers go to work to Kapellskär. During the rest of the day there is a continuous but very low flow of passengers until 20:00, which is the time when workers go back home and there are no more buses. It can also be seen from *Table AII.5* in Appendix II, that the total capacity in one weekday of the bus line 631 in this direction is around 350 numbers of seats/day, even though the real demand is lower because the buses are not always full.

For the line Kapellskär- Norrtälje (bus line 631), the number of buses per hour is obtained from *Figure AI.7* in Appendix I. The results obtained are in *Figure 2.3.6*.

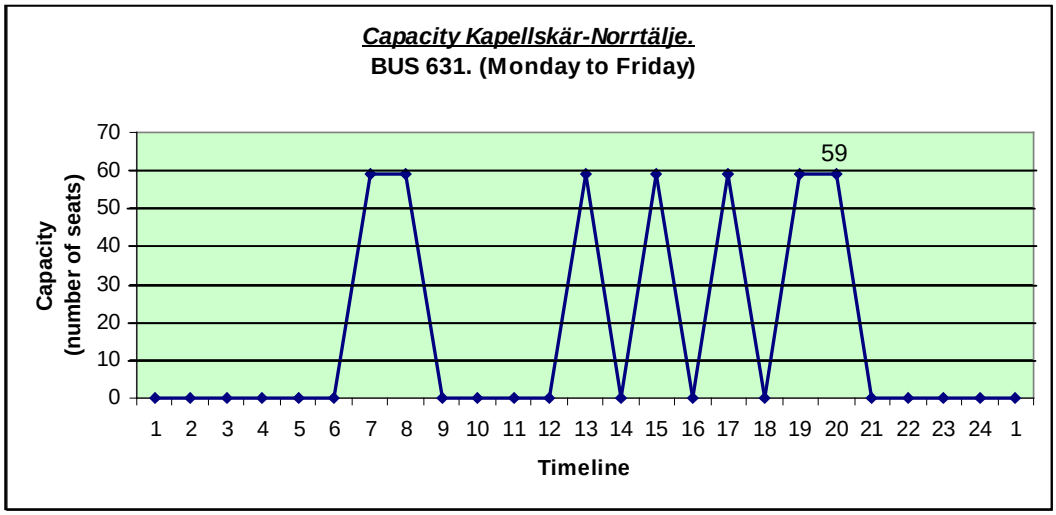

Figure 2.3.5: Capacity in bus line 631 Kapellskär - Norrtälje.

(Note: the times used for calculating the buses' capacities are the departure times).

From the graph above and *Table AII.6* in Appendix II it is shown that the highest demand (capacity) for the bus line 631 in the direction Kapellskär - Norrtälje, is 59 passengers, it means, 1 bus, and this occurs in different intervals of time: from 07:00 to 09:00, from 13:00-14:00, from 15:00-16:00, from 17:00-18:00, and from 17:00-21:00 (peak hours) which is when there is only one bus in that line (1 bus in 1 hour), and the frequency between buses is the highest (60 minutes in the interval 07:00-08:00).

Some conclusions that can be drawn from the demand calculation is that the highest demand from Kapellskär to Norrtälje from Monday to Friday is exactly the same in various intervals of time along the day, starting from 07:00-09:00 and with just one bus running every 130 minutes (an average time). The starting time corresponds to the time when the people in the port go back to Norrtälje. This morning peak is explained by the fact that during the morning there are shift-works of the port workers, so workers that have night shifts go back home to Norrtälje in the morning. It is also explained by the fact that this bus line also serves small villages along the line, and people from these villages go to work to Norrtälje in the morning also. During the rest of the day there is a continuous but very low flow of passengers until 21:00, which is the time when workers go back home and there are no more buses. It can also be seen from *Table AII.6* in Appendix II, that the total capacity in one weekday of the bus line 631 in this direction is around 410 number of seats/day, even though the real demand is lower because the buses are not always full. In this bus line the demand is higher than in the opposite way (Norrtälje - Kapellskär). The only reason to this is because there exists one more bus in the direction Kapellskär – Norrtälje (59 more seats).

2.4 Market requirements on future passenger train services

For analyzing the market effects that the new train line would have in the Stockholm region in the future, the Svealand railway line has been studied and compared as a similar case to the one that this Project plans and proposes, on the basis of the book *"Introduction of regional high speed trains. A study of the effects of the Svealand line on the travel market, travel behaviour and accessibility"*, by Oskar Fröidh, Division of Transportation and Logistics at KTH, 2003.

The Svealand line was opened in 1997 and replaced an older, less adequate train line. It consists of a newly built, and for the most part single-track line from Södertalje (81,791 inhabitants in 2006) to Eskilstuna (92,250 inhabitants in 2006), separated 79 km; and one stretch from Eskilstuna to Valskog (719 inhabitants in 2005), separated 35 km, in the Stockholm region, Sweden.

This train line is operated with regional high-speed trains X40, and while the Svealand line was being built, the slow trains that had been in operation on the old railway between Eskilstuna and Stockholm (a distance of 115 km) were replaced by buses operated by SJ[7] with a high frequency of service.

[7] *Swedish State Railways.*

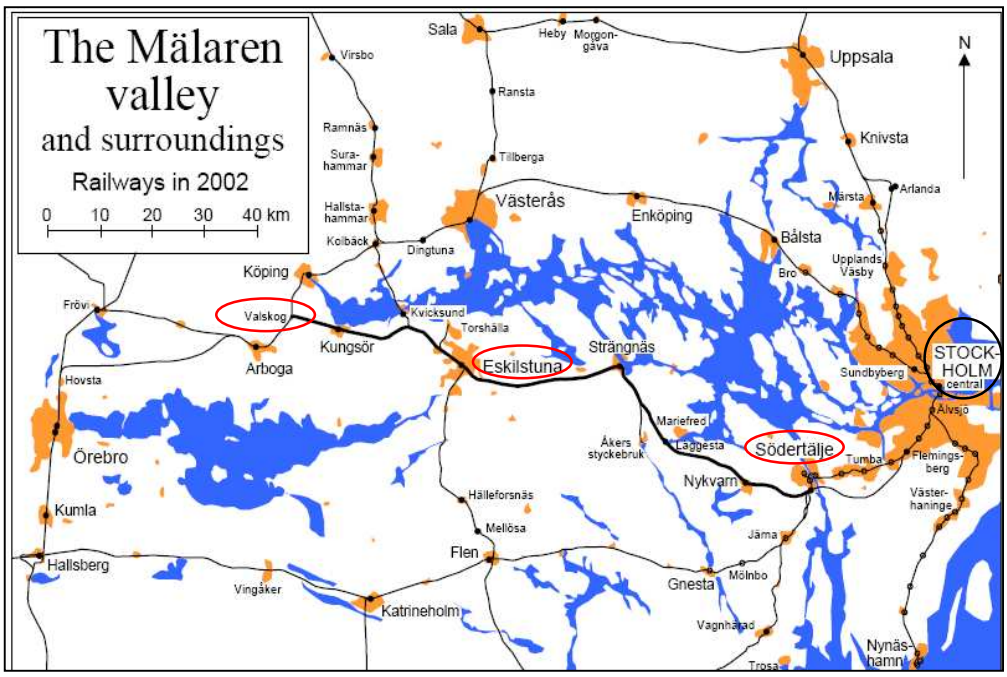

Figure 2.4.1: The Svealand train line (shown in semi bold). Source:"Introduction of regional high speed trains. A study of the effects of the Svealand line on the travel market, travel behaviour and accessibility", Oskar Fröidh, 2003.

The market effects of the introduction of the regional high-speed trains on the Svealand line have been studied in a case study from 1996 to 2002, and the results are used to compare this case study with the case related to this Project.

The aim of the research project of the Svealand line was to find general market effects as a result of an improved market supply, i.e. the connection between a radically improved supply of train services on the one hand and travel demand and accessibility on the other. The general resultant market effects can be used as indicators that some changes in the social structure will become apparent in the long term. The knowledge will be able to be used to improve and lately develop different models for transportation and social structure, may be used in studying other infrastructure investments that may be considered in the future, such as the new train line that this Project proposes.

"Underpinning the analyses are theories and models of the effects of infrastructure investments on regional economic development, and the linkage between traffic and social structure. The effects occur over varying lengths of time, and the effects of traffic are generally seen more quickly than the effects on the social structure. Through the mutual interaction between traffic and social structure, the effects of a radical change in supply will be observed in a change in demand over a prolonged period of time, until a new theoretical equilibrium emerges." [8]

In the case study of the effects of regional high-speed train services in the Svealand line, a before-and-after-study was carried out of the supply and its influence on the demand and accessibility. The study included field surveys of residents and public

[8] *"Introduction of regional high speed trains. A study of the effects of the Svealand line on the travel market, travel behaviour and accessibility", Oskar Fröidh, 2003.*

transport passengers along the line, before and after the Svealand line opened. Changes in knowledge, valuations and travel behaviour have been analyzed, as well as changes in accessibility. The supply and the demand for regional journeys by car, bus and train were also examined.

The improved public transport supply between Eskilstuna and Stockholm as a result of the new railway line has led to substantial increases in travelling due to improvements in travelling time, and supply among other factors. The frequency of the high-speed trains in the Svealand line is one train an hour, with some extra trains at peak periods.

There had been a railway on this route for a long time but supply was not good with long travelling times and infrequent trains. The results show that the Svealand line has meant an increase in travelling of up to seven times in regional travel by rail compared to the old railway between Eskilstuna and Stockholm in 1993. Travelling times have been halved, and the rail's service market share has risen from 6% to 30% for regional trips in the Svealand line. For trips to and from Stockholm especially, there has been an increase in travelling.

Approximately half of the passengers on the Svealand line in 1998 had previously been bus users, while the other half were newcomers to public transport.

Those who travel most are people who have access to a car at times (infrequent drivers). Habitual motorists (people who always have access to a car), on the other hand, account for the largest increase in travel by public transport. For all groups, trips have increased since the regional high-speed trains began operating, which indicates an increase in social and cultural contact outside people's home areas through the use of public transport.

In areas close to the railway stations new patterns of car ownership, travel behaviour, choice of transport mode and choice of destination have been found. For example, residents close to the railway stations have changed the distribution of transport mode for journeys on the Svealand line from 20-25% public transport in 1997 to 40-45% in 2000. Further from the stations, the proportions using public transport are substantially smaller.

Travelling times with public transport along the Svealand line were significantly shorter once the line has opened. For a trip from the central parts of the localities along the railway line, to the centre of Stockholm, the train is always faster than the car. The accessibility of Stockholm's market has been influenced by the faster public transport connections.

Commuting to work has also shown a marked increase. Travelling times are valued highly and especially motorists value the high-speed train mode of transport highly. Poorer train services and bus services are not attractive to motorists other than as are serve alternative to their own cars.

A general conclusion is that regional high-speed train services have had a major impact on the travel market, travel behaviour and accessibility. The improved accessibility to Stockholm in particular is especially noticeable among residents close to the railway stations.

Some more conclusions are that short travelling times, high frequency, and a reasonable price are decisive for train services' ability to take a greater market share and generate new regional journeys; also that regional high-speed trains contribute to

expand the region as daily commuting is possible over greater distances than the range of the car permits, and also contribute to better accessibility in the region, and can then provide a stimulus to the economic development of the region. The last conclusion is that the high concentration of places of work and the congestion on the roads in the centre of the region are factors that contribute to promote regional high-speed trains services in metropolitan conurbations.[9]

All these conclusions are the expected results in the future of the new train line that this Project proposes, since the Svealand line is a similar case study and is also located in a similar location (in the Stockholm region).

By looking at this case study, it can be seen that a new train line has many advantages for passengers but also for the economic growth of the region, so it is a good factor to take into account when developing a country.

There is also information related to comfort levels and service aspects in regional passenger trains, and what should be offered to the customer in a future in these type of trains (trains' requirements).[10]

Information obtained from travel studies show the following:

- Daily commuters are the most demanding train users in terms of good comfortability, punctuality, timetabling and services offered, more even than long distance travellers. The reason to this is because long distance travellers (5-7 hours travellers by train), just spend for instance 20 hours in a regional train a year, and instead, daily commuters who need to travel a short distance (up to 1 hour by train) everyday, may spend for instance 250 hours a year in a regional train. So commuters actually spend a part of their lives inside a train, this is why they are the most demanding train users. This user group should be the target for every successful train line.

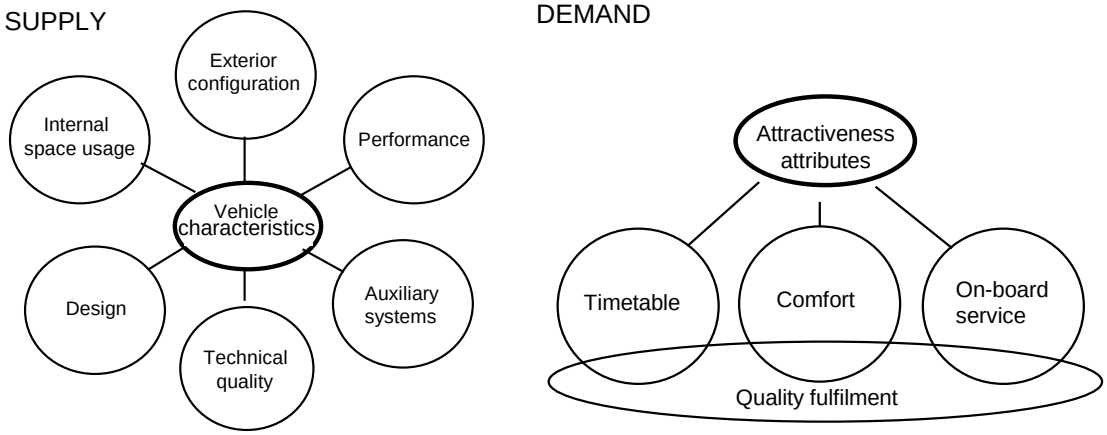

Figure 2.4.2: Classifications of vehicle characteristics and travellers' standard attributes. Source:"Evaluation of Passenger Train Concepts", Karl Kottenhoff.

[9] *"Introduction of regional high speed trains. A study of the effects of the Svealand line on the travel market, travel behaviour and accessibility", Oskar Fröidh, 2003.*
[10] *Karl Kottenhoff, Division of Transportation and Logistics at KTH.*

- There exist a ratio between public transportation travel time (train for instance) and car travel time. When this ratio is equal to 1.5, it has been studied that travellers have 50% of willingness to choose between public transportation and car, but when the ratio is higher than 1.5, there is more willingness for travellers to choose travelling by car instead than by public transportation. So as far as this ratio is lower or equal to 1.5, there is more probability to choose public transportation rather than private car, so any new public transportation route should also try to reach a ratio lower or equal to 1.5.

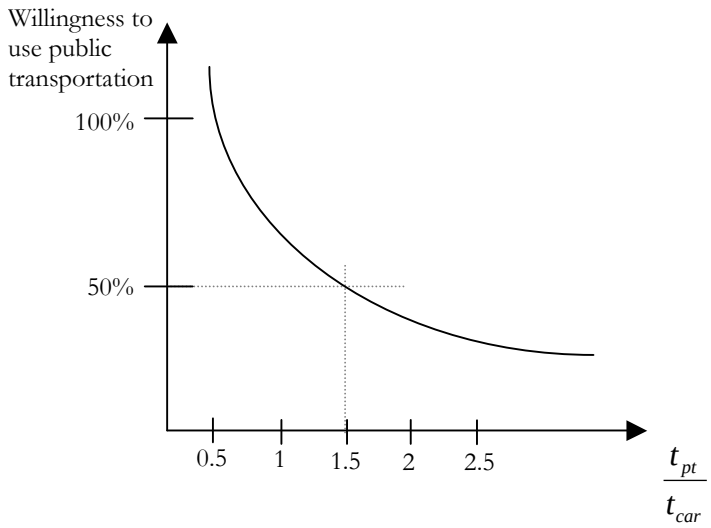

Figure 2.4.3: Ratio between public transportation travel time and car travel time. (Own elaboration based on information from Karl Kottenhoff).

Nowadays, the ratios between the travel time from Stockholm to Norrtälje by public transportation (bus) and by car, are approximately:

- Distance Stockholm-Norrtälje by road: 72 km, approximately by car 56' (assumption: average car speed 80 km/h).
- Travel time Stockholm-Norrtälje by bus: 62'.
- Ratio: $\frac{t_{pt}}{t_{car}} = \frac{62'}{56'} = 1.11$, this ratio corresponds approximately to a factor of 60% which means that travellers are more willing to use public transportation instead than car (willingness to use public transportation: 60%, willingness to use private car: 40%).

With the data obtained later on in *Chapter 5.3* (Results of the simulation) about the new passenger trains' travel time, the new ratio in the future would be:

- Travel time Stockholm-Norrtälje by car: 56'.
- Travel time Stockholm-Norrtälje by train (average travel time of all the route alternatives, see *Table 5.3.1*): 48'.

- Ratio: $\frac{t_{pt}}{t_{car}} = \frac{48'}{56'} = 0.86$, this ratio corresponds approximately to a factor of 75% which means that travellers are more willing to use public transportation instead than car (willingness to use public transportation: 75%, willingness to use private car: 25%). This ratio has been made lower with future trains compared with the nowadays existing ratio with bus services (it has subsequently improved).

- From travel surveys it has been obtained that travellers are not willing to change modes or public transport vehicles more than two times when they make a daily trip.

- The value of time is how people value in economical terms one minute of travel time, this means, it is the opportunity cost of the time that a traveller spends on his/her journey. This makes it the amount of money that a traveller would be willing to pay in order to save time, or the amount they would accept as a compensation for lost travel time. A reasonable value of time for regional trains passengers is 1 SEK=1 minute in Sweden. This is used when for example there are two or more options in mode/route choice:

  a) There is a train ticket that costs 85 SEK but by taking this train travellers will have to change trains once before arriving to their final destination.

  b) There is another train ticket that costs 100 SEK but in this train travellers do not change trains before arriving to their final destination.

  Is it worth to spend time changing trains for saving 15 SEK (the 15% of the original ticket price 100 SEK), or not?

  SP (Stated Preference) travel surveys show that 50% of the travellers would prefer to save money and spend more time, and the other 50% would prefer to save time instead by not changing trains.

  These are aspects to take into account when creating train scenarios in a new line.

- The most important measures when it comes to reducing the cost of train traffic are to produce vehicles with better, more effective internal space utilisation and to increase the average speed. This will make it possible to utilise the staff and the vehicles more effectively. Smaller trains lead to lower investment, maintenance and energy costs, and offer the same seating space.

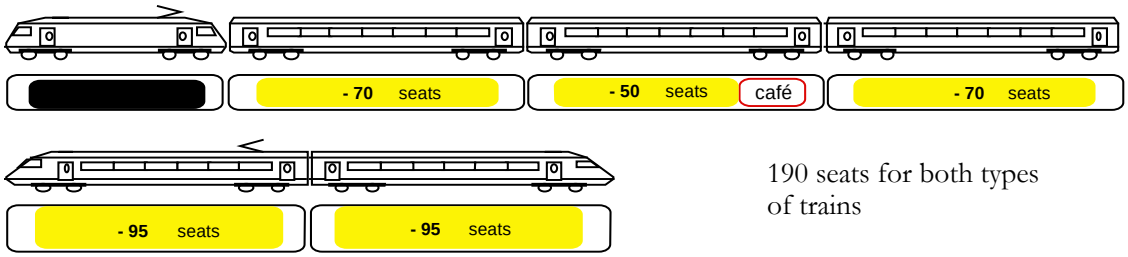

Figure 2.4.4: Increasing space utilisation – using smaller trains for the same seating space. Source:"Evaluation of Passenger Train Concepts", Karl Kottenhoff.

- Travellers value not only good timetable factors but also comfort, service and quality characteristics on board trains. These so-called secondary attributes mostly receive high valuations in SP interviews.
- Shorter travel times are given positive values by travellers. At the same time, they reduce the cost of train traffic.
- There are many comfort and service measures which cost less than the values they are assigned by travellers and which ought to be able easily to trade off some deterioration in the space standard.

3 Route alternatives

In this chapter the different route alternatives are defined, comparing one with each other and adding some conclusions at the end of each route alternative as well as giving some recommendations at the end of the chapter about which alternative is the one that fulfils most of the requirements and is likely to be the best alternative. These recommendations will not be the final decision, since the simulation with the RailSys® program still needs to be done (in *Chapter 5: Simulation*), and after all the analysis are carried out, the best alternative is chosen (in *Chapter 6: Conclusions and recommendations*).

Before defining the route alternatives, a conclusion that can be made from the studies already carried out in the chapters before is that from the passenger traffic perspective, the port of Kapellskär is not an interesting locality to link with the rest of the important points in the study area: Norrtälje, Rimbo, Märsta/Arlanda, Uppsala and Stockholm. The reason is that Kapellskär has a very low population (port workers), and the demand of passengers that go to/from Kapellskär currently by bus is also low (there is no sufficient traffic base), so it is not interesting neither worth to continue the passenger traffic railway line to Kapellskär. This destination is more interesting to link with in the case of freight traffic to/from the port, but not for passengers. It would just be interesting to continue the railway line to Kapellskär from the passenger perspective in order to connect certain trains to ferry passenger services.

As a result of what has already been studied, the passenger railway line will only be planned to arrive to Norrtälje and not to Kapellskär as it was supposed to be in the beginning of this Project. The main reason why it would be interesting to prolong passenger trains to the port of Kapellskär is in the case ferry companies are interested on running passenger trains to the port in order to serve their ship demand. The problem with this is that it is not a capacity problem, but an economic problem to do so.

Four (4) route alternatives have been defined linking the main localities in the study area with Stockholm (the most important point in the study zone) and some of the alternatives also provide a possibility to connect with Uppsala.

All the alternatives have different lengths and layouts, but some of the alternatives link the same localities as another alternative and the only difference is a stretch of the railway line. Another difference is that some of the alternatives use part of an already existing railway layout and tracks and others do not, it would all be new tracks for these last alternatives.

Besides defining the advantages and disadvantages of each route alternative and also its rail layout, and estimate the travel demand each alternative would cover, it is also defined the best location for all the new train stations in the localities where the new railway line passes by.

3.1 Alternative 1: Solna – Åkersberga - Norrtälje

This route alternative corresponds to the already planned Roslagspilen line.

In this case, the railway line passes by the localities of Solna, Danderyd, Täby, Arninge, Täljö, Åkersberga, Roslags-Kulla, Bergshamra, and Norrtälje. The connection with Stockholm is by the means of a section of the already existing railway line Stockholm – Uppsala between Solna and Stockholm of 5.6 km long (*see figures 3.1.1, 3.1.2*).

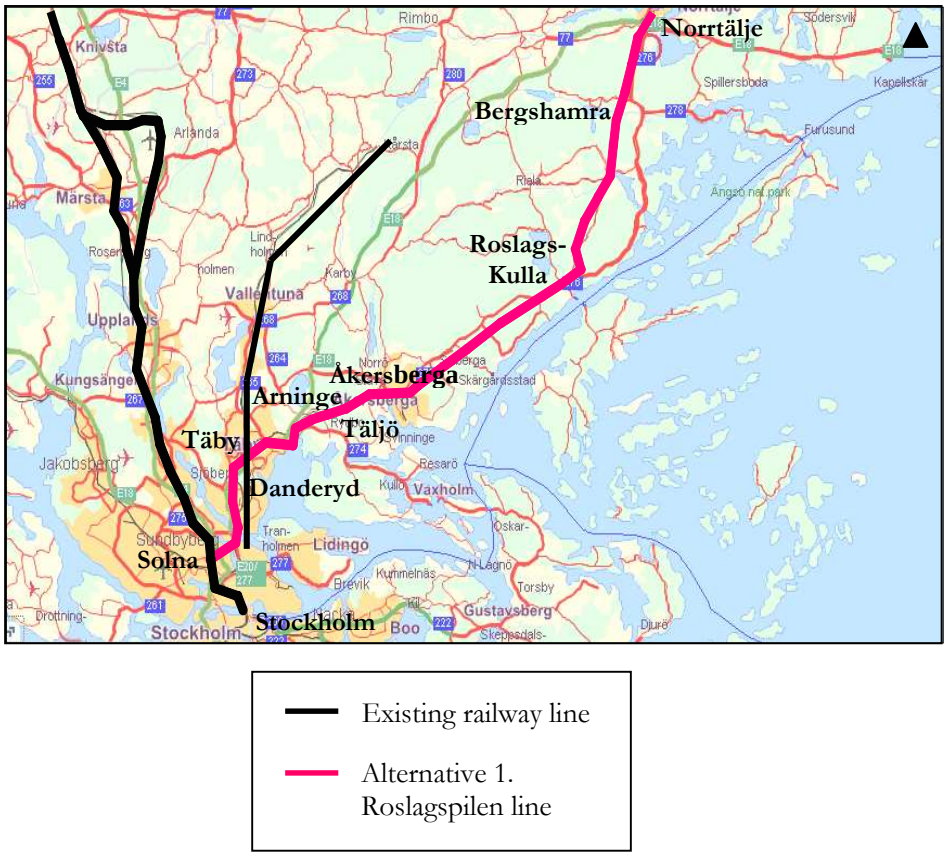

Figure 3.1.1: Alternative 1. Roslagspilen-line.

- **Layout**

This route alternative consists of a new built railway branch passing by nine (9) localities without counting Stockholm (Solna, Danderyd, Täby, Arninge, Täljö, Åkersberga, Roslags-Kulla, Bergshamra, and Norrtälje) but it just has **six (6) stops**:

- Stockholm
- Solna
- Åkersberga
- Roslags-Kulla
- Bergshamra
- Norrtälje

(see figure 3.1.2).

This route alternative partially exists from Täby to Åkersberga run by regional trains (the Österskär branch, part of the Roslagsbanan explained in *Chapter 2.1*). The problem with the existing railway line is that it is partially single-track (from Galoppfältet to Åkersberga, s*ee figure 3.1.2*) and narrow-gauge along all the line, and this is the reason why Banverket has already planned to change the existing tracks by double-tracks standard-gauge, but still keeping the same line layout and serving less towns than the existing Roslagsbanan line nowadays. The reasons why they are planning to do this is because this way it can be continued the railway line up to Norrtälje (the Roslagspilen line) in the future, and also have double-track standard-gauge that can be used for passenger high speed trains, regional trains, and freight trains.

Banverket, in its planning of the Roslagspilen line, has planned to build first the railway section from Solna to Arninge via tunnel. This section may be realized independently of the prolongation to Norrtälje. The part between Arninge and Åkersberga is planned to remain mainly in the same area as today's tracks (Roslagsbanan) *(see figure 3.1.3).*

Figure 3.1.2: Existing Roslagsbanan train line. Source: Roslagståg.

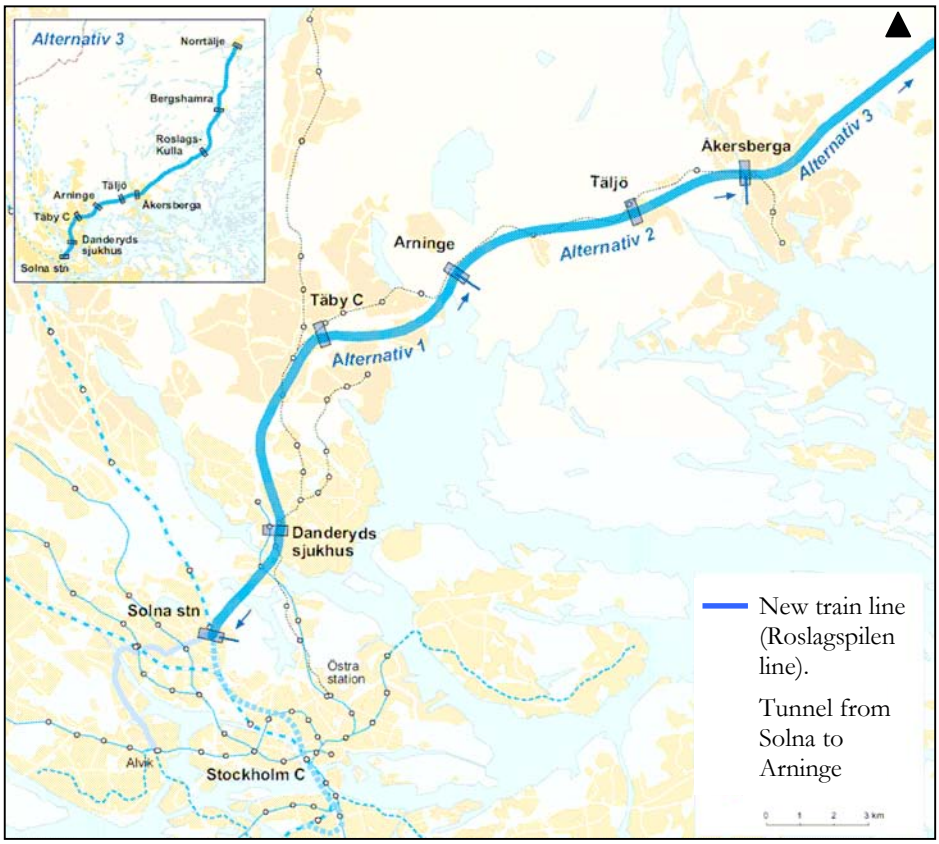

Figure 3.1.3: Part of the Roslagspilen-line between Solna and Åkersberga. Source: Banverket.

The reason why this proposed new route train line does not stop in each locality (it has been designed to just stop at Stockholm, Solna, Åkersberga, Roslags-Kulla, Bergshamra, and Norrtälje) is because if it did, trains would not be able to run up to 200 km/h, so it would not be regional high-speed because the localities where today trains stop at are separated an average distance of 7 km one from each other nowadays (a short distance for run near 200 km/h between stops), so it has been decided to stop at the most separated, important and bigger localities along this line.

In Åkersberga travellers can change to commuter trains that do not exist nowadays but that are already planned to be introduced[11] that will run from Stockholm to Åkersberga in order to cover the demand of the small localities situated in this area. These commuter trains will stop in each station of the following: Stockholm – Karlberg – Solna – Danderyd – Täby – Arninge – Täljö – Åkersberga.

This way, if a traveller running in this Route Alternative 1 wants to change to the already existing railway line Stockholm – Uppsala (for going to Uppsala or to Arlanda airport for instance), he/she can stop in Solna, and here change to the trains that run in the line Stockholm – Uppsala. Solna will be used in this route alternative as an interchange terminal for going to the North coming from the East.

This railway route alternative passes by very densily populated areas, so as a first approach, this route would not be the best choice from a freight traffic perspective,

[11] *Source: Banverket.*

since freight trains pass by without stopping in all stations, just in the most important like Stockholm and the port of Kapellskär (in case a new freight railway line is planned from Stockholm to the port of Kapellskär); and are not socially well accepted in terms of "passing by populated areas". Plus the fact that this route alternative has a section via tunnel (from Solna to Arninge), and freight trains do not run inside tunnels for safety reasons.

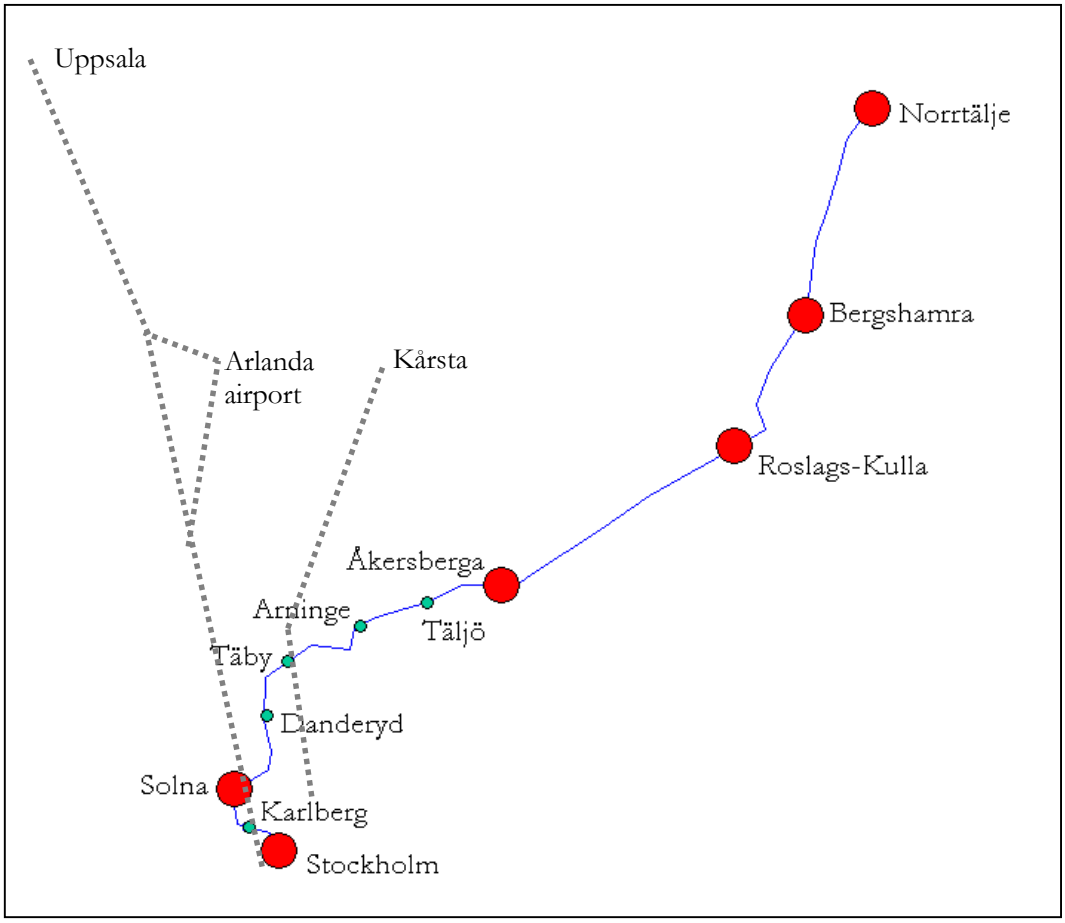

Figure 3.1.4: Sketch of Alternative 1.

The length of this line is approximately **70.8** km from Stockholm to Norrtälje, divided in the following approximate distances between stations:

- Stockholm - Solna: 5.6 km
- Solna - Åkersberga: 23.9 km
- Åkersberga – Roslags-Kulla: 16.5 km
- Roslags-Kulla - Bergshamra: 11 km
- Bergshamra - Norrtälje: 13.8 km

} Stock. - Norrtälje: 70.8 km

Approximate length of new build tracks from Åkersberga to Norrtälje: 41.3 km

The average distance between stations is 14.20 km.

For this route alternative as for the rest, the infrastructure would be double-tracks and standard gauge (1,435 mm) with a design speed of 200 km/h, even though it will probably be a lower speed in the Solna-Arninge section since it is planned to be via tunnel.

In the case of intersections between the railway line and roads or highways, this problem will be solved by the use of bridges or different level crossings.

- **Traffic potential**

The potential of a new railway line is defined here as the sum of the populations of the localities that do not have train services today and that the new railway line is able to serve.

The total passenger traffic potential that this route alternative would cover is the total sum of the population of the towns that are connected by bus services with the localities where this railway alternative stops at, plus the population of the localities where the train stops. This method is an approximate method of calculating the potential covered by each route alternative.

In this case, Stockholm and Solna have not been taken into account when calculating the potential because people living in those places are not the ones who will use the new train line very much to go to Stockholm (they will not be the new reached travellers), since Solna is already well connected to Stockholm by bus and train services (they are already served). In the other way (people from Stockholm and Solna going to Norrtälje), there will not be neither too many people making these trips. Travel demand is mainly in one direction: Norrtälje to Stockholm (and all the intermediate stations besides Solna), because most of the travellers that will use the new train line will be the people living in the north of Stockholm going to Stockholm (the newly served passengers).

The population numbers are from December 2005, so it is expected that these population values will be higher in the future, so a higher potential will be covered in the future.

For this first alternative, the potential reached is the following:

	POPULATION CENTRE	POPULATION 2005-12-31	POPULATION OF THE MAIN POTENTIAL GENERATORS
STATIONS	Stockholm urban area	1,252,020	-
	Solna	60,402	-
	Åkersberga	26,727	26,727
	Roslags-Kulla	5,157	5,157
	Bergshamra	751	751
	Norrtälje	16,263	16,263
	TOTAL:	1,361,320	**48,898**

Table 3.1.1: Potential population of the stations in Alternative 1.

(Note: for the small towns which population is smaller than 100 inhabitants, it was supposed a potential population of 100 inhabitants).

Station: ÅKERSBERGA	POTENTIAL POPULATION REACHED BY BUS LINES
Täljö	7,354
Kristineholm (Österskär)	23,906
Smaller towns: Arninge, Dyvik, Singö, Gåsvik	*400 (assumption)*
TOTAL:	**31,660**

Table 3.1.2: Potential of Åkersberga reached by bus lines.

Station: ROSLAGS-KULLA	POTENTIAL POPULATION REACHED BY BUS LINES
Smaller towns: Vira Bruk, Riala	*200 (assumption)*
TOTAL:	**200**

Table 3.1.3: Potential of Roslags-Kulla reached by bus lines.

Station: BERGSHAMRA	POTENTIAL POPULATION REACHED BY BUS LINES
Solbacka	*100 (assumption)*
TOTAL:	**100**

Table 3.1.4: Potential of Bergshamra reached by bus lines.

Station: NORRTÄLJE	POTENTIAL POPULATION REACHED BY BUS LINES
Rörvik	555
Hallstavik	4,530
Edsbro	515
Rimbo	4,606
Angarn	7,345
Svensboda	3,472
Rådmansö	1,006
Blidö	617
Vätö	1,465
Malsta	4,283
Länna	698
Smaller towns: Yxlan, Björkö, Vigelsjö, Vårgatan, Harö, Lohärad, Väsbylund, Söderhall, Grind	*500 (assumption)*
TOTAL:	**29,592**

Table 3.1.5: Potential of Norrtälje reached by bus lines.

TOTAL POTENTIAL POPULATION REACHED BY ALTERNATIVE 1	
Åkersberga	31,760
Roslags-Kulla	200
Bergshamra	100
Norrtälje	29,592
Population of the main potential generators	48,898
TOTAL:	**110,550**

Table 3.1.6: Total potential of Alternative 1.

Alternative 1 covers a total of **110,550** inhabitants as a potential population (people that are willing to use the new train line).

- **Advantages and Disadvantages of Alternative 1**

The advantages that this route alternative has are:

- It passes by very densely populated areas and so this line would cover more demand than other that does not pass through these zones.
- This line connects Norrtälje to Stockholm (two of the main localities in this Project) and passes by very close communities to Stockholm.
- The type of tracks used is double-track and standard gauge.
- Not a curvy layout, so that the speed of the trains is just defined by the stopping patterns.
- This line can be interconnected to the railway line Stockholm-Uppsala by the station in Solna, and also reach Arlanda airport (passenger intermodality).
- This alternative is also connected to commuter trains that serve more demand.

The disadvantages that this route alternative has, are:

- Not a good alternative for freight traffic since the line passes by very densely populated areas and partially via tunnel.
- Not much space for the tracks and train stations since this area is very populated and there are lots of housing areas.
- This line does not serve Rimbo (important locality for the Project) or Arlanda airport (a very important point for travel demand).
- The alternative does not connect directly with the line Stockholm – Uppsala.
- It is all new tracks from Åkersberga to Norrtälje; this alternative does not use any existing tracks nowadays.

- Many new stations to build.

- **Train stations**

All the train stations have been designed near the bus stations existing in each locality where the train stops at. This way passenger intermodality is promoted.

The train stations whose location has been specified are those that do not exist nowadays, it means, the localities that already have train station like Stockholm, Åkersberga and Solna, will use the same station localization as the existing nowadays.

The new train stations need a large piece of land and if they are planned to be localized inside the city, it is difficult to find enough space for this, that is why the best place for localizing the new train stations is in the outskirts of the localities where the train stops at, or even near public spaces such as parks or gardens.

There exist many different station configurations, but for this Project only two station types will be used:

- Stations with two platforms: one on each side of the tracks:

Figure 3.1.5: Sketch of station type: two platforms.

- Stations with just one platform between tracks:

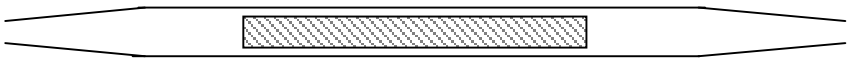

Figure 3.1.6: Sketch of station type: one platform.

The first type (*figure 3.1.5*) does not need too much longitudinal space because the distance between tracks is constant and there is no need of space for narrowing/widening the tracks. In the other hand, this configuration needs more transversal space because this type of station is wider since it has two platforms. This station type may be completed with the addition of tracks on the sides that allow trains to stop there or wait for another train to pass by without existing conflicts between trains. This configuration is more uncomfortable for the customers (passengers) from the passenger perspective because passengers need to change to different platforms depending on the train they are taking.

The second type of train station (*figure 3.1.6*) needs more longitudinal space but less transversal space. The reason why more longitudinal space is needed is because the incoming tracks are getting wider when they are approaching the station (the space

between tracks gets larger), since the platform is between tracks, and the space needed for widen the tracks is large. This occurs on both sides of the platform. In the other hand, this station type is more convenient from the passenger perspective since customers do not need to change platforms. With this configuration trains that are not stopping at this station need to slow down the speed because of the tracks configuration, so from the train perspective this is not the best configuration.

It can be said that the station type with two platforms is more space efficient than the second type, and also more convenient from the trains perspective, but depending on the layout and the availability of space for the station, one station type or the other is better to be used.

After defining the types of stations that will be used, the location of the stations is explained next.

For each locality there are several options of where to build the new train station:

- **STOCKHOLM:** there is already a train station nowadays and a new train station underground is now being built besides the existing one, so a recommendation is to study further to which station should the trains this Project proposes go to in a future.

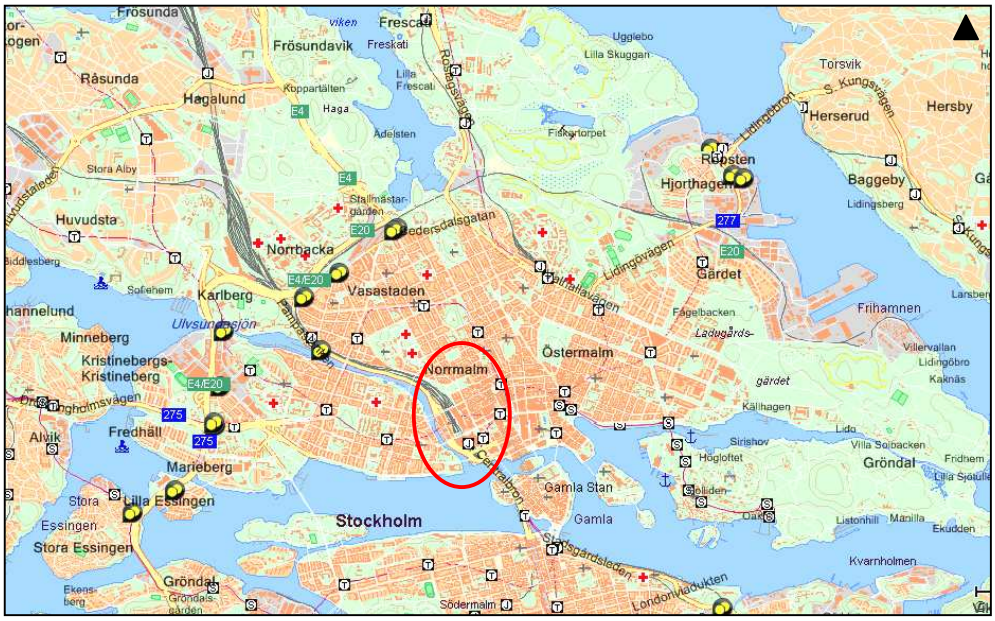

Figure 3.1.7: Train station in Stockholm. Map.

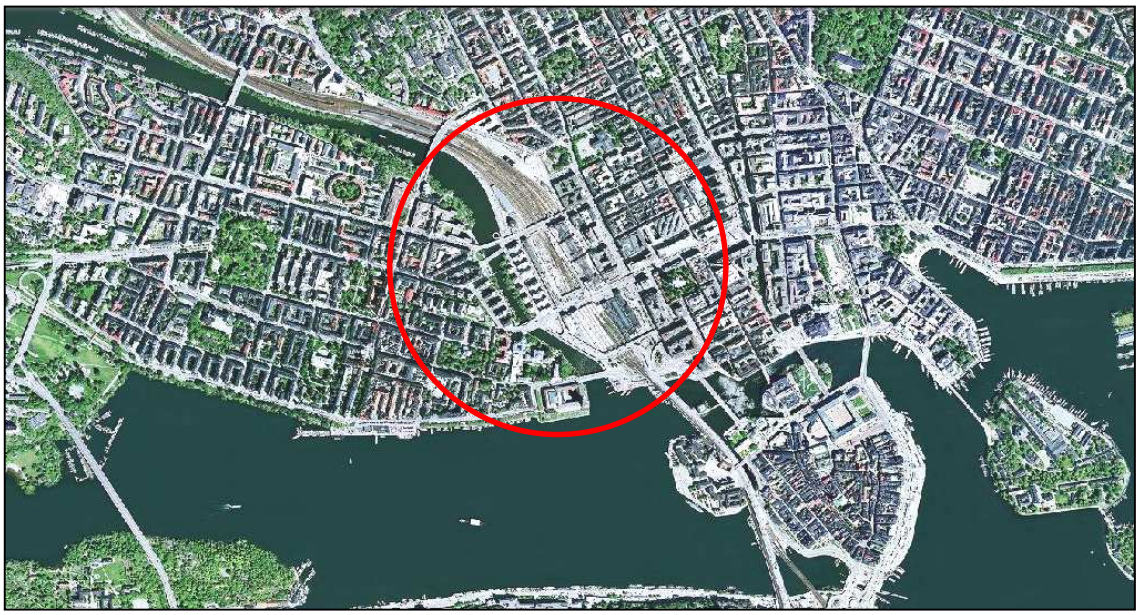

Figure 3.1.8: Train station in Stockholm. Aerial photograph.

This train station includes 19 platforms.

- **SOLNA:** the train station used will be placed in the same place as the existing one, but the station used will be the one already planned by Banverket (shown in *figure 3.1.11*).

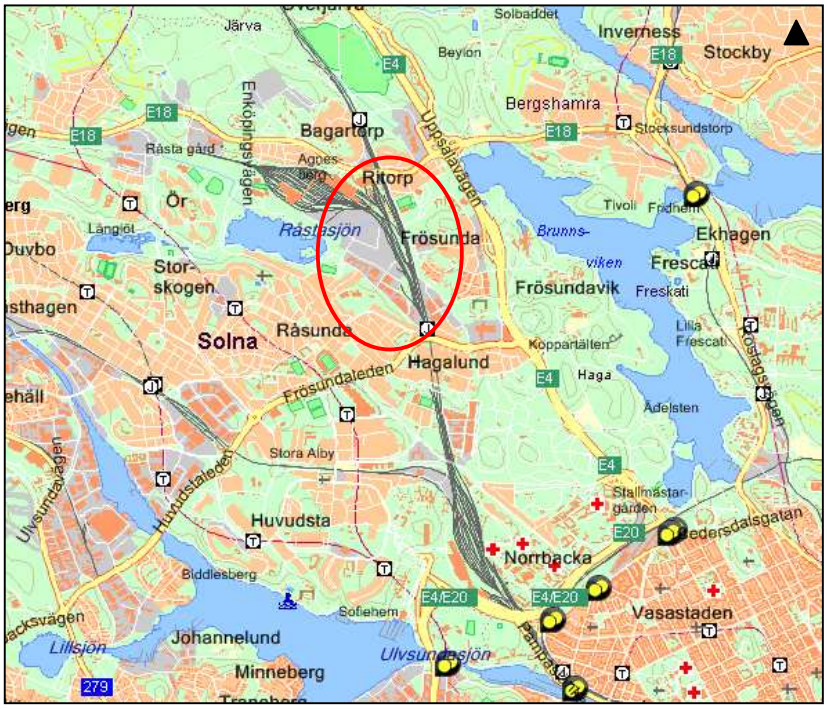

Figure 3.1.9: Train station in Solna. Map.

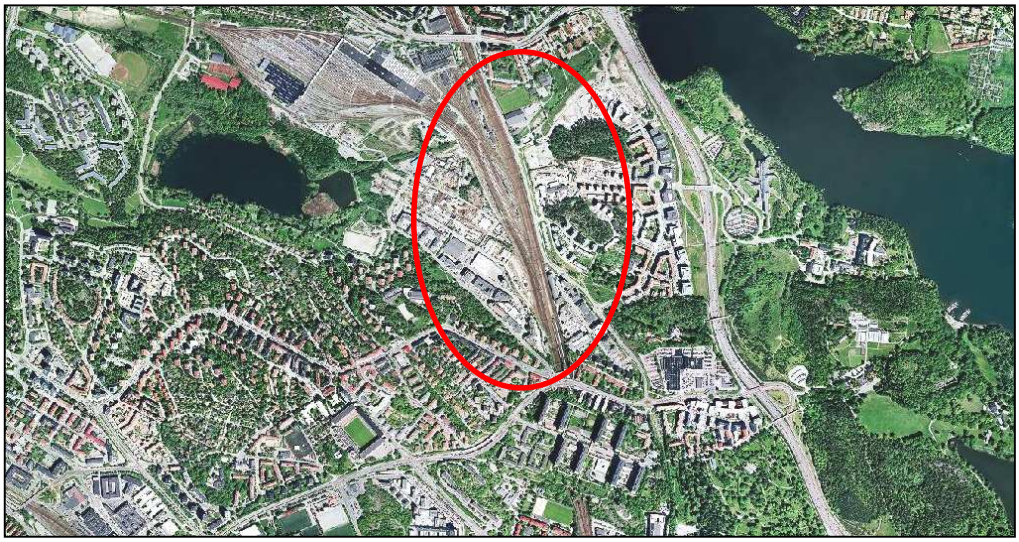

Figure 3.1.10: Train station in Solna. Aerial photograph.

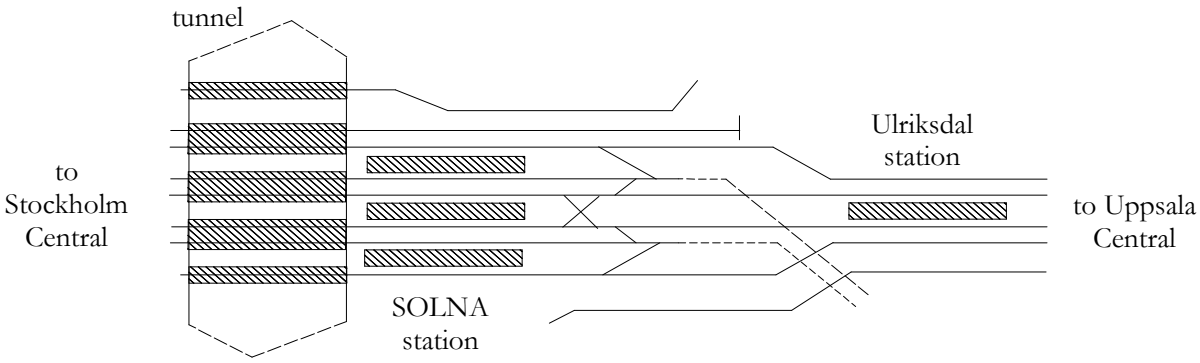

Figure 3.1.11: Future train station in Solna designed by Banverket.

- **<u>ÅKERSBERGA</u>:** the train station used will be the same as the existing one, even though the type of tracks will be changed to double-tracks standard-gauge, and so, maybe, the train station will also be changed, but it will remain in the same place where it is nowadays.

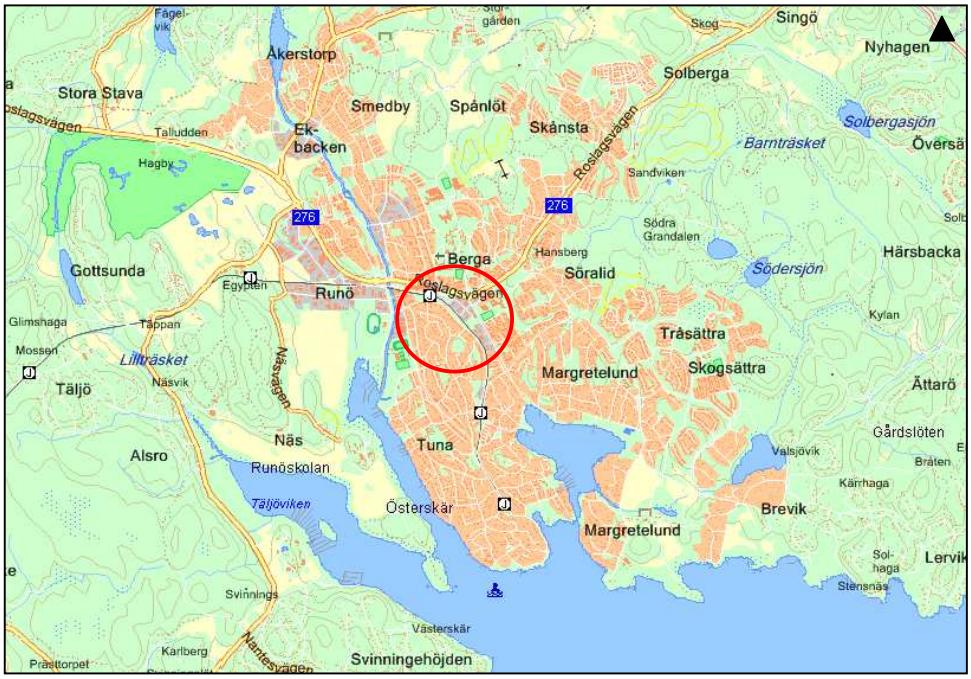

Figure 3.1.12: Train station in Åkersberga. Map.

Figure 3.1.13: Train station in Åkersberga. Aerial photograph.

- **ROSLAGS-KULLA:** here the task of where to localize the new train station should be rather easy, since the development of this area is partly a new municipality where railway station and houses can be planned as a whole. Two alternatives for the emplacement of the new train station are proposed.

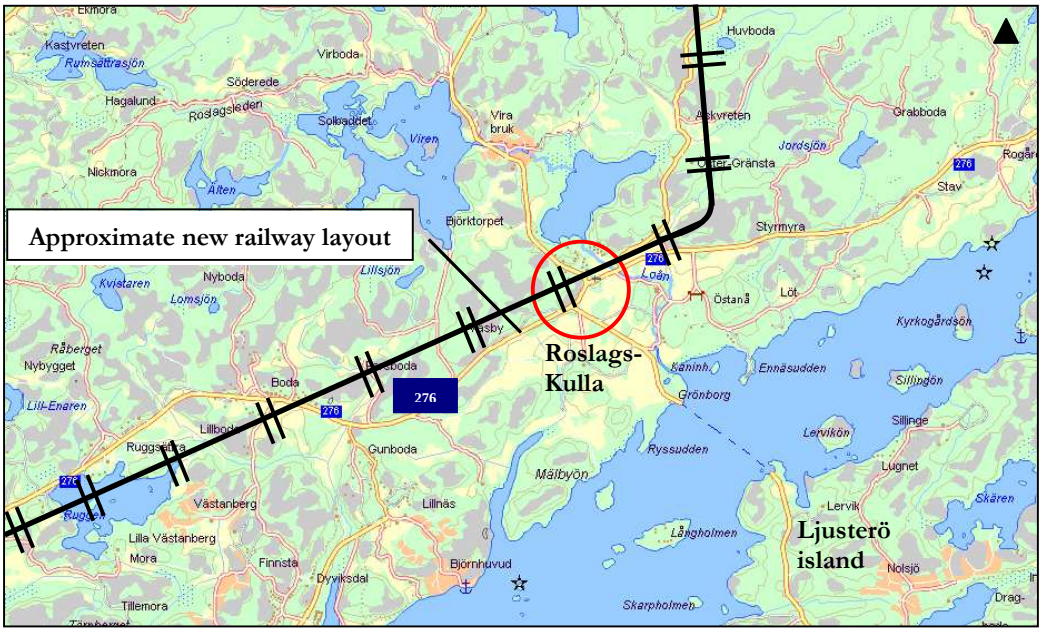

Figure 3.1.14: New railway layout in Roslags-Kulla. Map.

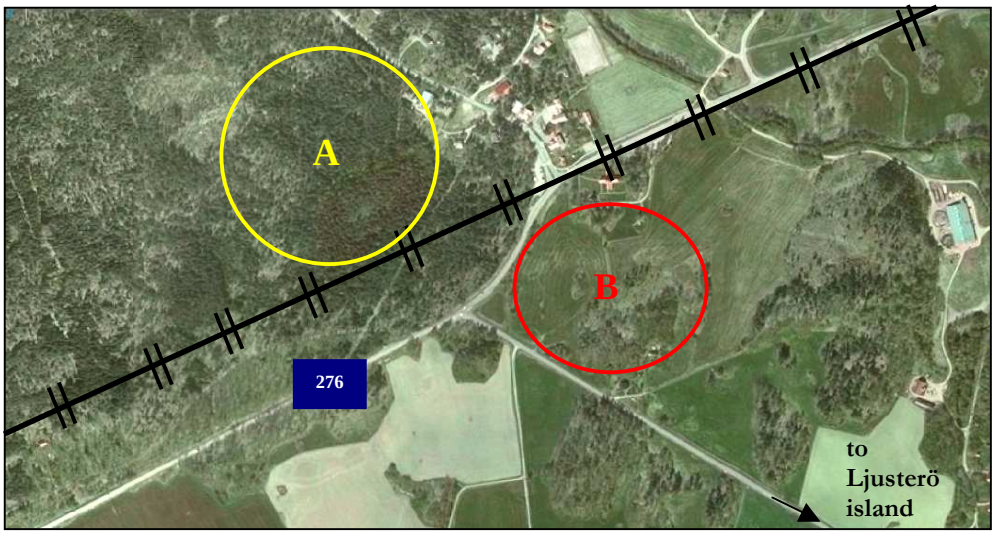

Figure 3.1.15: Alternatives for the new Roslags-Kulla's train station's location. Aerial photograph.

Both alternatives have space enough for the construction of the new train station, but in Alternative A there is a lot of forest and trees' areas, plus some houses, and in Alternative B there are not housing areas, not so many trees, and if the train station was localized here, it would serve two main roads: road 276 and the road that links with Ljusterö.

Because of all the before said, it has been decided to localize the new Roslags-Kulla's train station at the south of the train line (Alternative B), since this alternative has more advantages and less disadvantages than the other alternative.

- **BERGSHAMRA:** here the task of where to localize the new train station should be rather easy, since the development of this area is partly a new municipality where railway station and houses can be planned as a whole. Two alternatives for the emplacement of the new train station are proposed.

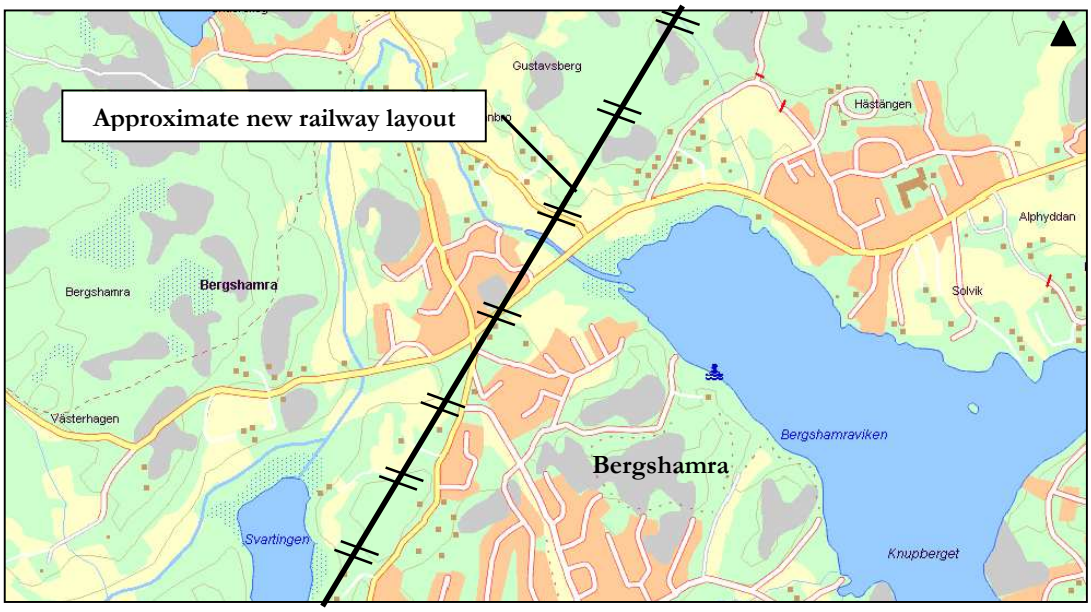

Figure 3.1.16: New railway layout in Bergshamra. Map.

The different alternatives for the location of the train station in Bergshamra are:

A) at the east of the road that crosses the rail layout.

B) at the west of the road that crosses the rail layout.

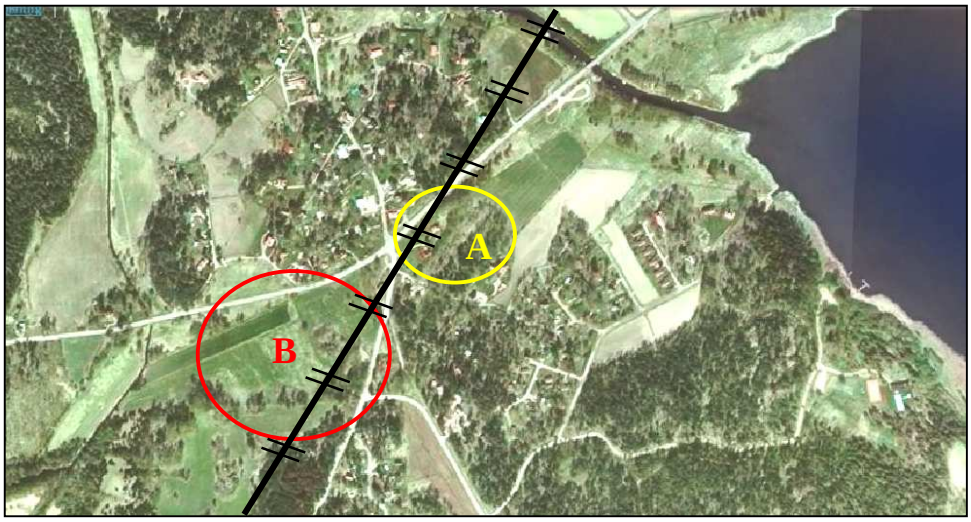

Figure 3.1.17: Alternatives for the new Bergshamra's train station's location. Aerial photograph.

Both alternatives have space enough for the construction of the new train station, but in Alternative A there are housing areas and forest, and in Alternative B there are not housing areas, not so many trees, and there is more space available for the station.

Because of all the before said, it has been decided to localize the new Bergshamra's train station at the west of the road that crosses the rail line (Alternative B), since this alternative has more advantages and less disadvantages than the other alternative.

Figure 3.1.18: Location of the new Bergshamra's train station. Aerial photograph.

- **NORRTÄLJE:**

The different alternatives for the location of the new train station in Norrtälje are:

A) Inside the town, so that the train serves the centre of Norrtälje. It was considered the idea of building the new train station where the old train station was, which is where the actual bus station is located.

B) In the South of Norrtälje by the road E18, where there is enough space for localising a train station for passengers and freight traffic.

Figure 3.1.19: Alternatives for the new Norrtälje's train station's location. Map.

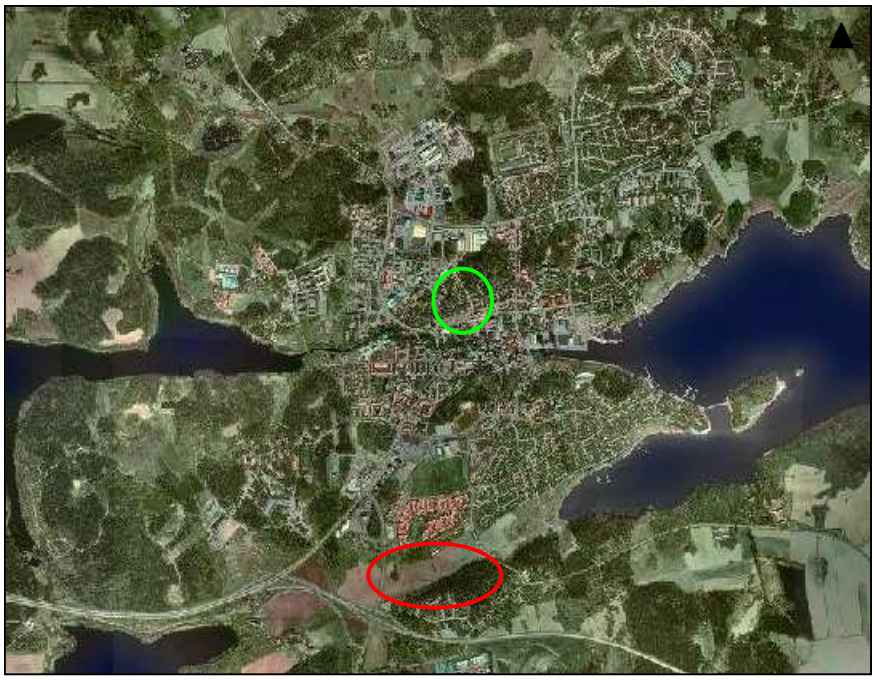

Figure 3.1.20: Alternatives for the new Norrtälje's train station's location. Aerial photograph.

Taking into account advantages and disadvantages of each alternative, the next conclusions have been made:

LOCATION OF THE NEW TRAIN STATION	ADVANTAGES	DISADVANTAGES
A) Inside Norrtälje	- Train serves the centre of the city. - No need for any other transportation system in order to arrive to the new train station. - Possible usage of the old train station area. - Passenger intermodality train-bus.	- Not enough space for a new station. - Too much noise for residents living close to the station. - Social problems. - Very difficult and high costs of building the new train station and tracks through the middle of the town. - If use of old train station area, the town will be congested because the actual bus station is localised there. - Contamination of the inner city. - No possibility of expansion and enlargement of the train station in the future.

B) South of Norrtälje	- Train serves suburbs and industries (farm lands) of the city (better from a freight traffic perspective). - No noise and social problems with residents. - No space problems. - No contamination of the inner city and congestion. - Possibility of expansion and enlargement of the train station in the future. - Possibility of creating a train-bus interchange terminal. - A main road passes near the train station (good from a transportation perspective). - Better location for freight traffic.	- Need for another transportation system in order to arrive to the new train station.

Table 3.1.7: Advantages and disadvantages of the new Norrtälje's train station's location.

From the *Table 3.1.7*, it has been decided that the best emplacement for the new Norrtälje's train station is at the South of Norrtälje (alternative B), since this alternative has more advantages and less disadvantages than the other alternative.

Figure 3.1.21: Location of the new Norrtälje's train station. Aerial photograph.

It has been proposed the new train station configuration for Norrtälje, since this locality is the end of the railway line and this station will not have the same configuration as the rest of intermediate stations.

The proposed design for the new Norrtälje's train station has been made taking into account possible future freight trains going from Norrtälje to the port of Kapellskär.

This proposal is the following, which advantages are explained below:

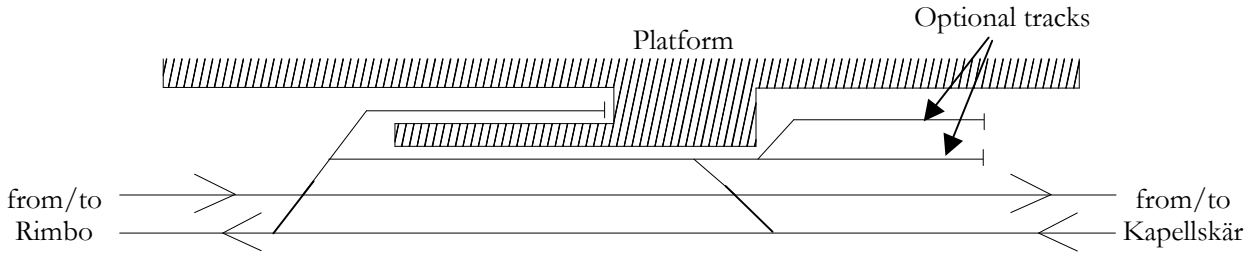

Figure 3.1.22: Proposal design for the new train station in Norrtälje.

Advantages of the proposal design:

- Freight trains are able to pass by without stopping in Norrtälje going to the port of Kapellskär.
- Possibility of accommodating two trains in the same station.
- Good passenger access: a passenger friendly station.
- Not many switches.
- Good for train operations.
- Optional tracks in order to have the possibility of parking/storing trains (storage tracks).

3.2 Alternatives 2a, 2b: Stockholm – Märsta/Arlanda – Norrtälje

In this subchapter two railway route alternatives will be proposed. They have almost the same layout just differing one from each other in a little track stretch.

3.2.1 Alternative 2a: Stockholm – Märsta - Norrtälje

In this case, the railway line stops in the localities of Norrtälje, Rimbo, Märsta, and Stockholm. In this alternative, part of the route is new tracks, and part belongs to the already existing railway line from Stockholm to Uppsala. The new built tracks would be the stretch from Norrtälje to the connection with the railway line Stockholm – Uppsala in the vicinity of Märsta. (*see figures 3.2.1.1, 3.2.1.2*).

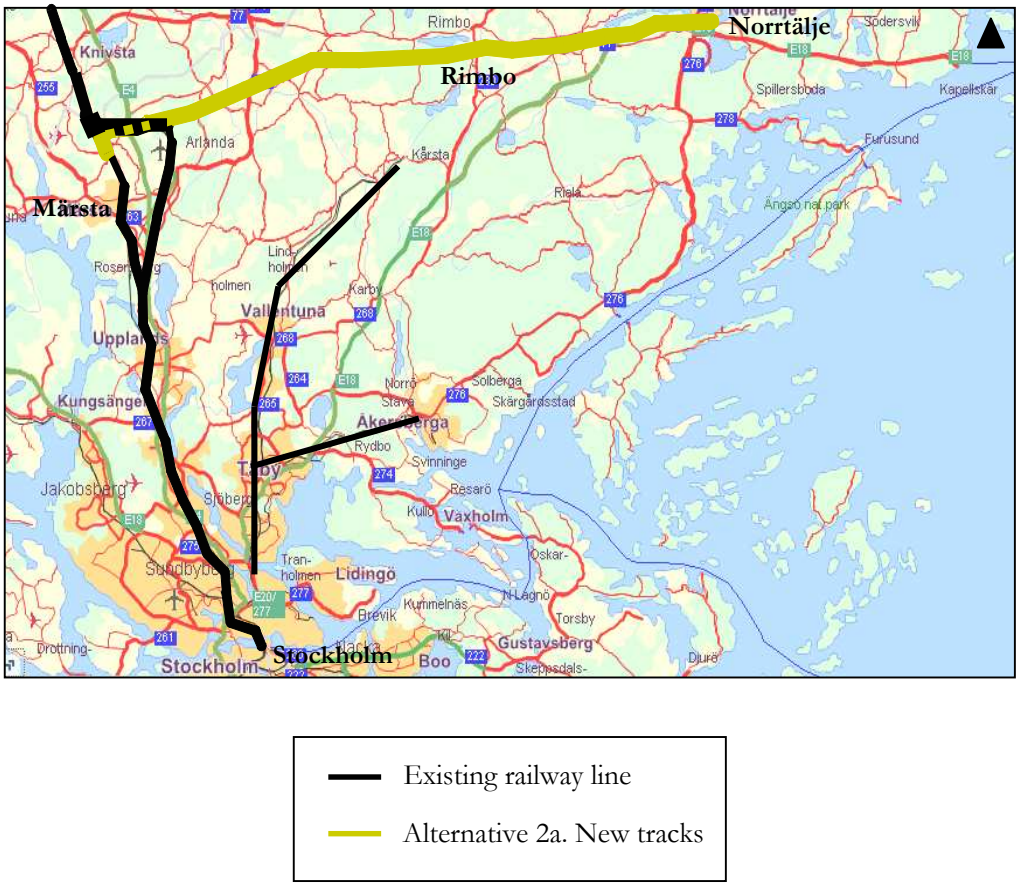

Figure 3.2.1.1: Alternative 2a.

- **<u>Layout</u>**

This route alternative consists of a new railway branch from Norrtälje to Märsta, and then, from Märsta to Stockholm following the already existing railway line Stockholm-Uppsala. Before connecting to the railway line Stockholm – Uppsala, the layout is the same as the Arlanda railway line for 3 km approximately but with the exception that a small stretch going south is built so that the route alternative passes by Märsta (*see figure 3.2.1.2*). The rest of the layout from Märsta to Stockholm is through the already existing railway line Stockholm – Uppsala.

This route Alternative 2a stops at three (3) localities without counting Stockholm: Norrtälje, Rimbo, and Märsta; and the train stops in all the localities with a total of **<u>four (4) stops</u>**:

- Stockholm
- Märsta
- Rimbo
- Norrtälje

(see figure 3.2.1.2).

The length of this line is approximately **<u>90.5</u>** km from Stockholm to Norrtälje, divided in the following approximate stretch lengths:

- Stockholm - Märsta: 37.5 km
- Märsta - Rimbo: 34 km
- Rimbo – Norrtälje: 19 km

} Stock. - Norrtälje: 90.5 km

The average distance between stations is 30 km.

The length of the new built tracks is approximately 48 km.

In Märsta travellers can change to commuter trains existing nowadays that run from Stockholm to Märsta and also change to bus services that connect Märsta with Arlanda airport. The commuter trains stop in each station of the following: Stockholm – Karlberg – Solna – Ulriksdal – Helenelund – Sollentuna – Häggvik – Norrviken – Rotebro – Rosersberg – Märsta. Märsta will be used in this route alternative as an interchange terminal for going to the North of Stockholm or to Arlanda airport coming from the Northeast.

In this route Alternative 2a, trains have the possibility to run directly from Norrtälje to Uppsala by using the linking stretch in the Arlanda railway line loop or also by changing train directions at Märsta.

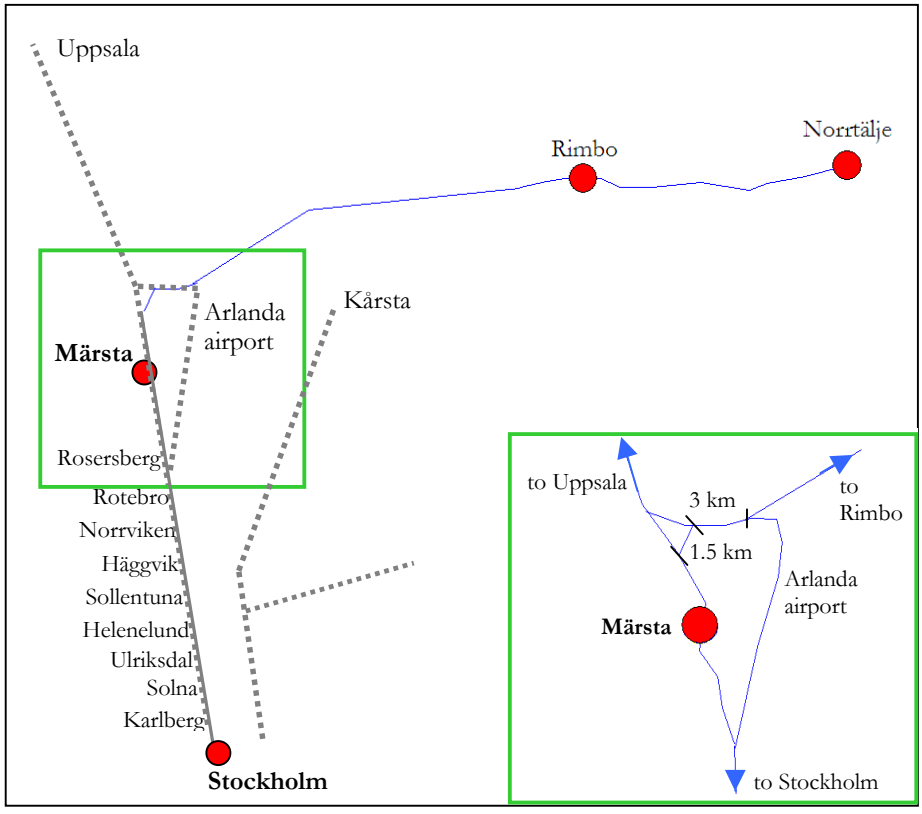

Figure 3.2.1.2: Sketch of Alternative 2a.

It is not interesting for economical reasons to build also a railway stretch going to Arlanda airport because Märsta is very close to Arlanda and well connected by bus services and so all the passenger demand in Arlanda is covered by Märsta.

This railway route alternative does not pass by very densily populated areas, so as a first approach, this route would be a good choice from a freight traffic perspective (in the case a freight traffic railway line is planned from Stockholm to the port of Kapellskär), but it does not cover the demand coming from Arlanda airport directly.

For this route alternative as for the rest, the infrastructure would be double-tracks and standard gauge (1,435 mm) with a design speed of 200 km/h.

In the case of intersections between the railway line and roads or highways, this problem will be solved by the use of bridges or different level crossings.

- **Traffic potential**

The potential of a new railway line is defined here as the sum of the populations of the localities that do not have train services today and that the new railway line is able to serve.

The total passenger traffic potential that this route alternative would cover is the total sum of the population of the towns that are connected by bus services with the localities where this railway alternative stops at, plus the population of the localities where the train stops. This method is an approximate method of calculating the potential covered by each route alternative.

In this case, Stockholm and Märsta have not been taken into account when calculating the potential because people living in those places are not the ones who will use the new train line very much to go to Stockholm (they will not be the new reached travellers), since Märsta is already well connected to Stockholm by commuter train services (it is already served). In the other way (people from Stockholm and Märsta going to Norrtälje), there will not be neither too many people making these trips. Travel demand is mainly in one direction: Norrtälje to Stockholm (and the intermediate station in Rimbo), because most of the travellers that will use the new train line will be the people living in the north of Stockholm going to Stockholm (the newly served passengers). In the other hand, it is possible that people from Märsta will also use the new passenger trains since they will not stop in any intermediate station between Märsta and Stockholm, so this will may be a faster way to get to Stockholm coming from Märsta and vice versa, that is the reason why Märsta should also be taken into account when calculating the potential (it was not taken into account in this Project though. This should be studied more in depth).

The population numbers are from December 2005, so it is expected that these population values will be higher in the future, so a higher potential will be covered in the future.

For this Alternative 2a, the potential reached is the following:

	POPULATION CENTRE	POPULATION 2005-12-31	POPULATION OF THE MAIN POTENTIAL GENERATORS
STATIONS	Stockholm urban area	1,252,020	-
	Märsta	22,548	-
	Rimbo	4,606	4,606
	Norrtälje	16,263	16,263
	TOTAL:	1,295,437	**20,869**

Table 3.2.1.1: Potential population of stations of Alternative 2a.

(Note: for the small towns which population is smaller than 100 inhabitants, it was supposed a potential population of 100 inhabitants).

Station: NORRTÄLJE	POTENTIAL POPULATION REACHED BY BUS LINES
Rörvik	555
Edsbro	515
Svensboda	3,472
Rådmansö	1,006
Blidö	617
Vätö	1,465
Malsta	4,283
Smaller towns: Yxlan, Björkö, Vigelsjö, Vårgatan, Harö, Lohärad, Grind	*400 (assumption)*
TOTAL:	**12,313**

Table 3.2.1.2: Potential of Norrtälje reached by bus lines.

Station: RIMBO	POTENTIAL POPULATION REACHED BY BUS LINES
Angarn	7,345
Hallstavik	4,530
Ubby	1,938
Länna	698
Smaller towns: Söderhall, Väsbylund, Rånäs, Varleda, Norrbyggeby, Fantbol, Beateberg	*400 (assumption)*
TOTAL:	**14,911**

Table 3.2.1.3: Potential of Rimbo reached by bus lines.

TOTAL POTENTIAL POPULATION REACHED BY ALTERNATIVE 2a	
Norrtälje	12,313
Rimbo	14,911
Population of the main potential generators	20,869
TOTAL:	**48,093**

Table 3.2.1.4: Total potential of Alternative 2a.

Alternative 2a covers a total of **48,093** inhabitants as a potential population (people that are willing to use the new train line).

- Note: the potential at Arlanda airport has not been added to the new railway line because the majority of the passengers arriving at Arlanda airport are going to Stockholm and not to the area where Rimbo and Norrtälje are, and there is already today a train service and bus service from Arlanda to Stockholm, so this potential is already served.

However, there is of course the possibility for people from Rimbo, Norrtälje and places served by connecting bus-lines to them to reach Arlanda by using the new passenger trains and vice versa.

Because there are no statistics available on how many passenger at Arlanda are coming (or going to) any of those communities, an assumption has been made for calculating these numbers of passengers. What has been done is the following:

- There are studies based on travel SP surveys (Stated Preference) that show that only around 5-10% of people living in Rimbo and Norrtälje use public transport today to go to Arlanda airport (bus services)[12]. With this data it has been made the assumption that 5-10% of the passengers/year at Arlanda airport are going to or coming from those communities:

  Passengers/year at Arlanda airport: 17.91 million[13].

  5-10% of the passengers/year at Arlanda airport: 895,500-1.791 million.

  Passengers/year that go to Rimbo, Norrtälje coming from Arlanda and vice versa nowadays: **895,500-1.791 million approximately.** It is supposed that in a future, with the new railway line in use, this number of passengers from those communities to the airport may be doubled or even triple.

- **Advantages and Disadvantages of Alternative 2a**

The advantages that this route alternative has are:

[12] *Karl Kottenhoff, Division of Transportation and Logistics at KTH.*
[13] *http://parking.essentialtravel.co.uk/worldairport/sweden/stockholm.htm. (08/03/20). Data from December 2007.*

- This line connects Norrtälje and Rimbo to Stockholm (three of the main localities in this Project).
- The type of tracks used is double-track and standard gauge.
- Not a curvy layout, so that the speed of the trains is just defined by the stopping patterns.
- This line is directly connected to the railway line Stockholm-Uppsala in the vicinity of Märsta, and in this place, Arlanda airport can also be reached by bus services (passenger intermodality).
- Arlanda airport demand is covered (a very important point for travel demand).
- This alternative is also connected to commuter trains in the line Stockholm – Märsta that serve more demand.
- This line does not pass by very densely populated areas, so it is a good option for freight traffic.
- There is enough space for the train tracks and for the stations.
- Part of the layout is new tracks, but the other part is by the use of the already existing railway line Stockholm – Uppsala (lower budget).
- This line has the option to run directly to Uppsala by the use of the already existing railway tracks that go from Arlanda to Uppsala.
- Only two new stations to build: in Norrtälje and Rimbo.

The disadvantages that this route alternative has, are:

- It does not pass by very densely populated areas and so this line may not cover the same demand than other line that passes through those zones.
- The new built tracks stretch is approximately 48 km long (longer distance than the new build tracks in Alternative 1).

- **Train stations**

All the train stations have been designed near the bus stations existing in each locality the train stops at. This way the passenger intermodality is promoted.

The train stations whose location has been specified are those that do not exist nowadays, it means, the localities that already have train station like Stockholm, and Märsta, will use the same station as the existing one.

The new train stations need a large piece of land and if they are planned to be localized inside the city, it is difficult to find enough space for this, that it why the best place for localizing the new train stations is in the outskirts of the localities the train stops at, or even near public spaces such as parks or gardens.

The same train station types as in Alternative 1 are used in this route Alternative 2a:

- Stations with two platforms: one on each side of the tracks.
- Stations with just one platform between tracks.

(See figures 3.1.5, 3.1.6 for more details).

For each locality there are several options of where to build the train station:

- **STOCKHOLM:** It is the same case as in route Alternative 1. *(See maps 3.1.7, 3.1.8).*

- **MÄRSTA:** the train station used will be the same as the existing one.

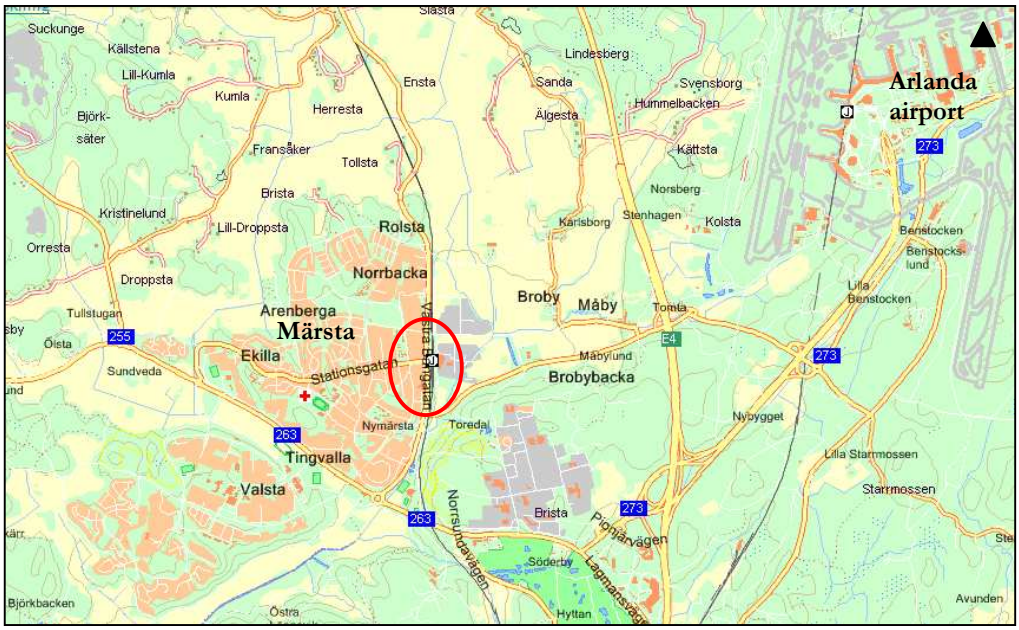

Figure 3.2.1.3: Train station in Märsta. Map.

Figure 3.2.1.4: Train station in Märsta. Aerial photograph.

- **RIMBO:**

The different alternatives for the location of the train station in Rimbo are:

A) In the centre of the town, so that the train passes through the middle of the town and serves the centre of Rimbo. It was considered the idea of building the new train station where the old train station was.

B) In the South of Rimbo by the road 280, where there is enough space for localising a new train station for passengers and freight traffic.

C) North of Rimbo.

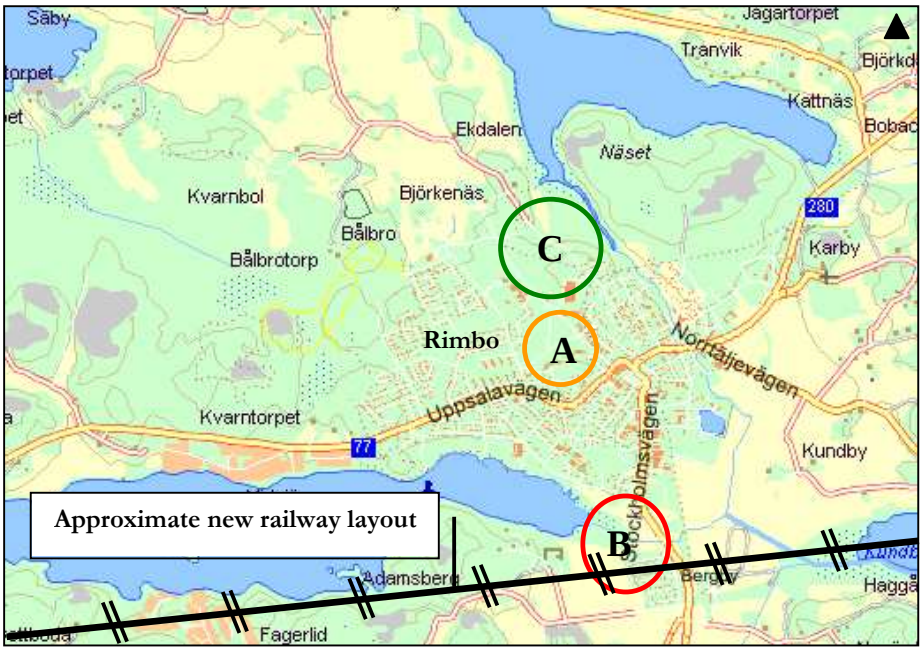

Figure 3.2.1.5: Alternatives for the new Rimbo's train station's location. Map.

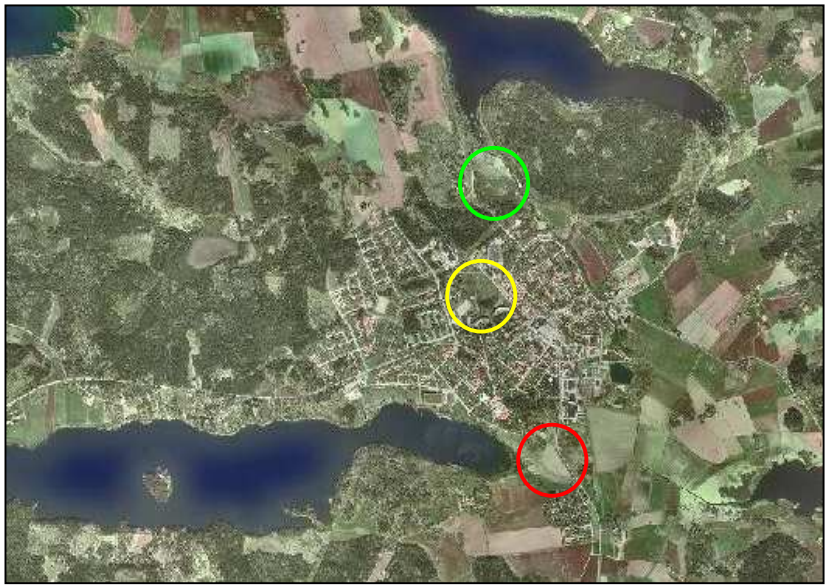

Figure 3.2.1.6: Alternatives for the new Rimbo's train station's location. Aerial photograph.

Taking into account advantages and disadvantages of each alternative, the next conclusions have been made:

LOCATION OF THE NEW TRAIN STATION	ADVANTAGES	DISADVANTAGES
A) Centre of Rimbo	- Train serves the centre of the city. - No need for any other transportation system to arrive to the train station. - Possible usage of the old train station area.	- Not enough space for a new station. - Too much noise for residents living close to the station. - Social problems. - Very difficult and high costs of building the new train station and tracks through the middle of the town. - Need of reducing speed of high speed trains that do not stop in Rimbo. - If use of old station area, trains need to change directions when passing by Rimbo (because of the old station shape). - Contamination of the inner city and congestion. - No possibility of expansion and enlargement of the station in the future.
B) South of Rimbo	- Train serves suburbs and industries (farm lands) of the city (better from a freight traffic perspective). - No noise and social problems with residents. - No space problems. - No need of reducing speed of high speed trains that do not stop in Rimbo. - No need of trains changing directions. - No contamination of the inner city or congestion. - Possibility of expansion and enlargement of the station in the future.	- Need for another transportation system in order to arrive to the train station.

	- Possibility of creating a train-bus interchange terminal. - A main road passes by the train station (good from a transportation perspective). - Better location for freight train traffic.	
C) North of Rimbo	- Train serves suburbs and industries (farm lands) of the city (better from a freight traffic perspective). - No noise and social problems with residents. - No space problems. - No need of reducing speed of high speed trains that do not stop in Rimbo. - No need of trains changing directions. - No contamination of the inner city or congestion. - Possibility of expansion and enlargement of the station in the future. - Possibility of creating a train-bus interchange terminal. - Better location for freight traffic.	- Need for another transportation system in order to arrive to the train station. - No main roads in this area. - More kilometres of tracks needed since the track layout arrives to Rimbo from the South (Arlanda). Higher costs.

Table 3.2.1.4: Advantages and disadvantages of new Rimbo's train station's location.

From the *Table 3.2.1.4*, it has been decided that the best emplacement for the new Rimbo's train station is at the South of Rimbo (alternative B), since this alternative has more advantages and less disadvantages than the rest of alternatives.

Figure 3.2.1.7: Location of the new Rimbo's train station. Aerial photograph.

- **NORRTÄLJE:** the location and design of the train station in Norrtälje will be in the same place as for route Alternative 1: alternative B. *(See figures 3.1.19, 3.1.20, 3.1.21, 3.1.22).*

Figure 3.2.1.8: Location of the new Norrtälje's train station. Aerial photograph.

3.2.2 Alternative 2b: Stockholm – Arlanda - Norrtälje

In this case, the railway line stops in the localities of Norrtälje, Rimbo, Arlanda airport, Upplands Väsby and Stockholm. In this alternative, part of the route is with new tracks, and part belongs to the already existing railway line from Stockholm to Uppsala. The new built tracks would be the stretch from Norrtälje to the connection with the railway line Stockholm – Arlanda. (*see figures 3.2.2.1, 3.2.2.2*).

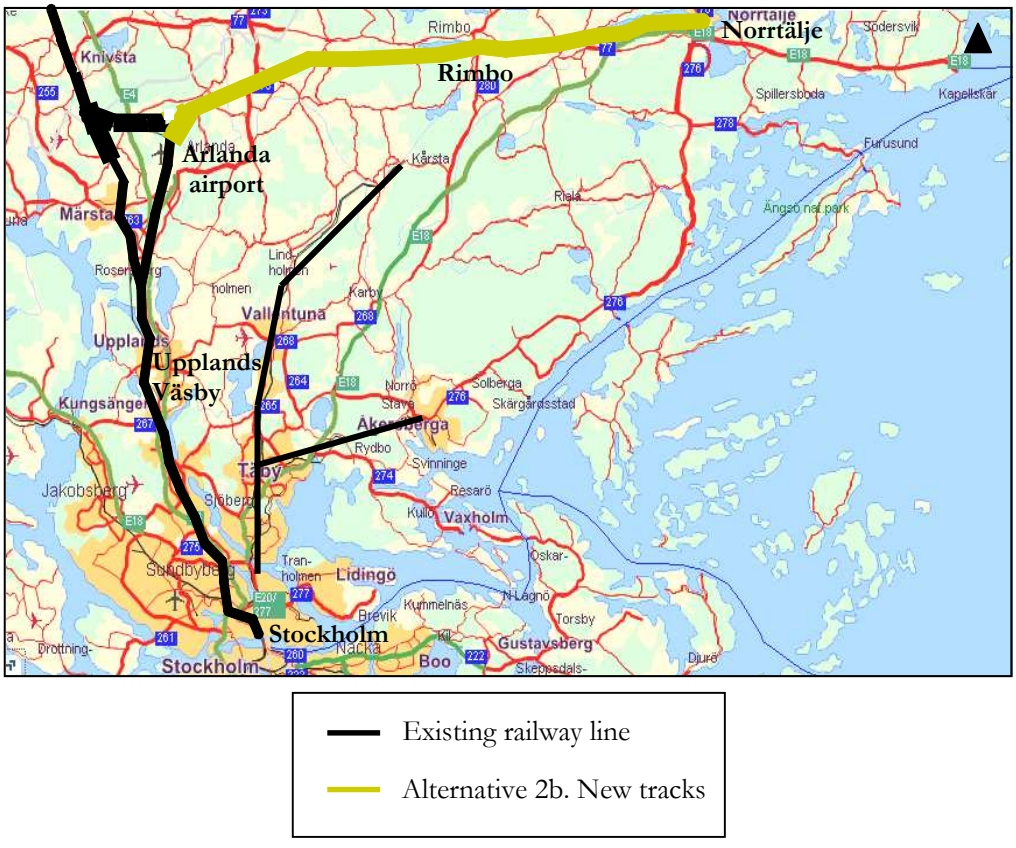

Figure 3.2.2.1: Alternative 2b.

- **Layout**

This route alternative consists of a new railway branch from Norrtälje to Arlanda airport (*see figure 3.2.2.2*). The rest of the layout from Arlanda airport to Stockholm is through the already existing railway line Stockholm – Uppsala.

This route Alternative 2b stops at four (4) localities without counting Stockholm: Norrtälje, Rimbo, Arlanda airport and Upplands Väsby; and the train stops in all the localities with a total of **five (5) stops**:

- Stockholm
- Upplands Väsby
- Arlanda airport
- Rimbo
- Norrtälje

(see figure 3.2.2.2).

The length of this line is approximately **91 km** from Stockholm to Norrtälje, divided in the following approximate stretch lengths:

- Stockholm – Upplands Väsby: 27 km
- Upplands Väsby - Arlanda airport: 15 km
- Arlanda airport - Rimbo: 30 km
- Rimbo – Norrtälje: 19 km

} Stock. - Norrtälje: 91 km

The average distance between stations is 22.8 km.

The length of the new built tracks is approximately 46 km.

In Upplands Väsby, travellers can change to commuter trains that exist nowadays that run from Stockholm to Märsta passing by Upplands Väsby. The commuter trains stop in each station of the following: Stockholm – Karlberg – Solna – Ulriksdal – Helenelund – Sollentuna – Häggvik – Norrviken – Rotebro – Upplands Väsby - Rosersberg – Märsta. Upplands Väsby will be used in this route alternative as an interchange terminal for going to the North coming from the Northeast; and Arlanda airport as a passenger intermodal hub for air-train-bus traffic.

In this route Alternative 2b, trains also have the possibility to run directly from Norrtälje to Uppsala if an optional track stretch of around 2.5 km is built (*see figure 3.2.2.2*). In case of not building this stretch, trains can also run to Uppsala by changing directions at Arlanda station.

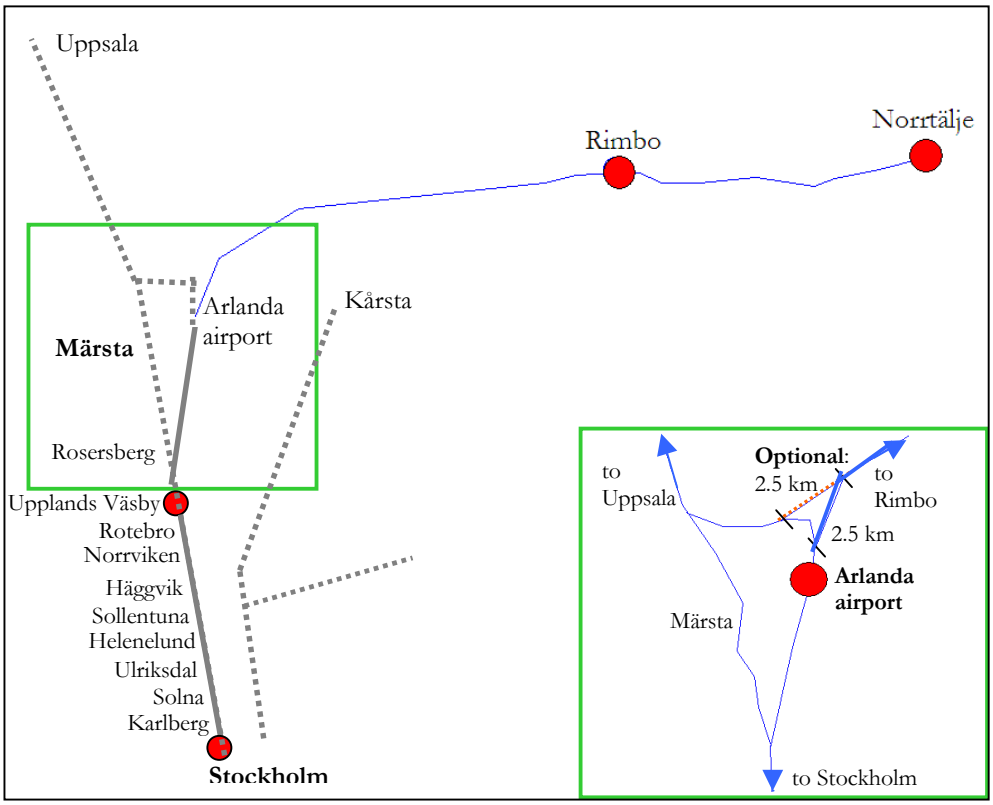

Figure 3.2.2.2: Sketch of Alternative 2b.

It is not interesting for economical reasons to build also a railway stretch going to Märsta because Märsta is so close to Arlanda and well connected by bus services that all the passenger demand in Märsta is covered by Arlanda airport.

This railway route alternative does not pass by very densily populated areas, so as a first approach, this route would be a good choice from a freight traffic perspective (in the case a freight traffic railway line is planned from Stockholm to the port of Kapellskär), but it does have a section via tunnel in the surroundings of Arlanda airport.

With this route alternative, Stockholm will be connected to Arlanda airport not just by high-speed trains (Arlanda Express), and by road, but also by regional trains (this is an advantage for those passengers who are not willing to pay a high-speed train ticket, but that are willing to take regional trains).

For this route alternative as for the rest, the infrastructure would be double-tracks and standard gauge (1,435 mm) with a design speed of 200 km/h.

In the case of intersections between the railway line and roads or highways, this problem will be solved by the use of bridges or different level crossings.

- **Traffic potential**

The potential of a new railway line is defined here as the sum of the populations of the localities that do not have train services today and that the new railway line is able to serve.

The total passenger traffic potential that this route alternative would cover is the total sum of the population of the towns that are connected by bus services with the localities where this railway alternative stops at, plus the population of the localities where the train stops. This method is an approximate method of calculating the potential covered by each route alternative.

In this case, Stockholm, Upplands Väsby and Arlanda airport have not been taken into account when calculating the potential because people living in Stockholm and Upplands Väsby will not use the new train line very much to go to Norrtälje or Rimbo, and because the majority of the passengers arriving at Arlanda airport are going to Stockholm and not to the area where Rimbo and Norrtälje are, and there is already today a train service and bus service from Arlanda to Stockholm (they are already served). Travel demand is mainly in one direction: Norrtälje to Stockholm (and the intermediate station in Rimbo), because most of the travellers that will use the new train line will be the people living in the north of Stockholm going to Stockholm (the newly served passengers).

The population numbers are from December 2005, so it is expected that these population values will be higher in the future, so a higher potential will be covered in the future.

The "population" at Arlanda airport has been assumed that corresponds to the number of passengers per year in the airport.

For this Alternative 2b, the demand reached is the following:

	POPULATION CENTRE	POPULATION 2005-12-31	POPULATION OF THE MAIN POTENTIAL GENERATORS
STATIONS	Stockholm urban area	1,252,020	-
	Upplands Väsby	35,977	-
	Arlanda airport (passengers/year)	17.91 million[14]	-
	Rimbo	4,606	4,606
	Norrtälje	16,263	16,263
	TOTAL:	19,218,866	**20,869**

Table 3.2.2.1: Potential population of stations of Alternative 2b.

(Note: for the small towns which population is smaller than 100 inhabitants, it was supposed a potential population of 100 inhabitants).

[14] *http://parking.essentialtravel.co.uk/worldairport/sweden/stockholm.htm. (08/03/20). Data from December 2007.*

Station: NORRTÄLJE	POTENTIAL POPULATION REACHED BY BUS LINES
Rörvik	555
Edsbro	515
Svensboda	3,472
Rådmansö	1,006
Blidö	617
Vätö	1,465
Malsta	4,283
Smaller towns: Yxlan, Björkö, Vigelsjö, Vårgatan, Harö, Lohärad, Grind	*400 (assumption)*
TOTAL:	**12,313**

Table 3.2.2.2: Potential of Norrtälje reached by bus lines.

Station: RIMBO	POTENTIAL POPULATION REACHED BY BUS LINES
Angarn	7,345
Hallstavik	4,530
Ubby	1,938
Länna	698
Smaller towns: Söderhall, Väsbylund, Rånäs, Varleda, Norrbyggeby, Fantbol, Beateberg	*400 (assumption)*
TOTAL:	**14,911**

Table 3.2.2.3: Potential of Rimbo reached by bus lines.

TOTAL POTENTIAL POPULATION REACHED BY ALTERNATIVE 2b	
Norrtälje	12,313
Rimbo	14,911
Population of the main potential generators	20,869
TOTAL:	**48,093**

Table 3.2.2.4: Total potential of Alternative 2b.

Alternative 2b covers a total of **48,093** inhabitants as a potential population (people that are willing to use the new train line).

- ***Note***: the potential at Arlanda airport has not been added to the new railway line because the majority of the passengers arriving at Arlanda airport are going to

Stockholm and not to the area where Rimbo and Norrtälje are, and there is already today a train service and bus service from Arlanda to Stockholm.

However, there is of course the possibility for people from Rimbo, Norrtälje and places served by connecting bus-lines to reach Arlanda by train and vice versa.

Because there are no statistics on how many passenger at Arlanda are coming (or going to) any of those communities, an assumption has been done for calculating these numbers of passengers. What has been done is the following:

- There are studies based on travel SP surveys (Stated Preferences) that show that only around 5-10% of people living in Rimbo and Norrtälje use public transport today to go to Arlanda airport (bus services)[15]. With this data it has been made the assumption that 5-10% of the passengers/year at Arlanda airport are going to or coming from those communities:

  Passengers/year at Arlanda airport: 17.91 million[16].

  5-10% of the passengers/year at Arlanda airport: 895,500-1.791 million.

  Passengers/year that go to Rimbo, Norrtälje coming from Arlanda and vice versa nowadays: **895,500-1.791 million approximately.** It is supposed that in a future, with the new railway line in use, this number of passengers from those communities to the airport may be doubled or even triplicate.

- **Advantages and Disadvantages of Alternative 2b**

The advantages that this route alternative has, are:

- This line connects Norrtälje and Rimbo to Stockholm (three of the main localities in this Project).
- The type of tracks used is double-track and standard gauge.
- Not a curvy layout, so that the speed of the trains is just defined by the stopping patterns.
- This line is directly connected to the railway line Stockholm-Uppsala in the vicinity of Rosersberg (*see figure 3.2.2.3*).
- Arlanda airport demand is directly covered (a very important point for travel demand).
- By stopping in Upplands Väsby, this alternative is also connected to commuter trains in the line Stockholm – Märsta that serve more demand and stop in Märsta.
- This line does not pass by very densely populated areas, so it is a good option for freight traffic.
- There is enough space for the train tracks and for the stations.

[15] *Karl Kottenhoff, Division of Transportation and Logistics at KTH..*
[16] *http://parking.essentialtravel.co.uk/worldairport/sweden/stockholm.htm. (08/03/20). Data from December 2007.*

- Part of the layout is new tracks, but the other part is by the use of the already existing railway line Stockholm – Uppsala (lower budget).
- This route alternative length is similar to Alternative 2a, but the new built tracks stretch is approximately 46 km long compared with 48 km of Alternative 2a (lower distance than the new tracks in Alternative 2a and lower budget therefore).
- This line has the option to run directly to Uppsala by building an additional railway stretch of 1.5 km approx. In case of not building this stretch, trains can also run to Uppsala by changing directions at Arlanda station.
- Arlanda airport will be a passenger intermodal terminal airplane-train-bus.
- Not many new stations to build: only in Norrtälje and Rimbo.

The disadvantages that this route alternative has, are:

- It does not pass by very densely populated areas and so this line may not cover the same demand than other line that passes through those zones.
- It has a section via tunnel: bad from a freight traffic perspective.

▪ **Train stations**

All the train stations have been designed near the bus stations existing in each locality the train stops at. This way the passenger intermodality is promoted.

The train stations whose location has been specified are those that do not exist nowadays, it means, the localities that already have train station like Stockholm, Upplands Väsby and Arlanda airport, will use the same station as the existing one.

The new train stations need a large piece of land and if they are planned to be localized inside the city, it is difficult to find enough space for this, that it why the best place for localizing the new train stations is in the outskirts of the localities the train stops at, or even near public spaces such as parks or gardens.

The same train station types as in Alternative 1 are used in this route Alternative 2b:

- Stations with two platforms: one on each side of the tracks.
- Stations with just one platform between tracks.

(See figures 3.1.5, 3.1.6 for more details).

For each locality there are several options of where to build the train station:

- STOCKHOLM: It is the same case as in route Alternative 1 and 2a. *(See maps 3.1.7, 3.1.8).*

- UPPLANDS VÄSBY: the train station used will be the same as the existing one.

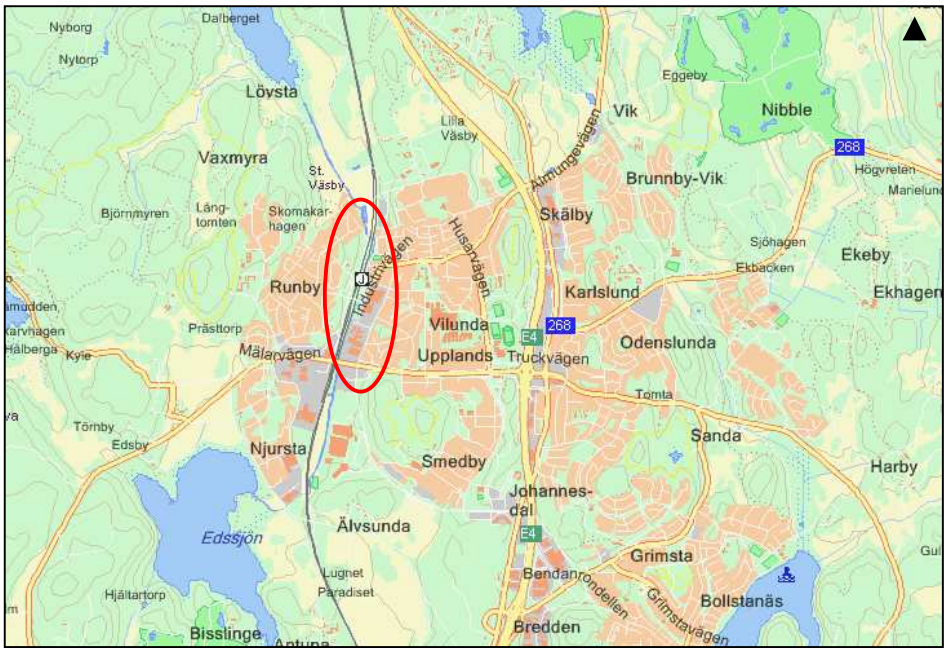

Figure 3.2.2.3: Train station in Upplands Väsby. Map.

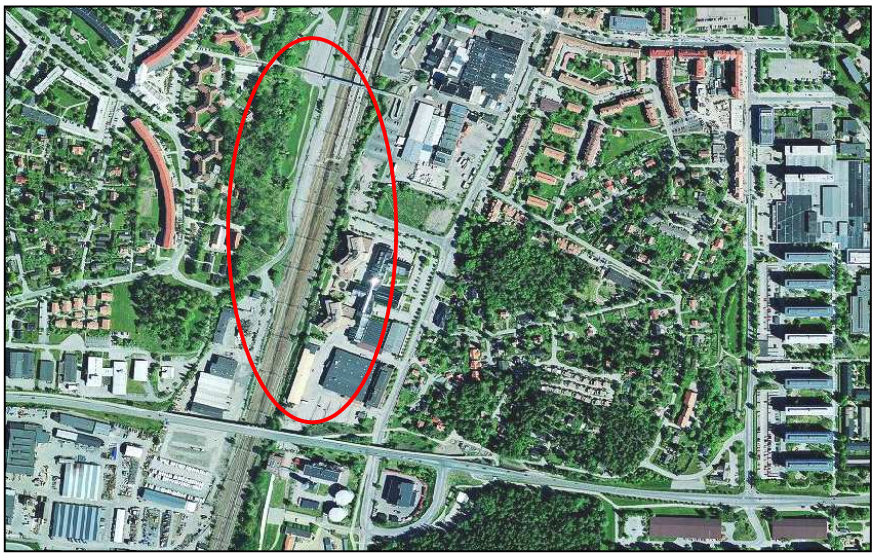

Figure 3.2.2.4: Train station in Upplands Väsby. Aerial photograph.

- **ARLANDA AIRPORT:** the train station used will be the same as the existing one. The train station here is under ground.

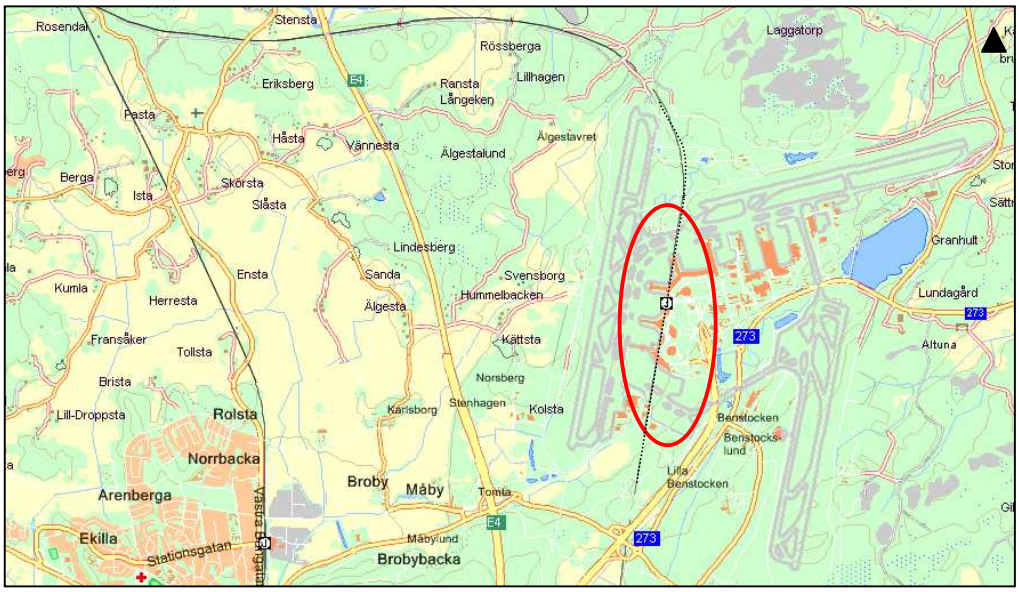

Figure 3.2.2.5: Train station in Arlanda airport. Map.

Figure 3.2.2.6: Train station in Arlanda. Aerial photograph.

- **RIMBO:** the location of the train station in Rimbo will be in the same place as for route Alternative 2a: alternative B. *(See figures 3.2.1.5, 3.2.1.6, 3.2.1.7).*

Figure 3.2.2.7: Location of the new Rimbo's train station. Aerial photograph.

NORRTÄLJE: the location and design of the train station in Norrtälje will be in the same place as for route Alternative 1 and 2a: alternative B. *(See figures 3.1.19, 3.1.20, 3.1.21, 3.1.22).*

Figure 3.2.2.8: Location of the new Norrtälje's train station. Aerial photograph.

3.3 Alternative 3: Stockholm – Vallentuna - Norrtälje

In this case, the proposed railway line corresponds to a prolongation of an already existing railway line that goes from Stockholm (from Östra station at KTH University) to Kårsta. With this extension, the railway line will be prolonged from Kårsta to Rimbo, and then from Rimbo to Norrtälje. This way the railway line will pass by the localities of Norrtälje, Rimbo, Vallentuna, Täby/Roslags Näsby, and Stockholm. (*see figures 3.3.1, 3.3.2*).

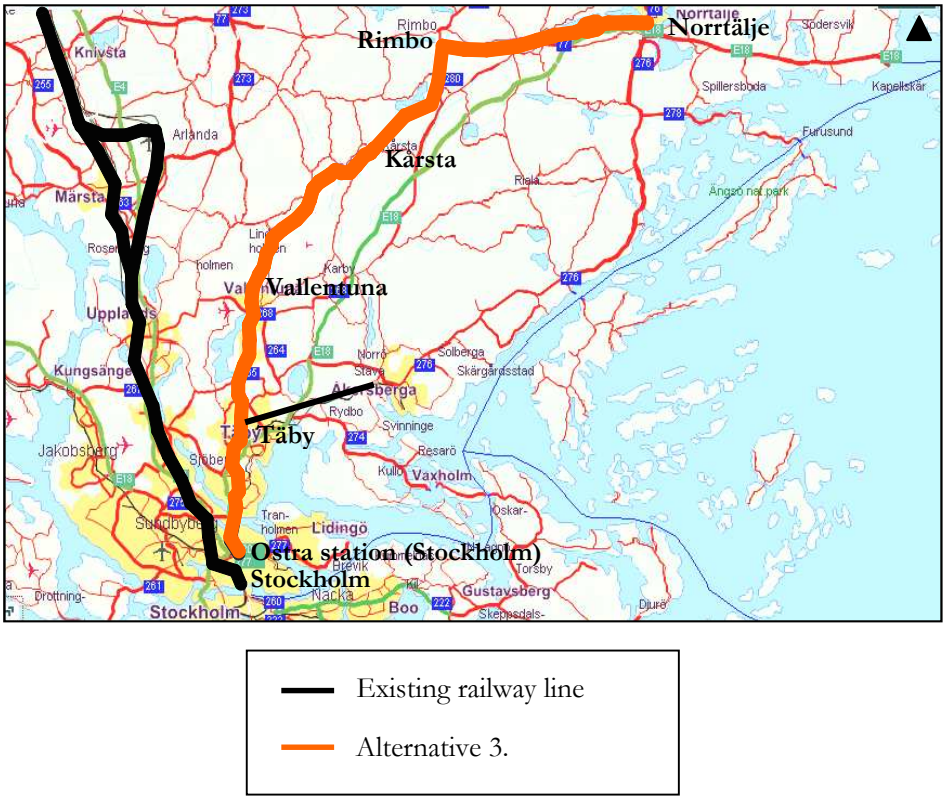

Figure 3.3.1: Alternative 3.

- **Layout**

This route alternative consists of a new built railway stretch from Norrtälje to Kårsta passing by Rimbo. From Kårsta to Stockholm all the existing infrastructure will need to be removed and changed by double-tracks standard-gauge since the already existing tracks are single-tracks narrow-gauge. The complete railway line will stop at four (4) localities without counting Stockholm (Norrtälje, Rimbo and Täby). This line will have a total of **five (5) stops**:

- Stockholm
- Täby/Roslags Näsby
- Vallentuna
- Rimbo
- Norrtälje *(see figure 3.3.2).*

This route alternative has been proposed because by looking at the map of the study area, it seems so obvious to propose a prolongation of the already existing railway branch from Kårsta to Norrtälje. Actually this prolongation to Rimbo and Norrtälje used to exist until the end of the 60's when it was dismantled just keeping the railway line from Stockholm to Kårsta.

As said before, this route alternative partially exists from Stockholm (Östra station) to Kårsta (is part of the Roslagsbanan explained in *Chapter 2.1*), and it is operated by regional trains. The problem with the existing railway line is that nowadays it is single-track narrow-gauge, plus the fact that is passes by very densely populated areas and that it has a very curvy layout.

One more problem that this line has compared with other route alternatives is that in case regional high-speed trains operate it (like this Project proposes), it would not be possible to serve all the stations that the existing line serves nowadays, since regional trains that operate this railway line actually stop at 21 stations in approximately 40 km long (the average distance between stations is 1.9 km (a short distance for run near 200 km/h between stops). The problem of this is that the localities where trains stop today are not connected with each other by bus services, so even having a train stop in Täby and in Vallentuna, not much potential will be reached with this railway line and many people living in the area between Täby and Rimbo will not be well connected to Stockholm.

Another important problem is that in this line travellers are not able to change to the nowadays existing commuter trains stopping in all the localities where today's regional trains stop at.

In the other hand, since Banverket has already planned to build a new railway stretch from Solna to Åkersberga served by commuter trains (see *Chapter 3.1, figure 3.1.3*) stopping at Täby, this proposed route Alternative 3 would be able in the future to connect to the important railway axis Stockholm-Uppsala by stopping in Täby, changing to commuter trains in the line Solna- Åkersberga, and going to Solna in order to reach the Stockholm-Uppsala railway line. This way travellers in this route Alternative 3 will be able to go to Arlanda airport and to any locality in the Stockholm-Uppsala axis. *(See figure 3.3.2).*

As said before, this railway route alternative passes by very densily populated areas, so as a first approach, this route would not be the best choice from a freight traffic perspective, since freight trains pass by without stopping in all stations, just in the most important stations like Stockholm and the port of Kapellskär; and are not socially well accepted in terms of "passing by populated areas" (in the case a freight traffic railway line is planned from Stockholm to the port of Kapellskär). Plus the fact that is has a very curvy layout.

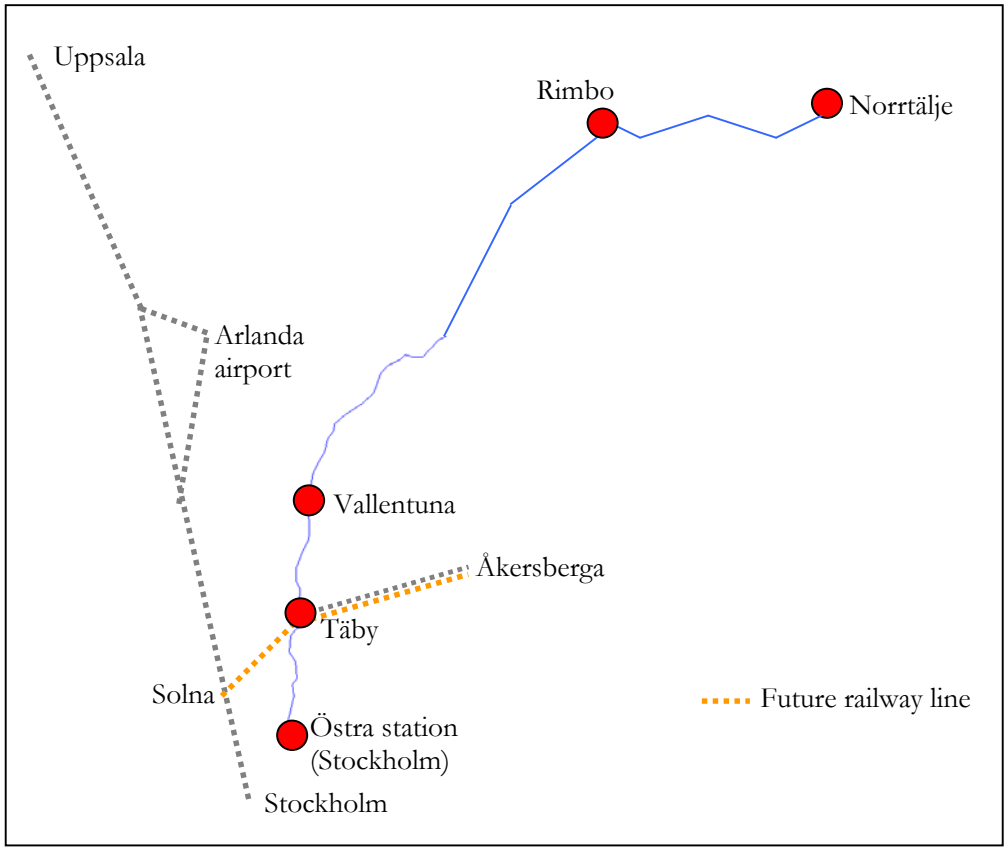

Figure 3.3.2: Sketch of Alternative 3.

The length of this line is approximately **68** km from Stockholm to Norrtälje, divided in the following approximate distances between stations:

- Stockholm - Täby: 10.5 km
- Täby – Vallentuna: 11.3 km
- Vallentuna - Rimbo: 34 km
- Rimbo - Norrtälje: 19 km

} Stock. - Norrtälje: 68 km

The average distance between stations is 18.7 km.

The new build tracks are approximately 43 km long.

For this route alternative as for the rest, the infrastructure would be double-tracks and standard gauge (1,435 mm) with a design speed of 200 km/h. The new infrastructure will go parallel to the already existing infrastructure (narrow gauge, single-track), since the already existing commuter trains will work together at the same time with the new passenger trains along this line.

In the case of intersections between the railway line and roads or highways, this problem will be solved by the use of bridges or different level crossings.

- **Traffic potential**

The potential of a new railway line is defined here as the sum of the populations of the localities that do not have train services today and that the new railway line is able to serve.

The total passenger traffic potential that this route alternative would cover is the total sum of the population of the towns that are connected by bus services with the localities where this railway alternative stops at, plus the population of the localities where the train stops. This method is an approximate method of calculating the potential covered by each route alternative.

In this case, Stockholm, Täby and Vallentuna have not been taken into account when calculating the potential because people living in those places are not the ones who will use the new train line very much to go to Stockholm (they will not be the new reached travellers), since Täby and Vallentuna are already well connected to Stockholm by train services (they are already served). In the other way (people from Stockholm, Täby and Vallentuna going to Norrtälje), there will not be neither too many people making these trips. Travel demand is mainly in one direction: Norrtälje to Stockholm (and the station in Rimbo), because most of the travellers that will use the new train line will be the people living in the north of Stockholm going to Stockholm (the newly served passengers).

The population numbers are from December 2005, so it is expected that these population values will be higher in the future, so a higher potential will be covered in the future.

For this first alternative, the potential reached is the following:

	POPULATION CENTRE	POPULATION 2005-12-31	POPULATION OF THE MAIN POTENTIAL GENERATORS
STATIONS	Stockholm urban area	1,252,020	-
	Täby	61,633	-
	Vallentuna	27,868	-
	Rimbo	4,606	4,606
	Norrtälje	16,263	16,263
	TOTAL:	1,362,390	**20,869**

Table 3.3.1: Potential population of the stations in Alternative 3.

(Note: for the small towns which population is smaller than 100 inhabitants, it was supposed a potential population of 100 inhabitants).

Station: NORRTÄLJE	POTENTIAL POPULATION REACHED BY BUS LINES
Rörvik	555
Edsbro	515
Svensboda	3,472
Rådmansö	1,006
Blidö	617
Vätö	1,465
Malsta	4,283
Smaller towns: Yxlan, Björkö, Vigelsjö, Vårgatan, Harö, Lohärad, Grind	*400 (assumption)*
TOTAL:	**12,313**

Table 3.3.2: Potential of Norrtälje reached by bus lines.

Station: RIMBO	POTENTIAL POPULATION REACHED BY BUS LINES
Angarn	7,345
Hallstavik	4,530
Ubby	1,938
Länna	698
Smaller towns: Söderhall, Väsbylund, Rånäs, Varleda, Norrbyggeby, Fantbol, Beateberg	*400 (assumption)*
TOTAL:	**14,911**

Table 3.3.3: Potential of Rimbo reached by bus lines.

TOTAL POTENTIAL POPULATION REACHED BY ALTERNATIVE 3	
Norrtälje	12,313
Rimbo	14,911
Population of the main potential generators	20,869
TOTAL:	**48,093**

Table 3.3.4: Total potential of Alternative 3.

Alternative 3 covers a total of **48,093** inhabitants as a potential population (people that are willing to use the new train line).

- **Advantages and Disadvantages of Alternative 3**

The advantages that this route alternative has are:

- It passes by very densely populated areas and so this line would cover more demand than other that does not pass through these zones.
- This line connects Norrtälje and Rimbo to Stockholm (three of the main localities in this Project) and passes by very close communities to Stockholm.
- The type of tracks used is double-track and standard gauge.
- The already existing railway layout can be reused for building the new tracks from Stockholm to Kårsta.
- Only two new stations to build: in Norrtälje and Rimbo.

The disadvantages that this route alternative has, are:

- Not a good alternative for freight traffic since the line passes by very densely populated areas and has a very curvy layout.
- Very curvy layout, so that the speed of the trains is not just defined by the stopping patterns, but also by the layout.
- This line can not be connected directly to the railway line Stockholm-Uppsala and neither reach Arlanda airport (the passenger intermodality is not promoted).
- Not much space for the tracks and train stations since this area is very populated and there are lots of housing areas.
- This alternative is not connected to commuter trains in its own layout that could serve more demand.
- This new line will not serve as many localities as the already existing railway line from Stockholm to Kårsta, and much potential will not be served because there are no good bus services between localities.

- **Train stations**

All the train stations have been designed near the bus stations existing in each locality where the train stops at. This way the passenger intermodality is promoted.

The train stations whose location has been specified are those that do not exist nowadays, it means, the localities that already have train station like Stockholm, Täby and Vallentuna, will use the same station localization as the existing one.

The new train stations need a large piece of land and if they are planned to be localized inside the city, it is difficult to find enough space for this, that it why the best place for localizing the new train stations is in the outskirts of the localities where the train stops at, or even near public spaces such as parks or gardens.

The same train station types as in Alternative 1 are used in this route Alternative 3:

- Stations with two platforms: one on each side of the tracks.
- Stations with just one platform between tracks.

(See figures 3.1.5, 3.1.6 for more details).

For each locality there are several options of where to build the train station:

- **STOCKHOLM:** It is the same case as in route Alternative 1, 2a and 2b. *(See maps 3.1.7, 3.1.8).*

- **TÄBY:** the train station is planned to be localized in the area between Täby station and Roslags-Näsby station.

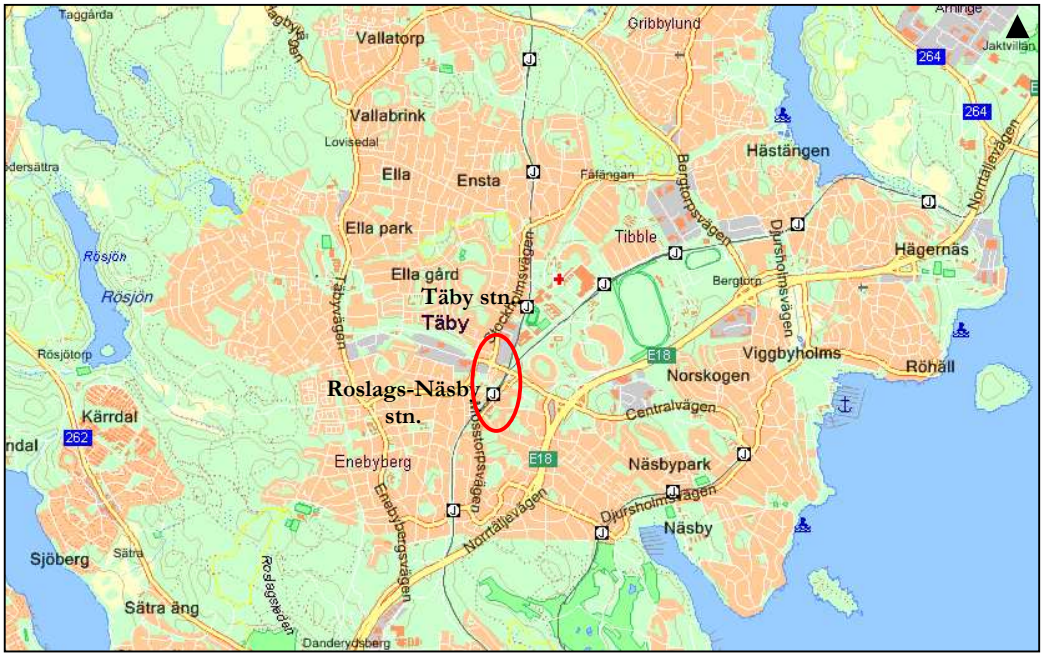

Figure 3.3.3: Train station in Täby. Map.

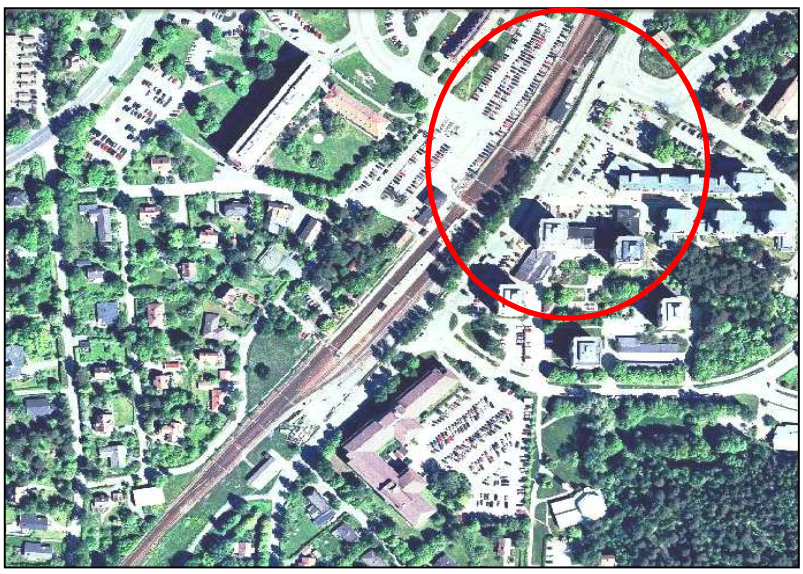

Figure 3.3.4: Train station in Täby. Aerial photograph.

- **VALLENTUNA:** the train station used will be the same as the existing one.

Figure 3.3.5: Train station in Vallentuna. Map.

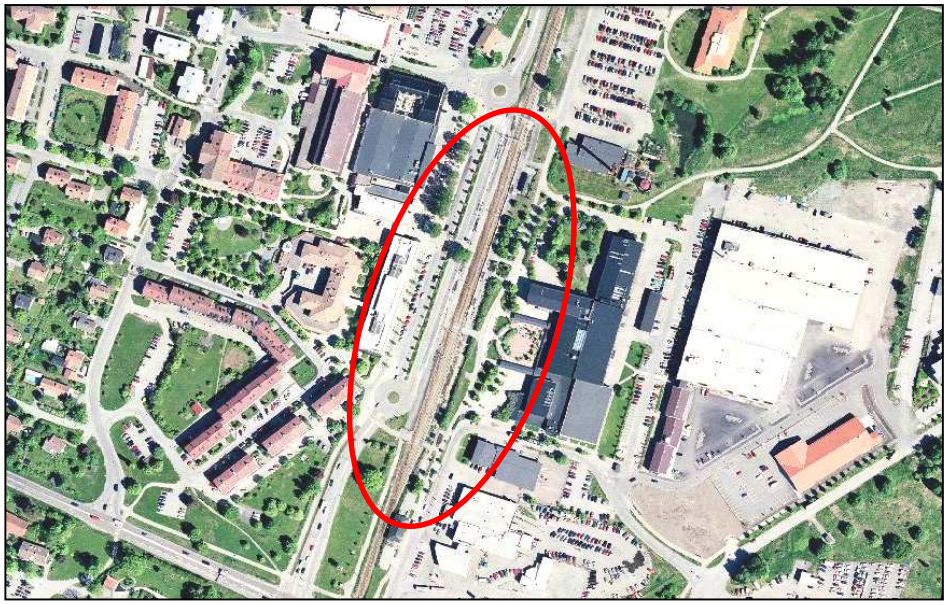

Figure 3.3.6: Train station in Vallentuna. Aerial photograph.

- **RIMBO:** the location of the train station in Rimbo will be in the same place as for route Alternative 2a and 2b: alternative B. *(See figures 3.2.1.5, 3.2.1.6, 3.2.1.7).*

Figure 3.3.7: Location of the new Rimbo's train station. Aerial photograph.

NORRTÄLJE: the location and design of the train station in Norrtälje will be in the same place as for route Alternative 1, 2a and 2b: alternative B. *(See figures 3.1.19, 3.1.20, 3.1.21, 3.1.22).*

Figure 3.3.8: Location of the new Norrtälje's train station. Aerial photograph.

3.4 Summary

In the next figure, all the route alternatives are shown, which characteristics have been explained before along this chapter:

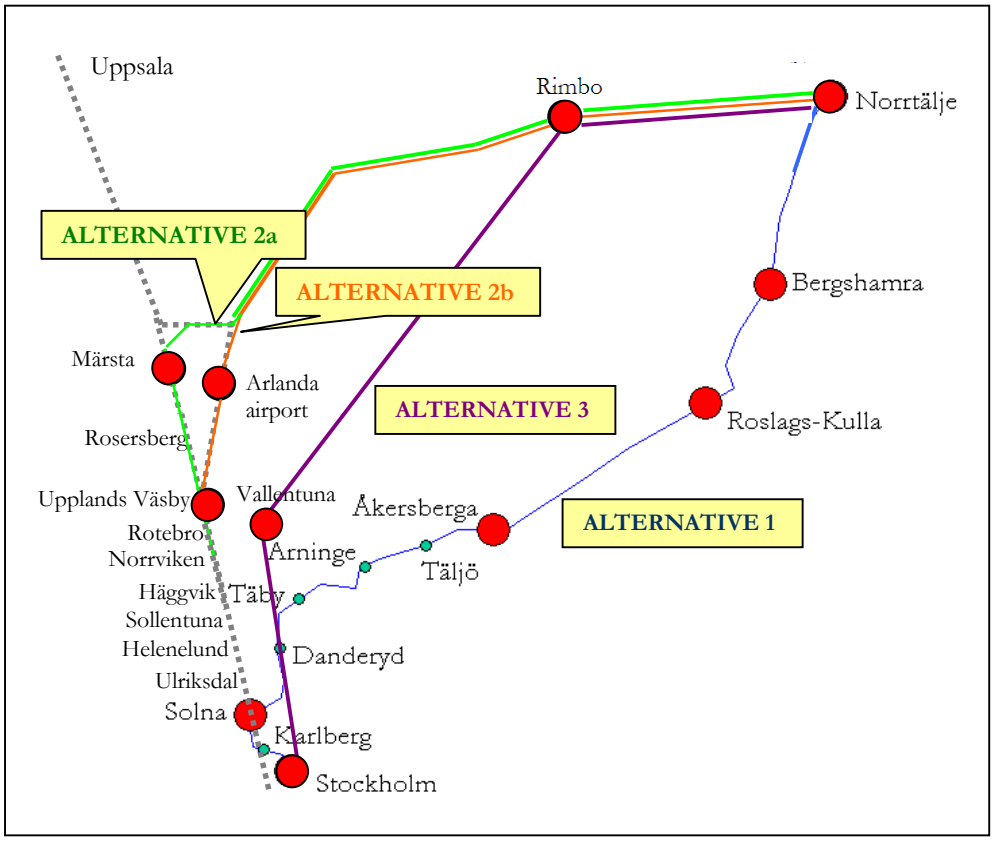

Figure 3.4.1: Sketch of all the route alternatives.

The potential that each alternative serves is shown in the table below:

	POTENTIAL REACHED (inhabitants)
Alternative 1	110,550
Alternative 2a	48,093
Alternative 2b	48,093
Alternative 3	48,093

Table 3.4.1: Potential reached by each route alternative.

From the results obtained, it can be seen that Alternative 1 is the one that reaches more demand (56.5% more demand than the other route alternatives), since it passes by very densely populated areas and also because more localities have been taken into account when calculating the reached potential than in the other alternatives. This has been done this way because in the area where this route alternative passes

by, there are no train services nowadays that go further than Åkersberga, so there is many new potential reached by the new railway line, but the fact is that most of this new potential is quite close to Stockholm, while the potential reached in the long distance (in the area between Norrtälje and Bergshamra) is lower.

In the other hand, this route Alternative 1 does not reach the passengers at Arlanda airport, which is a very important point in the study area, neither passes by Rimbo (another important objective in this Project). Another problem in this route is that passengers coming from Norrtälje who would like to change to the already existing railway line Stockholm-Uppsala, need to travel through all the railway line from Norrtälje to Solna to change lines.

One more characteristic of route Alternative 1 is that from Åkersberga to Norrtälje it is all new build tracks (the stretch from Stockholm to Åkersberga is already planned to be built by Banverket) while the other alternatives use part of already existing railway tracks; and also there are more new stations to be built than in other route alternatives (higher building costs).

By attending at all the before explained, it is important to remark that the reached potential is not the only factor when choosing the best route alternative, there are many other factors.

More studies have been carried out in the following chapters.

4 Traffic and infrastructure

Along this chapter it is explained the coordination of passenger trains with freight trains running on the same tracks, as well as advantages and disadvantages of running both types of traffic at the same time. It is also explained the integration of the new proposed passenger trains with the already existing trains that will share the same tracks, as well as the integration of the new railway network with the existing bus services in the study area.

The next thing to define are the timetable scenarios for the new passenger trains.

To end up with, the rolling stock for the new proposed passenger railway line and its technical characteristics are also defined in this chapter.

4.1 Coordination with freight traffic

In this chapter it is considered the option that besides passenger train traffic, freight train traffic will also exist on the best route alternative, and so the coordination of passenger traffic with freight traffic is explained, since both types of trains need to run on the same tracks but they will have different timetables and different stopping patterns.

Referred to the freight trains stopping patterns, these have different stops as passenger trains because freight trains do not stop in each station besides the port of Kapellskär and Stockholm (in case a new freight railway line is planned from the port of Kapellskär to Stockholm).

It has been assumed therefore that there will be a new freight railway line from the port of Kapellskär to the port of Stockholm running through the best route alternative. The reason why a freight railway line is also planned to exist is because this way the freight that nowadays arrives to Stockholm coming from Finland and Estonia, will arrive in the future (with the freight railway line working) to the auxiliary port of Kapellskär so that ships' congestions in the port of Stockholm made by the archipelago configuration of the city are reduced (maritime traffic is reduced in Stockholm).

The first thing to define when coordinating both types of traffic is the approximate timetable that passenger trains will have in the new railway line, since this type of traffic is determinant and freight trains will adapt to passenger trains. This is done by obtaining the current bus services' timetables in the study area going from Norrtälje to Stockholm (in order to find the peak hours when there are more buses from Norrtälje going to Stockholm and vice versa). With the buses' timetables it is possible

to know when during the day the highest frequency of buses departing from Norrtälje to Stockholm, and from Stockholm to Norrtälje is (peak hours). This analysis is carried out for Norrtälje and for Stockholm because they are the beginning and the end of the best railway alternative line.

Related to freight traffic, there exist the timetables of freight ships that arrive to the port of Stockholm nowadays (that in the future would be the ones that will arrive to the port of Kapellskär), so that freight trains also need to adapt their timetables to those freight timetables and the frequency of freight trains running on the line will depend on that.

Usually, most of freight trains run during the night or early in the morning when there are no passenger trains in service in order not to have conflicts with passenger trains, for not to disturb housing areas, and so that freight may arrive to its final destination early in the morning. A detailed timetable of passenger trains and freight trains is obtained in the Simulation chapter (*Chapter 5*) when it is simulated the train traffic of both passenger and freight trains. (*See Appendix III*).

Related to the infrastructure, one reason why it has been defined that the infrastructure of the best route alternative is double-tracks standard-gauge is because this way, freight trains are able to run at the same time as when there are passenger trains running. This is, a passenger train is running on one side of the tracks for instance, and a freight train (that does not stop in any station besides Kapellskär and Stockholm) is able to pass by the passenger train that is stopped in any other intermediate station by using the other track.

Another fact is that freight trains run at a lower speed than passenger trains because they are not high-speed, and so with double-tracks, passenger trains are not interrupted by freight traffic.

During peak hours for passenger trains, there are not any freight trains running, so that there are no conflicts between passenger and freight trains neither at these points of the time (peak hours in the morning and in the afternoon. See *Chapter 2.3* for peak hours).

There are advantages and disadvantages on running both types of trains at the same time and on the same tracks:

Advantages:

- Better usage of the tracks
- Very profitable for the railroads
- Freight does not arrive to Stockholm just during the night.

Disadvantages:

- Conflicts with passenger trains
- A lot of work when obtaining passenger and freight trains' timetables because they need to adapt to each other.

Some advantages of freight trains compared to road haulage are:

- Freight travels faster by train

- The use of freight trains reduces congestions caused by freight trucks in roads
- Freight trains are becoming faster and can offer timings and service reliability that cannot be matched by road
- Rail freight enjoys environmental advantages over road haulage.

Some disadvantages of freight trains compared to road haulage are:

- Not good to run freight trains through populated areas from a noise and visual impact perspective

By managing properly the timetables for both passenger and freight trains, it is possible to run both types of trains at the same time during the day.

All the coordination with freight traffic is shown in the simulation chapter *(Chapter 5)*, since the simulation has been carried out with freight trains and also passenger trains.

4.2 Integration with train services on the existing infrastructure

As said in the chapters before, there are existing railway lines working nowadays in the study area, and so the proposed by this Project passenger trains will need to run together with the already existing commuter, long distance, high-speed, regional passenger, and freight trains.

This work of integrating the new trains with the existing ones is done with the simulation program RailSys® in *Chapter 5* by the use of the exiting trains' timetables that run in the railway lines in the study area that affect the new trains.

For doing this, only the existing trains' timetables on the line Stockholm-Uppsala during the peak hour in the morning have been available, and they include commuter trains, regional, (Swedish) high-speed, Arlanda express, local, empty runs, intercity non-high-speed, long distance passenger trains, and freight trains running on this line.

The simulation has been made for each route alternative with the new passenger and freight trains explained in *Chapter 4.1* (freight trains from the port of Kapellskär to Stockholm) running together with the existing trains. When introducing the new passenger and freight trains, the already existing trains in the railway line Stockholm-Uppsala need to adapt to the new trains and vice versa, and so some of the existing trains have been moved some minutes up or down in order to make the new trains run with them. This procedure is very difficult to make in reality since from the movement of one minute of the timetable of one train, depend many other trains' timetables around the country. For instance, if one train is changed one minute, the rest of the trains in its line will also need to change one minute, and the trains depending on those will also need to change their timetables and so on. So, the simulation in *Chapter 5* gives as a result approximate timetables of the new trains, but just taking into account the trains in the line Stockholm-Uppsala and without taking into account the rest of the trains in Sweden. The results are also approximate

because the trains' timetables of the other existing railway lines in the study area (*see figure 2.1.2*) are not available, so they have not been taken into account neither.

The most difficult interval of time during the day for adjusting the new trains with the existing ones is during the peak hours, since the frequency of all passenger trains is higher (except from freight trains).

Since the available trains' timetables on the line Stockholm-Uppsala are during the peak hour in the morning (the most difficult interval of time to introduce the new trains because it is the most congested), it is supposed that if it is managed that the new trains are able to run together with the existing trains during these intervals of time (peak hours), then they will be able to run together during the rest of the day, since it is easier to introduce the new trains when it is not the rush hour.

The different things to take into account when integrating new trains in an already existing railway network are:

- frequencies of the existing trains
- stopping patterns of the existing trains: stopping stations and stopping times
- peak hours
- timetables of the existing trains (arriving/departing times)
- speeds of the existing trains
- the type of the existing trains: commuters, regionals, high-speed, etc.
- the tracks on which the existing trains are running on
- length of the existing trains (train configurations)
- the type of tracks: single/double-tracks
- departure/arriving times must be at full minute for all trains.

4.3 Integration with connecting bus network

When the new passenger trains are in service, their main goal is to connect part of the localities that are nowadays not connected by train services to Stockholm like Norrtälje and Rimbo, where many workers go to work everyday to Stockholm. The fact is that these localities are actually connected by bus services to Stockholm, so the objective of the new trains is in part to improve the efficiency and the service (like travel time) of public transportation between the capital city and those towns by offering new regional passenger train services in order to facilitate daily commuting so that people living in the region can live and work in different places.

By doing this, bus services will need to adapt to the new trains and their stopping patterns in order to achieve a good and efficient transport level in the area, this way daily passenger intermodality train-bus is promoted. Bus services will not be as

frequent as nowadays though, but they will still be useful in order to pick up potential passengers for the new trains coming from localities between stations.

The reason why the existing buses need to adapt to the new trains is because it is easier to do so than to adapt trains to buses, since buses' timetables are easier to change.

The new train stations have been planned to be located near bus stations so that passenger-intermodality is promoted.

4.4 Timetable scenarios

What is expected by the use of the new passenger trains is that the capacity of the nowadays existing bus services connecting localities in the study area is maximized by the use of the new trains among other goals.

There are three simulated timetable scenarios which have been obtained from the combination of passenger trains' timetable scenarios and freight trains' timetable scenarios explained later in this chapter.

The three different passenger trains' scenarios are:

- 100% capacity: passenger trains cover the same capacity as in the present situation bus services do.
- 200% capacity: passenger trains cover the double of the capacity as in the present situation bus services do.
- 300% capacity: passenger trains cover the triple of the capacity as in the present situation bus services do.

For the 100% capacity case, the initial passenger trains' timetables that are introduced in the simulation program are estimated by attending at the present situation bus services' timetables and buses' frequencies in order to find where the peak hours are along the day (*see Chapter 2.1*). The frequency and departing/arriving times of the new passenger trains are not the same as for the already existing buses, since one train is able to serve more capacity than one bus (one bus has 59 seats while one train has 167 seats), so less trains are needed for covering the same demand as bus services cover today.

Note: there will also be bus services working when the passenger trains work, but they will adjust to the new train services.

The initial passenger trains' timetables introduced in the simulation program are shown next. These timetables will be changed when adjusting one train with others: passenger trains with freight trains, and with the already existing trains in the Stockholm-Uppsala line during the peak hour in the morning (all the morning trains from 05:00-11:00 h, since these last trains were the only available timetables in that line):

Norrtälje-Stockholm
05:00
05:30
06:00
06:15
06:30
06:45
07:00
every 15'
08:00
08:30
09:00
09:30
every 30'
20:00
21:00
22:00

Stockholm- Norrtälje
05:00
05:30
06:00
06:30
07:00
07:20
07:40
08:00
08:30
every 30'
13:00
13:20
every 20'
16:00
16:15
every 15'

Stockholm- Norrtälje (cont.)
17:15
17:35
17:55
every 20'
18:55
19:25
every 30'
20:55
21:55

Table 4.4.1: Initial passenger trains' timetables. 100% capacity case.

For the 200% capacity case, the new passenger trains' timetables that are introduced in the simulation program have been obtained by halving the time intervals of the 100% case trains, so that there will be the double of trains in the same time interval:

Norrtälje-Stockholm
05:00
05:15
05:30
05:45
06:00
06:07
06:15
every 7'
07:30
07:45
every 15'
20:00
20:30
21:00
21:30
22:00

Stockholm- Norrtälje
05:00
05:15
05:30
every 15'
07:00
07:10
07:20
every 10'
08:00
08:15
every 15'
13:00
13:10
every 10'
16:00
16:07

Stockholm- Norrtälje (cont.)
16:10
every 5'
17:15
17:22
every 7'
18:55
19:05
19:15
every 10'
20:55
21:15
every 20'
21:55

Table 4.4.2: Initial passenger trains' timetables. 200% capacity case.

For the 300% capacity case, the new passenger trains' timetables that are introduced in the simulation program have been obtained by tripling the time intervals of the 100% case trains, so that there will be the triple of trains in the same time interval:

Norrtälje-Stockholm
05:00
05:10
05:20
every 10'
06:00
06:05
06:10
every 5'
07:30
07:40
every 10'
20:00
20:20
20:40
every 20'
22:00

Stockholm- Norrtälje
05:00
05:10
05:20
every 10'
07:07
07:14
every 7'
08:00
08:10
08:20
every 10'
13:00
13:17
every 7'
16:00
16:05

Stockholm- Norrtälje (cont.)
16:15
every 7'
17:15
17:25
every 10'
18:55
19:10
every 15'
20:55
21:25
21:55

Table 4.4.3: Initial passenger trains' timetables. 300% capacity case.

For freight trains, the timetable scenarios are 10%, 25%, and 50% of the capacity. The initial timetables are created by using as a reference the current timetables of freight ships arriving/departing nowadays to/from the port of Kapellskär and the port of Stockholm (that in the future will arrive to the port of Kapellskär), and by changing those timetables' time intervals depending on the respective capacity percentages (scenarios).

10% of capacity freight trains	
Kapellskär-Stockholm	**Stockholm-Kapellskär**
1:00 - 05:00	12:30
12:00	22:30

Table 4.4.4: Initial freight trains' timetables. 10% capacity case.

25% of capacity freight trains	
Kapellskär-Stockholm	**Stockholm-Kapellskär**
1:00	5:30
9:00	10:00
11:00	15:00
12:00	22:30
18:30	
21:00	

Table 4.4.5: Initial freight trains' timetables. 25% capacity case.

50% of capacity freight trains	
Kapellskär-Stockholm	**Stockholm-Kapellskär**
1:00	22:30
8:00	5:00
9:00	6:00
11:30	10:00
12:00	14:30
12:30	16:00
18:30	19:00
19:30	
21:00	

Table 4.4.6: Initial freight trains' timetables. 50% capacity case.

These initial timetables will be changed when adjusting one train with others.

The three scenarios that have been simulated as combination of both passenger and freight trains are:

- 300% capacity for passenger trains + 50% capacity for freight trains (the maximum capacity case).
- 200% capacity for passenger trains + 25% capacity for freight trains (the medium capacity case).
- 100% capacity for passenger trains + 10% capacity for freight trains (the minimum capacity case).

The final timetables obtained with the simulation program are shown in the "Results" chapter (*Chapter 5.2)* and analysis of the results in *Chapter 5.3*.

4.5 Rolling stock

The rolling stock that will be operating the best route alternative is regional high-speed trains two-car Regina type running at an average speed of 180-200 km/h, and the infrastructure will be double-tracks standard gauge (1,435 mm). The speeds in the surroundings of stations, at stations and inside tunnels will be lower though.

The Regina train type is a Bombardier Transportation intercity high-speed vehicle used in Sweden.

"The Regina electric-multiple-unit usually has a two car configuration, although capacity can be increased with additional cars. Each car has two wide doors per side and spacious vestibules. This also means effective passenger flows also when passengers have a lot of luggage. One car also has a low-floor entrance on a level with the standard platform height and an internal wheelchair lift.

The Regina multiple unit in its regional version is a train for journey times of 30-60 minutes and frequent stops at stations. Regina is a wide train, with up to five seats abreast, and passengers have a good chance of finding a seat even during the rush

hour. The interior fittings are optimized to give passengers a very high level of comfort for this type of service.

The Regina train meets high environmental requirements. The regeneration of electrical energy during braking gives approximately 25% lower energy consumption."[17]

Some more information about this type of trains is:

Capacity (seated passengers)	167 (2-car unit)
Car length	53,900 mm (2-car unit)
Width	3,450 mm
Maximum speed	180-200 km/h
Weight	120 t (2-car unit)
Power output	1590 kW (2-car unit)
Gauge	1,435 mm
Voltage	15 kV 16$^{2}/_{3}$ Hz AC

Table 4.6.1: Regina 2-car trains technical data.[18]

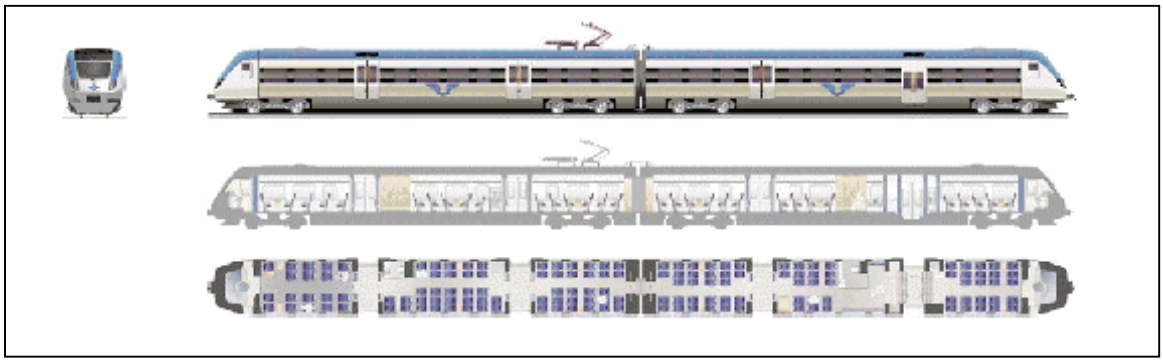

Figure 4.6.1: 2-car Regina electric multiple unit. Source: Bombardier.

[17] *Bombardier webpage.*
[18] *Bombardier webpage.*

Figure 4.6.2: Regina train.

Like explained before, the designed train configuration is a two-car train (*see figure 4.6.1*) Regina type, 53.9 m long. By using this configuration, all the demand is covered and the stations have space enough to accommodate these trains. During the peak hours though, double-trains are planned to be used so that the highest demand during the rush hour is also covered, this means, 2 trains with 2 cars each running together (4 cars in total), with a total length of 53.9 x 2=107.8 metres during the peak hours. The length of the stations will need to be able to accommodate double-trains as well (at least stations 200 m long for train operations).

Figure 4.6.3: Double 2-car Regina electric multiple unit for the peak hours.

5 Simulation

5.1 Simulation tool RailSys®

Along this chapter the simulation tool RailSys® is described as well as the steps followed when simulating the new trains' route alternatives: infrastructure design, signalling system, timetabling, etc.

All the steps for the simulation are explained in the simulation subchapter (5.1.2), and to end up with this chapter, the obtained results are also shown and a deep analysis of them is carried out at the end of the chapter.

5.1.1 Introduction

"The timetable and infrastructure management program RailSys® is a German software system for analysis, planning and optimization of operational procedures and facilities in rail born transport networks of any size. Operational procedures are realistically displayed on desktop computers and the investigation of whole systems is just as easily accomplished as the processing of specific, local problems.

Simulation is the only way of optimizing proposed operations and facilities for rail born transport systems as practical trials and experimentation are not possible. RailSys® enables the economic use due to the clarity of:

- the raw data,
- the planning and working steps,
- the intermediate and final results.

RailSys® is a tool for iterative planning processes. It renders the possibility of:

- the output/display of raw data, intermediate and final results
- the running of plausibility checks
- the updating/revising of specifications/raw data based on the results.

RailSys® achieves:

- wide acceptance and extensive application of the results,
- a high level of efficiency and quality in the planning process,
- a reduction of planning costs.

The timetable and infrastructure management program RailSys® guarantees comprehensive reliability in the railway planning."[19]

The application fields of RailSys® are:

- Trains' timetable construction and modelling
- Assessment of the operational quality
- Running time calculation
- Planning of capacities (UIC 406 capacity method)
- Infrastructure planning
- Operational planning for track work
- Modular data model without redundancy
- Scheduling possessions and planning of special traffic
- Planning of logistic concepts for large scale projects
- Design, investigation and registration of timetables
- Validation of nationwide basic interval timetables
- Investigation of operational quality, punctuality and guaranteed connections
- Completion of disposition strategies in cases of delays and operational disturbances
- Cost-benefit analysis
- Elaboration of technical documents for transport related tenders
- Microscopic and accurate display of all data.

In the next figure it is shown the system structure of the program RailSys®:

[19] *rmcon, Rail Management Consultants.*

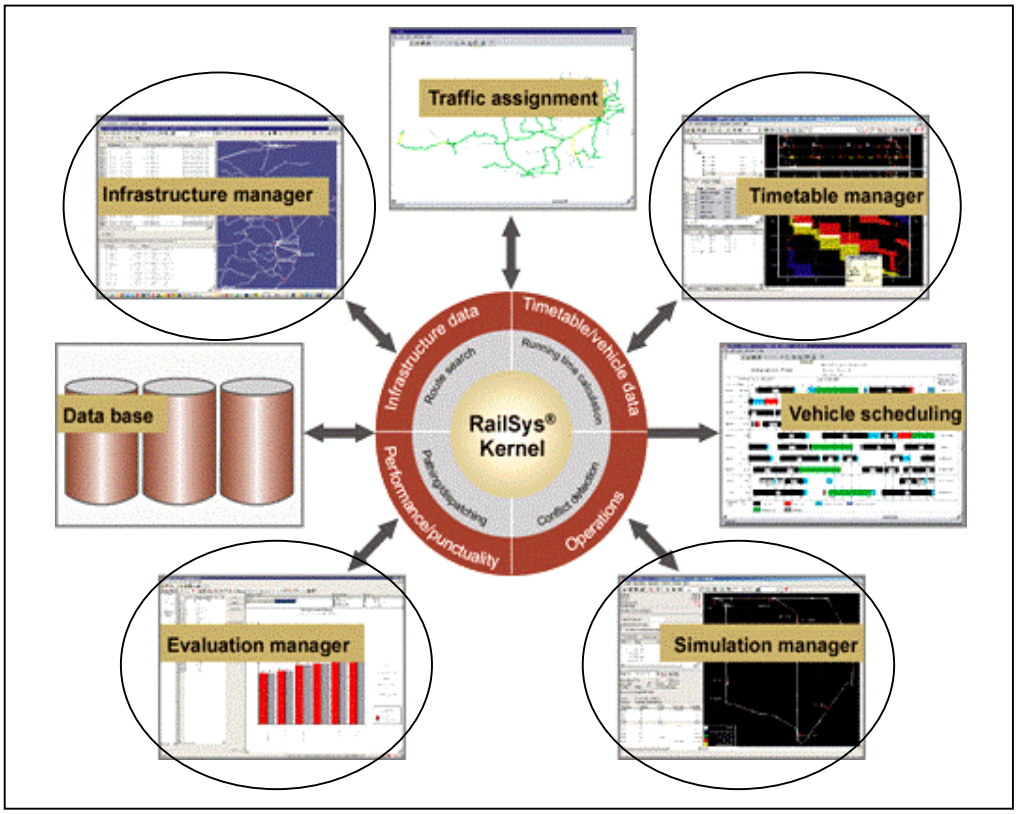

Figure 5.1.1.1: RailSys® system structure. Source: rmcon, Rail Management Consultants.

The four steps or system components when creating a new train network in the RailSys® program are the following:

1) INFRASTRUCTURE MANAGEMENT

- **Exact microscopic data**

All data may be entered with an accuracy of one meter. This is the base for exact results. Configuration parameters for every element of track include:

- Length
- Maximum track speed (several profiles/speedbands)
- Gradient
- Curvature/Radius
- Electrification
- Tunnel cross-section
- Superrelevation.

It is possible to progress successfully without configuring every individual parameter.

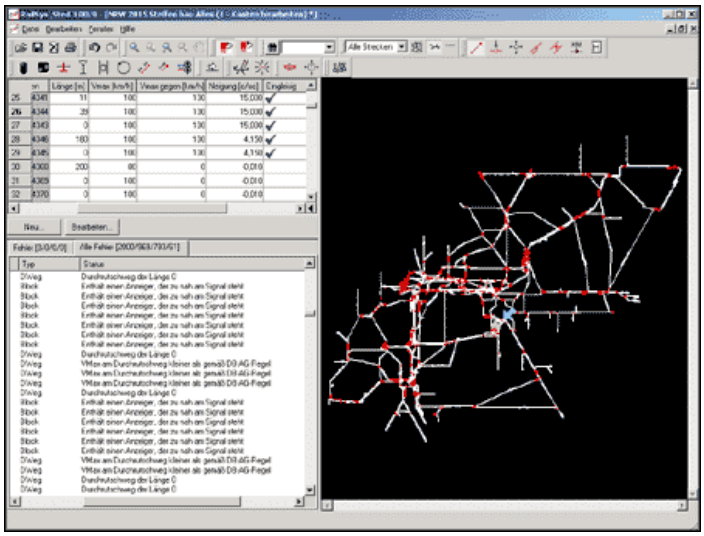

Figure 5.1.1.2: Microscopic network. Source: rmcon, Rail Management Consultants.

- **Any size of networks**

Due to an efficient data model there is no limitation for the size of the network.

2) TIMETABLE MANAGEMENT

- Efficient timetable entry
- Timetable editing
- Immediate running time calculations
- Conflict detection
- Track occupation
- Capacity management (UIC)

3) SIMULATION MANAGEMENT

- Timetable simulation
- Operational simulation
- Statistical simulation

4) EVALUATION MANAGEMENT

- Identifying problems
- Timetable statistics
- Simulation statistics
- Network graphs
- Rolling stock circulation plans
- Infrastructure statistics[20]

[20] *rmcon, Rail Management Consultants.*

5.1.2 Simulation

The simulation with the RailSys® program has been made for passenger trains and freight trains running together on the same tracks.

This simulation has been carried out for all the route alternatives except for route Alternative 3 (Stockholm-Vallentuna-Norrtälje). The reason why this route alternative has not been simulated is because part of this railway line already exists from Stockholm to Kårsta and it is single track narrow-gauge nowadays, plus the fact that this layout is very curvy and passes by very densely populated areas, so from all the route alternatives, this is the one that is less likely to be the best choice because it would be too difficult and laborious to fit a new double-track standard-gauge line in the already existing layout since there is not much free space for doing so because of the housing areas. Another reason is because since the simulation has been made taking into account that also freight trains are running on the same tracks as passenger trains, this route alternative is the less friendly alternative for this purpose, since all the housing areas would be disturbed by freight trains passing by and the curvy layout is very difficult to run from a freight traffic perspective (see Advantages/Disadvantages of route Alternative 3 in *Chapter 3.3*).

The following diagram shows the procedure when working with RailSys®:

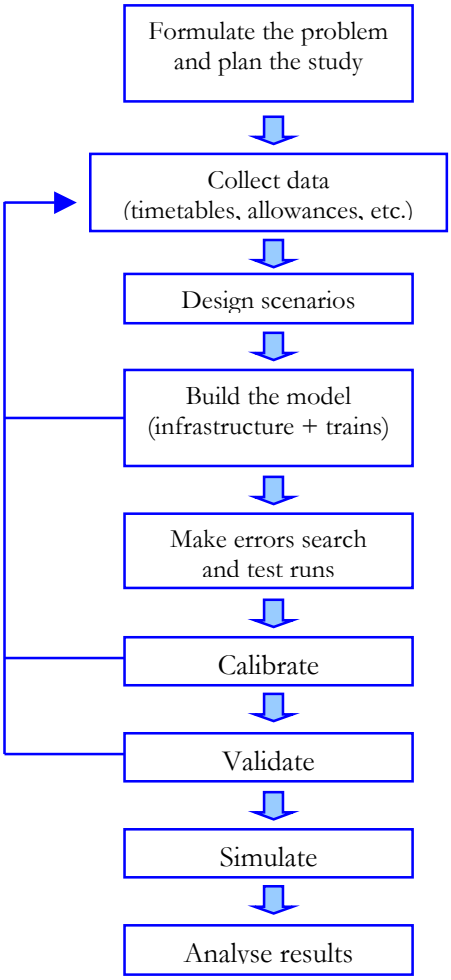

Figure 5.1.2.1: RailSys® procedure diagram. (Own elaboration).

When creating a new railway network, the next steps have been followed:

1. **Infrastructure design**

   - *Basic definitions:* a "**link**" is a stretch of track drawn in the simulation program where the same conditions as speed, gradient and slope among others, are the same along the link. The connections between links are called "**nodes**". Every node connects at least two links. A node may represent a change in speed, gradient, or signalling.
   - *Creation of new lines' layouts and connect them to the already existing railway lines*: as said before, the simulation includes existing lines and the new lines' alternatives that this project proposes. The only existing railway line included in the simulation program in the Stockholm-Uppsala line passing by Märsta and the deviation loop to Arlanda airport.

     From this railway layout the rest of the new lines have been drawn in the program with the geometrical characteristics (lengths) explained in each route Alternative (*see Chapter 3*).

     All the new tracks are double-track standard-gauge except for the stretch between Norrtälje and the port of Kapellskär (21.6 km), which is single-track and just freight trains have been designed to operate this stretch. The already existing railway stretch from Stockholm to Skavstaby (junction located between Rosersberg and Upplands Väsby where the railway line diverts in Y-shape to Uppsala and to Arlanda airport, see *figure 2.1.2*) has four tracks. From Skavstaby to the north, the railway network has two tracks (double track).

     The network has been designed with a maximum speed of 200 km/h and 80-120 km/h on the surroundings of the stations. For the stretch between Norrtälje and Kapellskär just operated by freight trains, the limit speed is 100 km/h.

     All the new alternatives except Alternative 3 have been plot in the program (alternative 1, 2a, 2b), linking them with the existing railway line Stockholm-Uppsala (the complete network is shown in *figure 5.1.2.2*). When simulating each route alternative, just the alternative that is being simulated will be activated; the other alternatives will be deactivated in the simulation program.

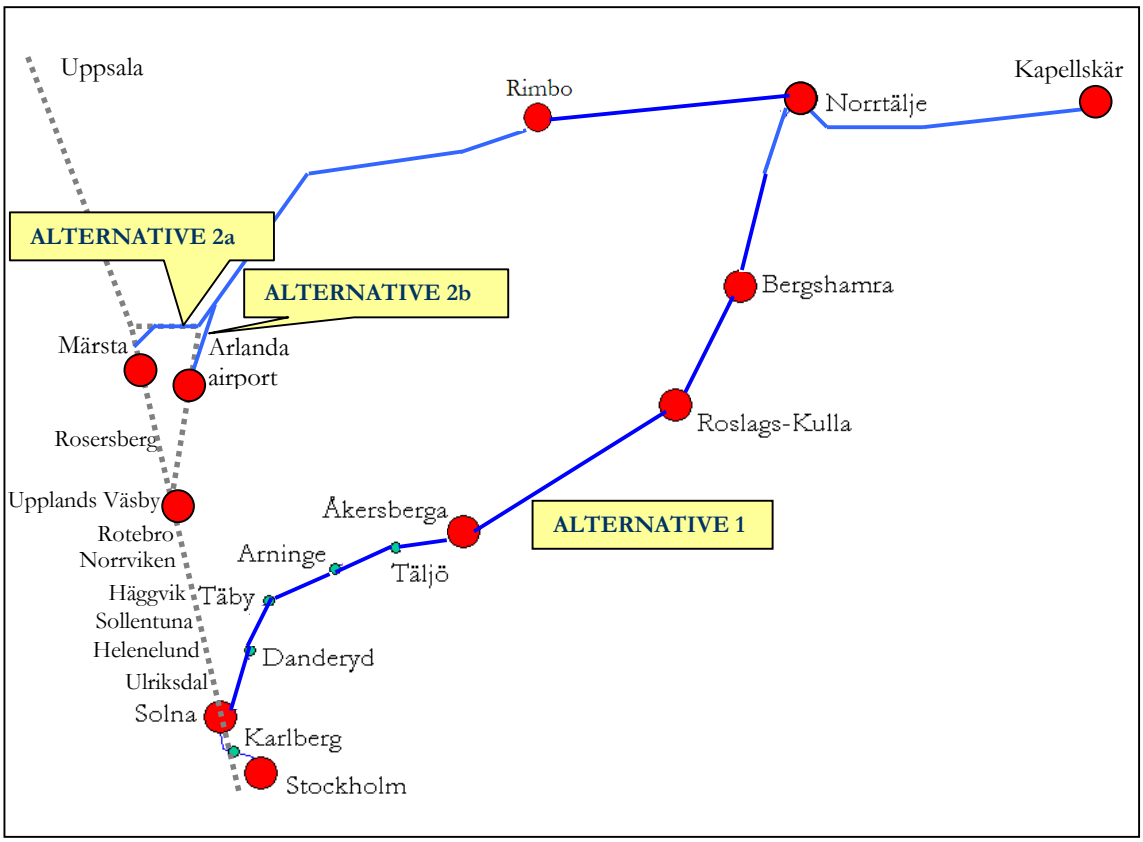

Figure 5.1.2.2: Sketch of the complete railway network in RailSys®.

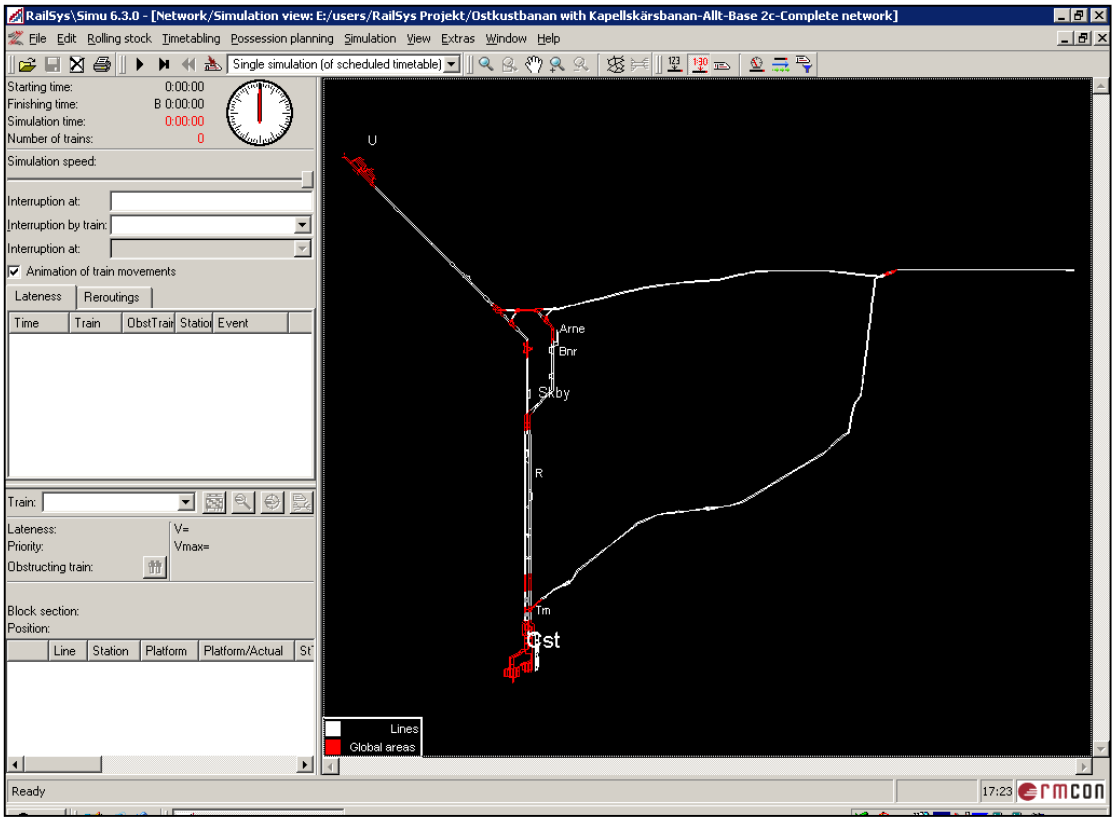

Figure 5.1.2.3: Complete railway network in RailSys®.

- *Stations*: is where switches to change tracks, timing points and stopping signals are. The length of the station (station borders), position and width of the station platforms needs to be designed due to the fact that from that data will depend the switches and the position and numeration of the tracks. Stations define the stopping patterns of the trains (passenger trains may not stop at each station every time they run, and freight trains do not stop in any station besides Kapellskär and Stockholm). The length of the station has been designed to be 200 m long (they are able to accommodate one double-train Regina type and also space enough for train operations). Simplified stations one platform-type (*see figure 3.1.6*) have been used in the simulation program, but this does not introduce any changes in the results obtained from the simulation if any other type of station is preferred to be used.
- *Global areas*: each railway stretch between two consecutive stations is an individual link. Global areas are areas of the network where there is the junction of two or more links (each station is a global area).

2. Signalling system

- With the signals, "**block sections**" are made: stretches of the railway line where two trains cannot be on at the same time (on the same track). The occupancy of the tracks is very important.
- The different types of signals to use among others are: stop boards, stop signals, and speed boards.
- "**Speed boards**": these signals indicate where trains have to change their speed. They are placed before and after switches, and before, after and inside stations. They control speed limits. The network has been designed with a maximum speed of 200 km/h and 80-120 km/h in the surroundings of the stations. For the stretch between Norrtälje and Kapellskär just operated by freight trains, the limit speed is 100 km/h. The bigger and more important the stations are (like in Stockholm and Norrtälje), the lowest the train speed limit. As said before, in switches and connections the design speed is lower as well.

3. Train routes

- In this step the train routes are defined for each route alternative. A train route is the route that trains have from one station to another. It has been assumed that trains run on the left tracks.

4. Timetabling

- In this step all the trains are defined (passenger trains and freight trains as well). They are given a name and their characteristics are defined like maximum speed, length, etc. For passenger trains it has been used Regina-type trains with a maximum speed of 200 km/h, and for freight trains, max. speed 100 km/h.
- The stations where each train stops at, the stopping times (the time each train stays in each station: dwell time), the time each train takes between two consecutive stations, as well as departure/arriving times are also defined. It has

been designed that the scheduled stopping time in each station is 60 seconds, and the minimum stopping time in case the train is delayed is 45 seconds.

- For the timetabling, the first attempt was using the three different scenarios that are explained in *Chapter 4.4* resulting from the combination of passenger trains' scenarios and freight trains' scenarios. When they were introduced in the simulation program and adjustments were starting to be made, the new route alternatives became so congested in the stretch of the railway line Stockholm-Uppsala by so many different types of trains (since it has nowadays capacity problems), and impossible to simulate that these initial three scenarios had to be changed by new timetable scenarios. The three initial simulated passenger trains' scenarios were (explained in *Chapter 4.4*):

  - 100% capacity: passenger trains cover the same capacity as in the present situation bus services do.
  - 200% capacity: passenger trains cover the double of the capacity as in the present situation bus services do.
  - 300% capacity: passenger trains cover the triple of the capacity as in the present situation bus services do.

  For the 100% capacity case, the new passenger trains timetables that were first introduced in the program were estimated by attending at the present situation bus services' timetables and the buses' frequencies in order to find where the peak hours are along the day (*see Chapter 2.1*). The frequency and departure/arriving times of the new passenger trains were not the same as for the already existing buses, since one train is able to serve more capacity than one bus (one bus has 59 seats while one train has 167 seats), so less trains are needed for covering the same demand as bus services cover today.

  Note: there will also be bus services working when the passenger trains work, but they will adjust to the new train services.

  The initial passenger train timetables that were first introduced in the RailSys® program are shown in *Tables 4.4.1, 4.4.2, 4.4.3* for 100% capacity, 200% capacity, and 300% capacity respectively. These timetables have been changed when adjusting one train with others: passenger trains with freight trains, and with the already existing trains in the Stockholm-Uppsala line during the peak hour in the morning (since these last trains were the only available timetables of the existing trains in that line).

  For freight trains, the initial simulated timetable scenarios were 10%, 25%, and 50%. The initial timetables were created by using as a reference the current timetables of freight ships arriving/departing nowadays to/from the port of Kapellskär and the port of Stockholm (that in the future will arrive to the port of Kapellskär), and by changing those timetables' time intervals depending on the respective percentages. Those timetables are shown in *Tables 4.4.4, 4.4.5, 4.4.6*.

  These initial timetables have been changed when adjusting one train with others.

  The scenarios that were first simulated as combination of both passenger and freight trains were the same for each route alternative:

- 300% capacity for passenger trains + 50% capacity for freight trains (the maximum capacity case).
- 200% capacity for passenger trains + 25% capacity for freight trains (the medium capacity case).
- 100% capacity for passenger trains + 10% capacity for freight trains (the minimum capacity case).

After seeing that those initial timetable scenarios were impossible to simulate due to congestion charges in the railway line Stockholm-Uppsala (since it has nowadays capacity problems), new timetable scenarios were simulated, different for each route alternative, since each route alternative has different network characteristics (the simulated route alternatives are Alternative 1, Alternative 2a, and Alternative 2b as explained before).

The new simulated timetable scenarios are:

Alternative 1 (Solna–Åkersberga-Norrtälje)	**Alternative 2a** (Stockholm-Märsta-Norrtälje)	**Alternative 2b** (Stockholm-Arlanda-Norrtälje)
100% capacity passenger trains	100% capacity passenger trains + 10% capacity freight trains	100% capacity passenger trains
200% capacity passenger trains	200% capacity passenger trains + 25% capacity freight trains	200% capacity passenger trains
	200% capacity passenger trains + 50% capacity freight trains	

Table 5.1.2.1: New timetable scenarios simulated in RailSys®.

As seen in Table 5.1.2.1, there are seven timetable scenarios simulated, different for each route alternative. The reason why there are no freight trains simulated in route Alternative 1 and 2b is because in these lines there is part of the tracks that is via tunnels, and freight trains cannot run through tunnels. One more reason why freight trains do not run through route Alternative 1 is because it passes by more population centres than the other alternatives (not good from a freight traffic perspective), and because there are not interesting freight points along this route alternative (in route Alternative 2a there is an intermodal terminal in Rosersberg which may be a future freight train stop, for example).

The final timetables obtained with the RailSys® program are shown in the "Results" chapter (*Chapter 5.2)* and analysis of the results in *Chapter 5.3*.

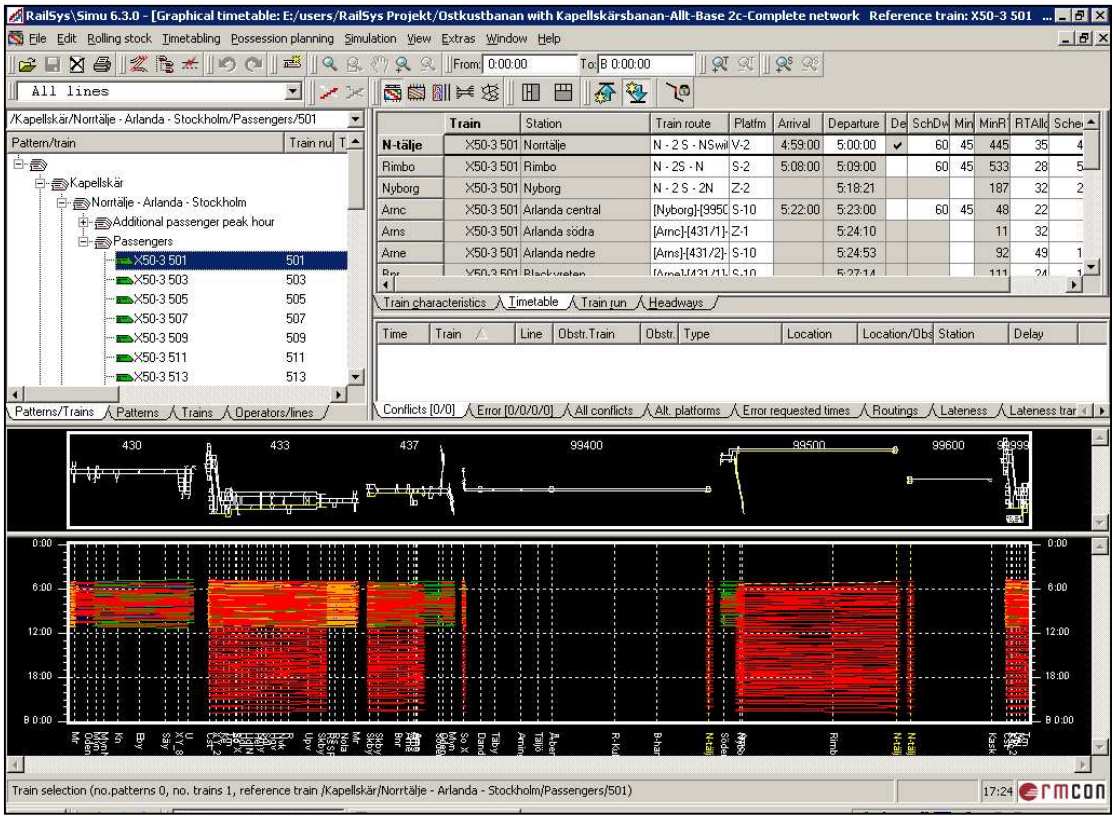

Figure 5.1.2.4: Timetable window in the RailSys® program.

5. Simulation

For being able to introduce all the new passenger and freight trains with the already existing trains in the railway line Stockholm-Uppsala during the peak hour in the morning (all the morning trains from 05:00-11:00 h) without train conflicts, some of the timetables of the existing trains in that line have been changed a few minutes in order to adjust one train with others. In the real situation this could not be possible since from the movement of one minute of the timetable of one train, depend many other trains' timetables around the country. For instance, if one train is changed one minute, the rest of the trains in its line will also need to be changed one minute, and the trains depending on those will also need to change their timetables and so on. So, the simulation gives as a result approximate timetables of the new trains, but just taking into account the trains in the line Stockholm-Uppsala during the peak hour in the morning (all the morning trains from 05:00-11:00 h) and without taking into account the rest of the trains in Sweden. The results are also approximate because the trains' timetables of the other existing railway lines in the study area (*see figure 2.1.2*) are not available, so they have not been taken into account neither.

In the other hand, since the available trains' timetables in the line Stockholm-Uppsala are during the peak hour in the morning (the most difficult interval of time to introduce the new trains because it is the most congested), it is supposed that if it is managed that the new trains are able to run together with the existing trains during these interval of time (peak hour), then they will be

able to run together during the rest of the day, since it is easier to introduce the new trains when it is not the rush hour.

The simulation has been made for the seven different scenarios explained before:

Alternative 1 (Solna–Åkersberga-Norrtälje)	**Alternative 2a** (Stockholm-Märsta-Norrtälje)	**Alternative 2b** (Stockholm-Arlanda-Norrtälje)
100% capacity passenger trains	100% capacity passenger trains + 10% capacity freight trains	100% capacity passenger trains
200% capacity passenger trains	200% capacity passenger trains + 25% capacity freight trains	200% capacity passenger trains
	200% capacity passenger trains + 50% capacity freight trains	

Table 5.1.2.2: New timetable scenarios simulated in RailSys®.

Besides the new trains (passengers' and freight's), and the already existing trains in the railway line Stockholm-Uppsala, two additional skip-stop trains have been introduced during the peak hours in the new route alternatives 2a (Stockholm-Märsta-Norrtälje) and 2b (Stockholm-Arlanda airport-Norrtälje):

- one during the peak hour in the morning (06:00-08:00) Norrtälje-Rimbo-Stockholm (just stopping in those stations).
- one during the peak hour in the afternoon (16:00-17:00) Stockholm-Rimbo-Norrtälje (just stopping in those stations).

Also commuter trains every 15 minutes in route Alternative 1 (Solna-Åkersberga-Norrtälje) have been introduced along the day stopping in all the stations where the current existing trains nowadays stop along the existing railway stretch Stockholm-Åkersberga (like it would be in the future situation since Banverket already planned it this way):

Stockholm – Karlberg – Solna – Danderyd – Täby – Arninge – Täljö - Åkersberga

In the already existing railway stretch from Stockholm to Skavstaby that has four tracks, commuter and freight trains run in the inner tracks while long-distance, Arlanda express and the new passenger trains run in the outer tracks (*see figure 3.1.11 for the four-tracks railway line in Solna station*).

Once all the trains fit well one with each other and there are no conflicts between the existing and the new trains (passengers' and freight's), all the trains are simulated by making them run into each route alternative network. This way timetables are obtained from the simulation *(see Appendices III and IV)*.

5.2 Results

When simulating in RailSys® all the timetable scenarios (see *Table 5.1.2.2*), it became impossible to simulate the scenarios that have 200% of capacity for passenger trains just by halving the time intervals between consecutive new passenger trains as explained in *Chapter 4.4*. The reason to this is because part of the network of the Stockholm-Uppsala railway line (where there are nowadays capacity problems) became so congested by too many new passenger trains that it could not be possible to simulate it that way since any more new passenger trains were able to fit into the network (because there were the double number of trains in the same time interval of time as in the 100% of capacity case).

The solution to this problem is to use for the 200% of capacity case exactly the same number of trains and the same timetables and frequencies as in the 100% of capacity for passenger trains, but with double trains. This way eventhough the time intervals between two trains are the same for the 100% case and for the 200% case, the capacity of the trains is doubled in the 200% case (as it was supposed to be).

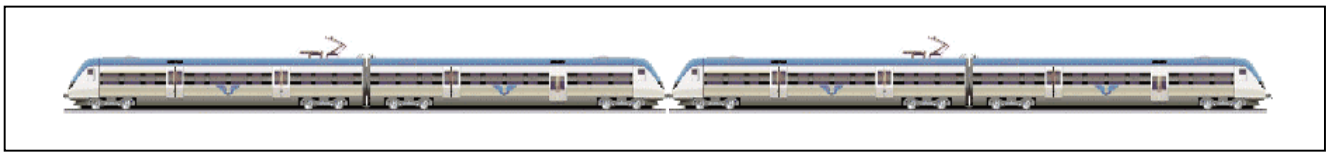

Figure 5.2.1: Double 2-car Regina electric multiple unit for the 200% of capacity for passenger trains.

All the resultant trains' timetables obtained from the simulation are shown in Appendices III and IV:

- Appendix III: Trains' timetables
- Appendix IV: Graphic timetables

• Appendix III: Trains' timetables

(In this printable version of the Project, only the new passenger trains for the chosen best alternative from a passenger traffic perspective are shown in Appendix III. The rest of the timetable´s results for all the simulated route alternatives and trains are shown in the full version of the Appendices available digitally on request).

In this appendix all the resulting from the simulation timetables are shown, for each alternative and for each scenario:

<table>
<tr><th>Alternative 1
(Solna–Åkersberga-Norrtälje)</th><th>Alternative 2a
(Stockholm-Märsta-Norrtälje)</th><th>Alternative 2b
(Stockholm-Arlanda-Norrtälje)</th></tr>
<tr><td>100% capacity passenger trains</td><td>100% capacity passenger trains
+ 10% capacity freight trains</td><td>100% capacity passenger trains</td></tr>
<tr><td rowspan="2">100% capacity double trains
(200% capacity passenger trains)</td><td>100% capacity double trains
(200% capacity passenger trains) +
25% capacity freight trains</td><td rowspan="2">100% capacity double trains
(200% capacity passenger trains)</td></tr>
<tr><td>100% capacity double trains
(200% capacity passenger trains) +
50% capacity freight trains</td></tr>
</table>

Table 5.2.1: New timetable scenarios simulated in RailSys®.

The timetables have been obtained for weekdays (which are the most congested), and the times shown in the timetables are the departing times.

The symbol " | " in the timetables means that the train passes by the station where it is showed, without stopping at that station.

The symbol " x " in the timetables means that the train does stop in that station but the stopping time is just not shown. Just the stopping times in the most important stations are shown.

The new proposed passenger trains are shown in red colour.

See Appendix III.

- **Appendix IV: Graphic timetables**

In this appendix, the resultant graphic timetables from the simulation are shown. *(In this printable version of the Project, only the graphic timetables of all the trains for the chosen best alternative from a passenger traffic perspective are shown. The rest of the timetable´s results for all the simulated route alternatives and trains are shown in the full version of the Appendices available digitally on request).*. They represent the graphics of the trains' timetables shown in *Appendix III*.

Eeach line in the graphics represents a train. The slope of the lines represents the speed of the trains: the steep it is, the faster the train goes from its origin to its destination.

Table of colours:

- Green colour trains: new additional skip-stop trains during the peak hour.
- Red colour trains: new proposed passenger trains.
- Orange colour trains: all trains that already exist in the railway line Stockholm-Uppsala (including passenger trains and freight trains). All the existing trains.
- Purple colour trains: new commuter trains.
- Blue colour trains: new freight trains.

See Appendix IV.

5.3 Analysis of results

By analyzing the resulting timetables (*see Appendix III*), a comparison of the actual travel times from Stockholm to Norrtälje by bus services and the future travel times by passenger trains may be made:

	Norrtälje-Stockholm		
	Travel time by bus nowadays	**Travel time by new passenger train in the future**	
Alternative 1	60-62 '	**44'**	**+ 3' waiting time**
Alternative 2a	60-62 '	**50'**	
Alternative 2b	60-62 '	**50'**	
	+10' by subway to reach the centre of the city + 3' of waiting time		
TOTAL:	**73-75'**		

Table 5.3.1: Comparison of travel times from Norrtälje to Stockholm with and without trains.

SHORTEST TRAVEL TIMES		
Norrtälje - Stockholm	**BUS:**	60'
	NEW TRAIN:	**44'**
Norrtälje - Rimbo	**BUS:**	30'
	NEW TRAIN:	**9'**
Norrtälje - Arlanda	**BUS:**	80'
	NEW TRAIN:	**23'**

Table 5.3.2: Comparison of travel times from with and without trains.

(*Note*: It should be taken into account that trains going to Stockholm stop at Central Station, i.e. directly into the city centre, with good connections to all subway lines; while bus services terminate at Tekniska Högskolan and passengers need to change from bus to subway to reach the city centre (one of the busiest subway sections in the subway line network) plus the waiting time.)

As seen in *Table 5.3.1*, the travel times Norrtälje-Stockholm have been reduced by 22-26 minutes (**reduction of travel time of around 40%**), and from *Table 5.3.2* it can be seen that the furthest the distance between two points, the largest the reduction in time, so for instance, for the stretch Norrtälje-Rimbo, the travel time reduction is 21 minutes, but for the stretch Norrtälje-Arlanda airport, the travel time reduction is 57 minutes. This is a considerable reduction in travel time, so this means that public transportation in the future using passenger trains will be improved and more profitable and efficient because more demand than today will even be reached.

Related to the frequency between trains, in order to introduce a new passenger train service in any area, one important factor to take into account is to have a sufficient

service level in terms of frequency, which can be considered as equivalent to the current bus service. This needs to be met in a new passenger railway line.

The capacity of passenger trains is higher than the bus service's, even with a reduced train frequency (due to the fact that a train loads more passengers than a bus). Trains' frequency needs to be such that it does not lead to long waiting times for passengers.

The average interval of time (frequency) between two consecutive new passenger trains for each route alternative is (depending on the timetable scenarios and on the interval of hours during the day):

- Alternative 1: 15 minutes
- Alternative 2a: 21 minutes
- Alternative 2b: 21 minutes

Being the time interval between two consecutive new passenger trains during the peak hours in the morning and in the afternoon less or equal to 15 minutes in each route alternative.

Comparing this results to the actual existing bus services in the study area (*see Appendix I*), the buses' frequency is also improved with the use of new passenger trains, plus the fact that if new passenger trains are used in the future, bus services will still also be operating in the study area, and both transport modes may suplement each other, so that better services are offered to the customers.

By comparing these frequencies with the studied case of the Svealand line (in *Chapter 2.4*), in the Svealand line the frequency between passenger trains is nowadays one train per hour, while in the studied and simulated route alternatives their frequencies is much higher (3-4 times higher frequency than in the Svealand case), so this shows that the obtained frequencies from the simulation are even better than in the actual operating Svealand line.

As seen in *Chapter 2.4*, the ratio between car travel time and public transportation travel time (new train passenger service in this case) from Norrtälje to Stockholm is also improved with the introduction of new passenger trains between those two localities:

Nowadays, the ratios between the travel time from Stockholm to Norrtälje by public transportation (bus) and by car, are approximately:

- Distance Stockholm-Norrtälje by road: 72 km, approximately by car 56' (assumption: average car speed 80 km/h).
- Travel time Stockholm-Norrtälje by bus: 62'.
- Ratio: $\frac{t_{pt}}{t_{car}} = \frac{62'}{56'} = 1.11$, this ratio corresponds approximately to a factor of 60% (see *Figure 2.4.3*) which means that travellers are more willing to use public transportation instead than car (willingness to use public transportation: 60%, willingness to use private car: 40%).

With the resultant data (see *Table 5.3.1*) about the new trains' travel time, the new ratio in the future would be:

- Travel time Stockholm-Norrtälje by car: 56'.

- Travel time Stockholm-Norrtälje by train (average travel time of all the route alternatives, see *Table 5.3.1*): 48'.

- Ratio: $\frac{t_{pt}}{t_{car}} = \frac{48'}{56'} = 0.86$, this ratio corresponds approximately to a factor of 75% (see *Figure 2.4.3*) which means that travellers are more willing to use public transportation instead than car (willingness to use public transportation: 75%, willingness to use private car: 25%). This ratio has been made lower with future trains compared with the nowadays existing ratio with bus services (it has subsequently improved).

6 Conclusions and recommendations

After introducing and studying all the route alternatives, the simulation, as explained in the Simulation chapter (*Chapter 5*), has only be done for route alternatives 1, 2a and 2b, ruling out route Alternative 3 (Stockholm-Vallentuna-Norrtälje) because of all its disadventages compared to the rest from a passenger and freight trains perspective (see Advantages/Disadvantages of route Alternative 3 in *Chapter 3.3*).

One conclusion that can be made from the studies carried out is that from the passenger traffic perspective, the port of Kapellskär is not an interesting locality to link with the rest of the important points in the study area (Norrtälje, Rimbo, Märsta/Arlanda, Uppsala and Stockholm) by the use of new passenger trains because Kapellskär has a very low population (port workers), and the demand of passengers that go to/from Kapellskär currently by bus is also low (there is no sufficient traffic base). But it is indeed an interesting point to link with the rest by the use of freight trains (as it was done in the simulation).

The final decision of the best route alternative has therefore three different perspectives in this Project: from a passenger traffic perspective, from a freight perspective (by prolonging the railway line from Norrtälje to the port of Kapellskär), or from a passenger and freight traffic perspective since both types of trains are likely to run together along the same infrastructure. The three perspectives are studied in this chapter.

- **Passenger traffic perspective**

When comparing the three different route alternatives, several factors need to be taken into account in order to ”choose” the best alternative. Some of them may be:

- Potential reached by each alternative (see *Table 3.4.1*).
- Characteristics of the alternatives' layouts: track length, number of stations, points reached, length of new build tracks, etc. (see *Chapter 3*).
- Simulation results: timetables, frequency, travel times.
- If the selected route alternative is able to be operated by freight trains as well.
- Direct connection with other important railway lines (i.e. Stockholm-Uppsala railway line).

By focusing on those factors, the following conclusions have been made:

	Total approx. lenght (km)	Length new tracks (km)	New stations	Travel time (mins.)	Frequency (mins.)	Potential reached (inhabitants)	Freight/no freight	Important stations (besides Stockholm)	Connection with Stockholm-Uppsala line
Alternative 1	70.8	41.3	3	44	15	110,550 but low potential in the long distance	No (tunnel section)	Norrtälje	No
Alternative 2a	90.5	46	2	50	21	48,093	Yes	Norrtälje, Rimbo	Yes
Alternative 2b	91	48	2	50	21	48,093	No (tunnel section)	Norrtälje, Rimbo, Arlanda airport	Yes

Table 6.1.1: Characteristics of each route alternative. Comparison table.

The above table is a colour table where red colour cells represent factors that are not met by the route alternatives (negative points), and green colour represents factors that are met (positive points).

By the use of the table and colours, the three route alternatives are compared and it is a method for choosing the best route alternative.

By attending at *Table 6.1.1*, Alternative 1 is the one that reaches more demand (56.5% more demand than the other route alternatives. (See *Chapter 3.4*). In the other hand, this route Alternative 1 does not reach the passengers at Arlanda airport, which is a very important point in the study area, neither passes by Rimbo (another important objective in this Project). Another problem in this route is that passengers coming from Norrtälje who would like to change to the already existing railway line Stockholm-Uppsala, need to travel through all the railway line from Norrtälje to Solna to change lines. This route alternative is not connected to the Stockholm-Uppsala railway line neither.

More characteristics of route Alternative 1 is that there are more new stations than in the other route alternatives (higher building costs), and that since part of the railway layout is by means of a tunnel (from Solna to Arninge), freight trains cannot operate this line (bad from a freight traffic perspective).

Some good things route Alternative 1 has is that it has the shortest new build tracks (since Banverket has already planned to build the tracks from Solna to Åkersberga), the travel time in this alternative is 6 minutes shorter than in the others, and the frequency between the new passenger trains is 6 minutes higher compared to the other alternatives also.

To summarize, as shown in *Table 6.1.1*, route Alternative 1 has five "red cells" ("bad points" compared with the other alternatives) and three "green cells" ("good things" compared with the other alternatives).

Referring to the other alternatives, Alternative 2a is slightly shorter in terms of new build tracks than Alternative 2b, and has the same number of stations as Alternative 2b as well. Related to the travel time, frequency between new passenger trains, potential reached and connection to the Stockholm-Uppsala railway line, it is also in the same conditions as Alternative 2b. The only things that make this route

Alternative 2a different than Alternative 2b is that it does not serve the potential in Arlanda airport (very important to be served), and since this alternative's layout does not have any section via tunnel, freight trains are able to operate this route Alternative 2a (this does not happen in route Alternative 2b because part of the tracks in Arlanda airport are inside a tunnel and freight trains cannot run inside tunnels because of safety reasons and in case of dangerous goods).

One more fact is that with route Alternative 2b (Stockholm-Arlanda airport-Norrtälje), one more connection from Stockholm to Arlanda airport is achieved operated by regional high-speed trains (the proposed trains). This is an advantage for Stockholm (to have one more connection with Arlanda), and also for passengers who are not willing to pay an Arlanda Express train ticket, but that are willing to pay a regional train ticket.

To summarize, both route alternatives (2a and 2b) have four "green cells" and one "red cell". They are in the same conditions, but these two alternatives fulfil most of the requirements.

Comparing these two (2a and 2b) with Alternative 1, the last one has more "red cells" and less "green cells" than the others, this means that less important requirements that need to be taken into account in this Project are fulfilled in route Alternative 1, so this proposal is ruled out.

Now the matter is to decide between route Alternative 2a and 2b, since both have the same number of "positive points" (green) and "negative points" (red).

- **Freight traffic perspective**

The most important factor to take into account for freight trains is if it is possible to operate them or not, since in layouts with stretchs via tunnel it is impossible to do so.

The conclusion from this perspective (freight), is that route Alternative 2a is able to operate freight trains and route Alternative 2b is not.

- SOLUTION

Since the only difference between those two route alternatives (2a and 2b), besides their layout of course, is that 2b stops in Arlanda airport and therefore reaches the potential in the airport, and that Alternative 2a is able to be also operated by freight trains, the final conclusion is that route **Alternative 2a is the best solution from a freight traffic perspective**, and that route **Alternative 2b is the best solution from a passenger traffic perspective.** Both route alternatives stop at Rimbo and Norrtälje (two of the main objectives in this Project).

The optimum solution is to have both route alternatives built (2a and 2b), since both alternatives may supplement each other, so that freight trains can run through Märsta (alternative 2a) without passing by Arlanda airport, and so that passenger trains can stop at Arlanda airport reaching the potential there. This would be the best solution **from a passenger and freight traffic perspective**. See following figure.

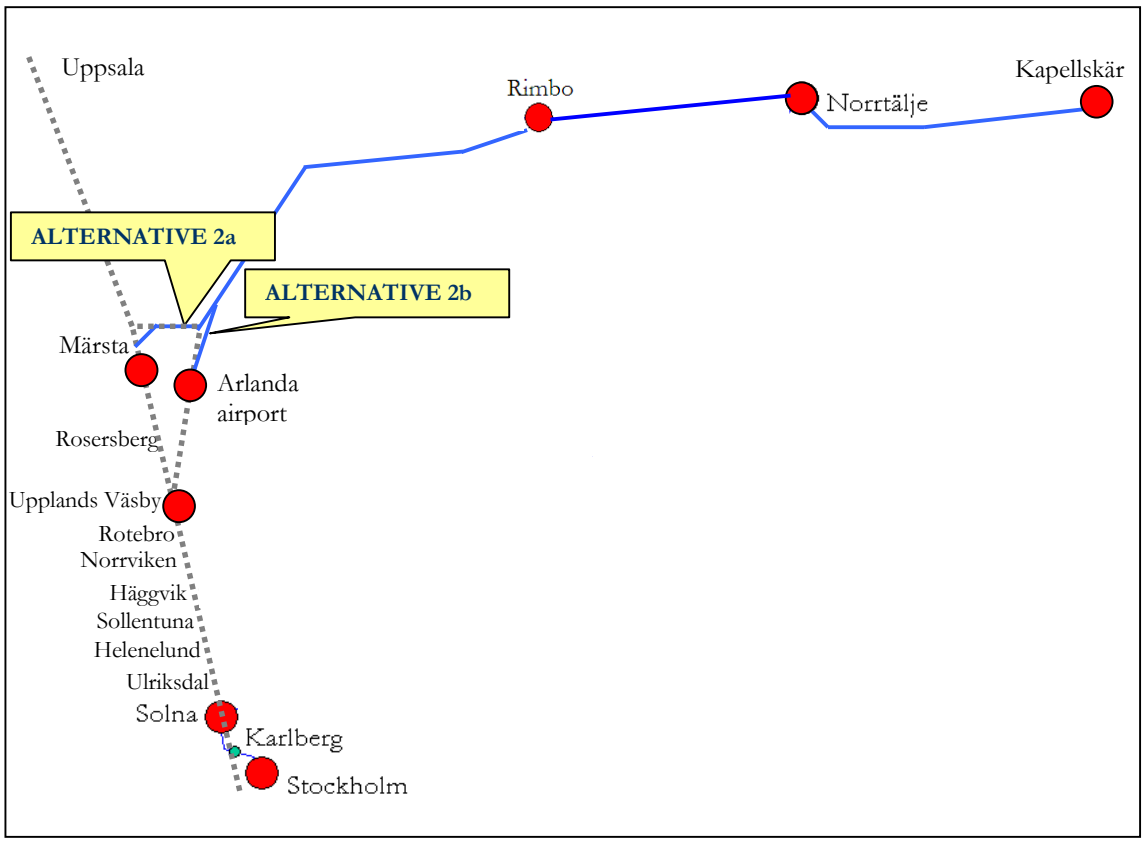

Figure 6.1.1: Sketch of the optimum solution from a passenger and freight perspective.

- RECOMMENDATIONS

From the simulation it was obtained as a result that since nowadays the already existing railway line Stockholm-Uppsala is already quite congested (there are capacity problems), in the future, with more passenger trains, this line will be so much congested (reason why it was impossible to fit the 200% case of capacity of new passenger trains in this railway line by doubling the number of trains of the 100% case. The proposed solution is to use double trains as explained in *Chapter 5.2*). So for being able to stop the new passenger trains of the route Alternative 2b (Stockholm-Arlanda-Norrtälje) at Upplands Väsby, extra outer platforms are needed in this station for this purpose.

Another recommendation is that since this Stockholm-Uppsala line will get so congested in the future, a new bypass from Skavstaby to the north will also be needed so that trains going in the direction from Stockholm to Uppsala do not need to change tracks at Skavstaby for avoiding the trains that go from Stockholm to Arlanda, and so that they can all run at the same time. This way Skavstaby will have more simultaneous possibilities if as much traffic should pass by Märsta as it passes by Arlanda.[21]

One more recommendation for further in-depth studies is to study in-depth if more new passenger trains are able to be introduced in route Alternative 1 (Solna-

[21] *Source: Johannes Wolfmaier.*

Åkersberga- Norrtälje), because as said before, it was not possible to fit the 200% of capacity of new passenger trains by doubling the number of trains of the 100% case since there are commuter trains running from Stockholm to Åkersberga every 15 minutes as well and the line also got congested in the simulation. But maybe it is just not possible to fit the double number of trains as in the 100% case (200% of capacity), but it is possible to introduce more new passenger trains than in the 100% of capacity case but less than in the 200% case. This needs to be studied more in detail.

It should also be studied in-depth the possibility to introduce new passenger trains in the freight single-track railway line that is proposed in this Project from Norrtälje to the port of Kapellskär in order to serve ferry passenger services that arrive to this port and connect them to certain trains. There should not be capacity problems in this single-track railway line since the number of freight trains is not as high as passengers', plus the fact that the proposed train station in Norrtälje (see *Figure 3.1.22*) is designed to make it possible for freight trains to pass by without any problem.

More recommendations are to study more in detail the configuration of the proposed train stations because there is the possibility that they may be made better by adding auxiliary tracks; study further if there is the possibility to connect the proposed new railway lines (route Alternatives 2a and 2b) with any other locality that also needs an improvement in its public transportation system, inside or outside the study area (other possible railway destinations); as well as study in-depth the prognosis of future travel demand.

7 Literature

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- rmcon (Rail Management Consultants, a rail transport management and a software development enterprise) webpage: www.rmcon.de/english/uber_railsys.html

APPENDICES

Contents

A full version of the Appendices is available digitally on request.

APPENDIX I: Present situation buses' timetables

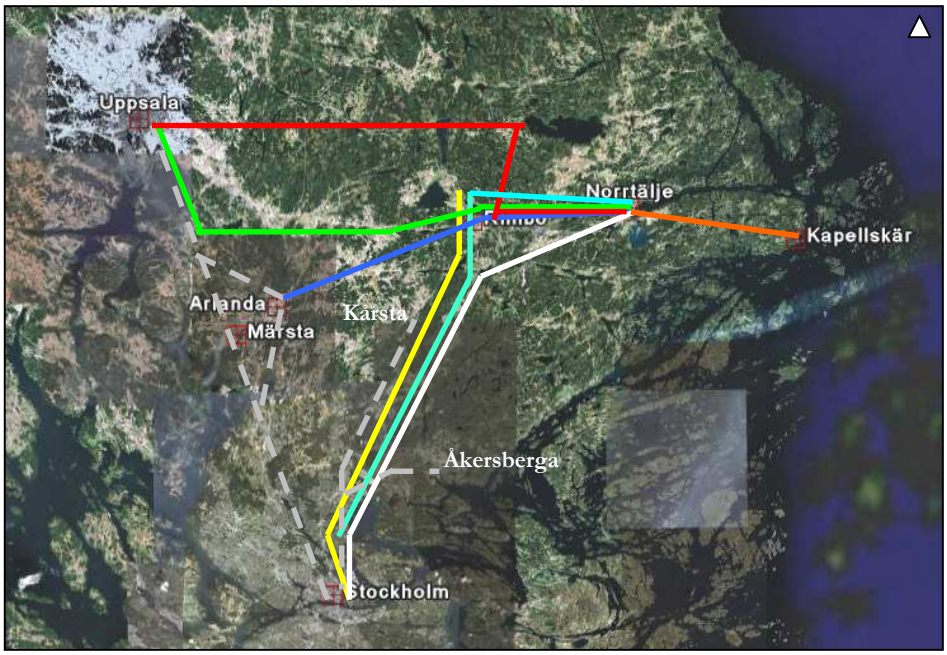


Figure AI.1: Present passenger tranport system in the study area.

BUS LINES:
676 625 UL 807 631
647 639 UL 809

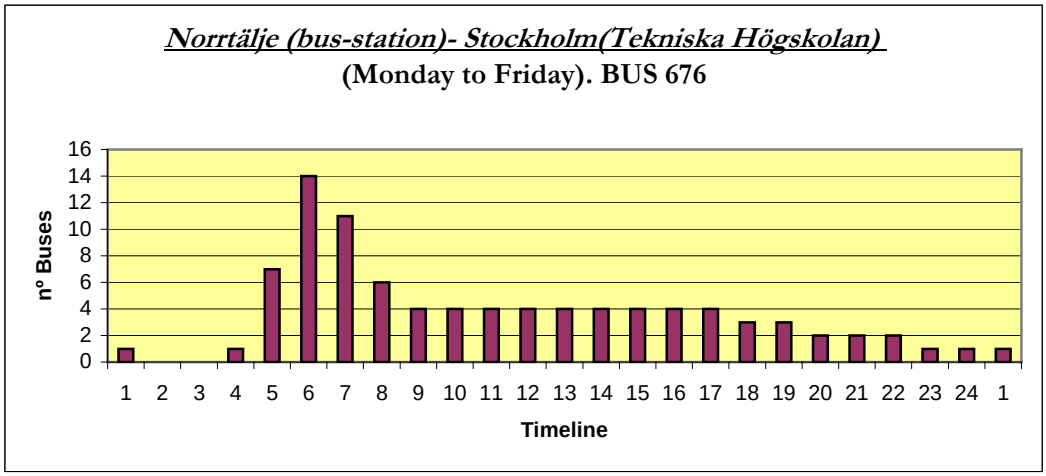
- **BUS LINE 676**

Number of seats in one bus: 59

Norrtälje -Stockholm (Monday-Friday). BUS 676	
Timeline	**Frequency (minutes)**
01:00 - 02:00	60
02:00 - 03:00	-
03:00 - 04:00	-
04:00 - 05:00	25
05:00 - 06:00	10
06:00 - 07:00	**5**
07:00 - 08:00	**5**
08:00 - 09:00	10
09:00 - 10:00	15

10:00 - 11:00	15
11:00 - 12:00	15
12:00 - 13:00	15
13:00 - 14:00	15
14:00 - 15:00	15
15:00 - 16:00	15
16:00 - 17:00	15
17:00 - 18:00	15
18:00 - 19:00	20
19:00 - 20:00	20
20:00 - 21:00	30
21:00 - 22:00	30
22:00 - 23:00	30
23:00 - 24:00	60
24:00 - 01:00	60

Table AI.1: Frequency of buses Norrtälje- Stockholm from Monday to Friday, line 676.



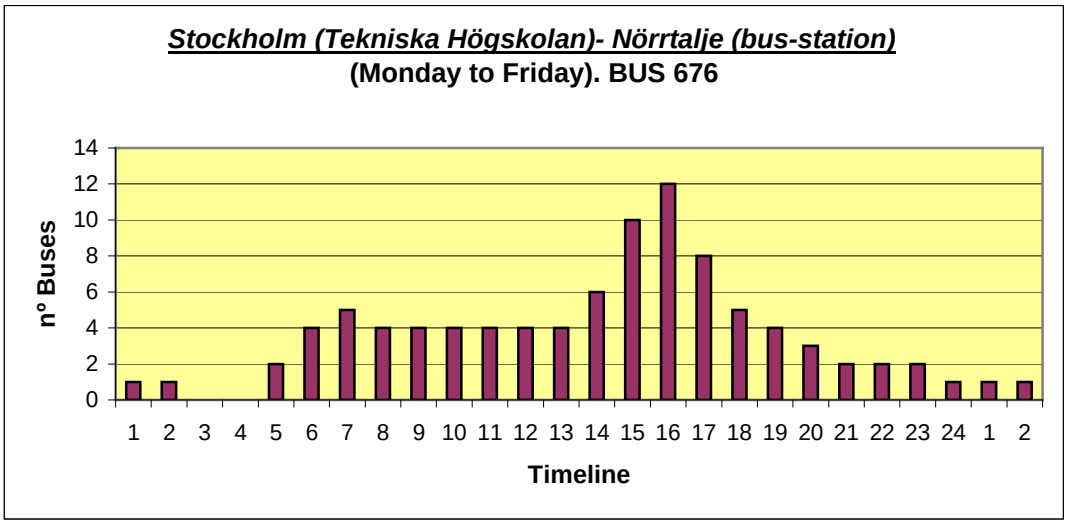
90 buses in total

Figure AI.2: Number of buses Norrtälje- Stockholm from Monday to Friday, line 676.

Stockholm- Norrtälje (Monday-Friday). BUS 676	
Timeline	**Frequency (minutes)**
01:00 - 02:00	60
02:00 - 03:00	60
03:00 - 04:00	-
04:00 - 05:00	-
05:00 - 06:00	15
06:00 - 07:00	15
07:00 - 08:00	15
08:00 - 09:00	15
09:00 - 10:00	15
10:00 - 11:00	15
11:00 - 12:00	15
12:00 - 13:00	15

13:00 - 14:00	15
14:00 - 15:00	10
15:00 - 16:00	**7**
16:00 - 17:00	**5**
17:00 - 18:00	**7**
18:00 - 19:00	10
19:00 - 20:00	15
20:00 - 21:00	20
21:00 - 22:00	30
22:00 - 23:00	30
23:00 - 24:00	30
24:00 - 01:00	60

Table AI.2: Frequency of buses Stockholm-Norrtälje from Monday to Friday, line 676.



91 buses in total

Figure AI.3: Number of buses Stockholm-Norrtälje from Monday to Friday, line 676.

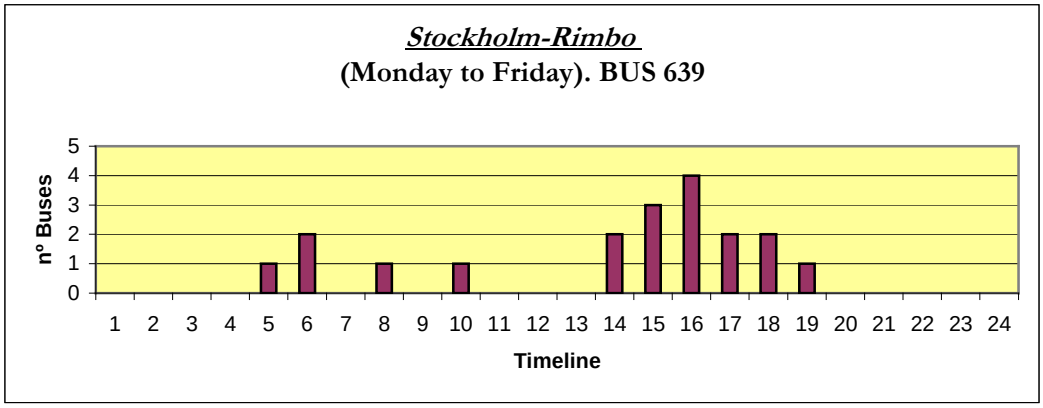
- **BUS LINE 639**

Number of seats in one bus: 59

Stockholm-Rimbo (Monday-Friday). BUS 639	
Timeline	**Frequency (minutes)**
01:00 - 02:00	-
02:00 - 03:00	-
03:00 - 04:00	-
04:00 - 05:00	-
05:00 - 06:00	**30**
06:00 - 07:00	140
07:00 - 08:00	140
08:00 - 09:00	140
09:00 - 10:00	90
10:00 - 11:00	220
11:00 - 12:00	220

12:00 - 13:00	220
13:00 - 14:00	220
14:00 - 15:00	40
15:00 - 16:00	**30**
16:00 - 17:00	**15**
17:00 - 18:00	**30**
18:00 - 19:00	60
19:00 - 20:00	-
20:00 - 21:00	-
21:00 - 22:00	-
22:00 - 23:00	-
23:00 - 24:00	-
24:00 - 01:00	-

Table AI.3:Frequency of buses Stockholm- Rimbo from Monday to Friday, line 639.



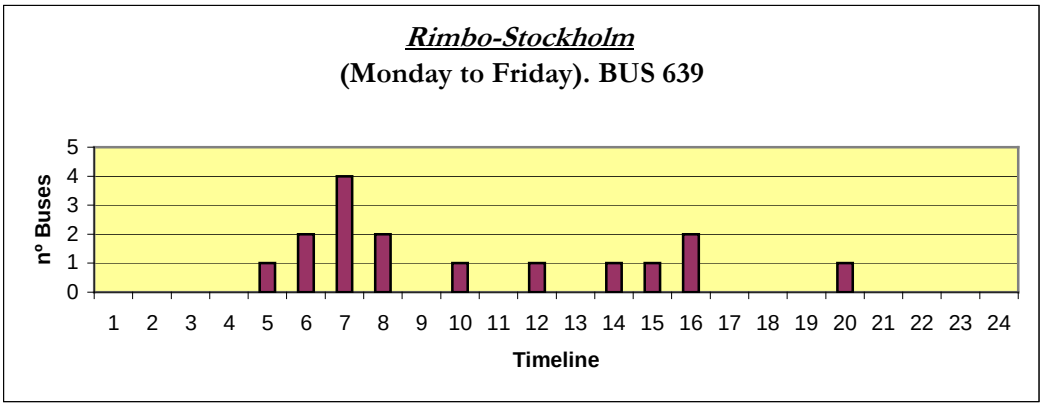
19 buses in total

Figure AI.4: Number of buses Stockholm- Rimbo from Monday to Friday, line 639.

Rimbo-Stockholm (Monday-Friday). BUS 639	
Timeline	**Frequency (minutes)**
01:00 - 02:00	-
02:00 - 03:00	-
03:00 - 04:00	-
04:00 - 05:00	-
05:00 - 06:00	**30**
06:00 - 07:00	**20**
07:00 - 08:00	**20**
08:00 - 09:00	45
09:00 - 10:00	80
10:00 - 11:00	115
11:00 - 12:00	115
12:00 - 13:00	115
13:00 - 14:00	115
14:00 - 15:00	60

15:00 - 16:00	60
16:00 - 17:00	**35**
17:00 - 18:00	210
18:00 - 19:00	210
19:00 - 20:00	210
20:00 - 21:00	-
21:00 - 22:00	-
22:00 - 23:00	-
23:00 - 24:00	-
24:00 - 01:00	-

Table AI.4: Frequency of buses Rimbo- Stockholm from Monday to Friday, line 639.



16 buses in total

Figure AI.5: Number of buses Rimbo- Stockholm from Monday to Friday, line 639.

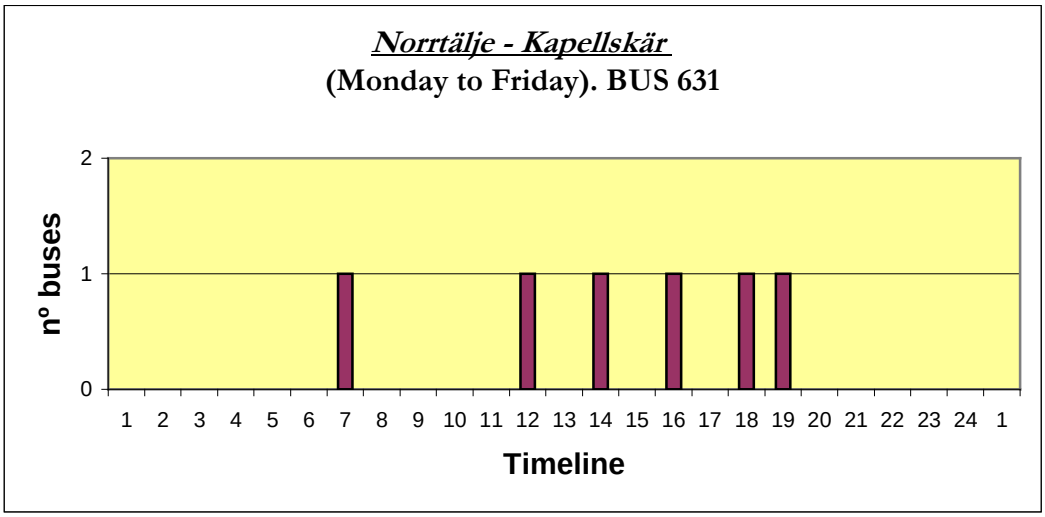
- **BUS LINE 631**

Number of seats in one bus: 59

Nörrtalje-Kapellskär (Monday-Friday). BUS 631	
Timeline	**Frequency (minutes)**
01:00 - 02:00	-
02:00 - 03:00	-
03:00 - 04:00	-
04:00 - 05:00	-
05:00 - 06:00	-
06:00 - 07:00	-
07:00 - 08:00	300
08:00 - 09:00	300
09:00 - 10:00	300
10:00 - 11:00	300
11:00 - 12:00	300
12:00 - 13:00	120
13:00 - 14:00	120
14:00 - 15:00	120
15:00 - 16:00	140

16:00 - 17:00	100
17:00 - 18:00	100
18:00 - 19:00	**80**
19:00 - 20:00	**80**
20:00 - 21:00	-
21:00 - 22:00	-
22:00 - 23:00	-
23:00 - 24:00	-
24:00 - 01:00	-

Table AI.5: Frequency of buses Norrtälje - Kapellskär from Monday to Friday, line 631.



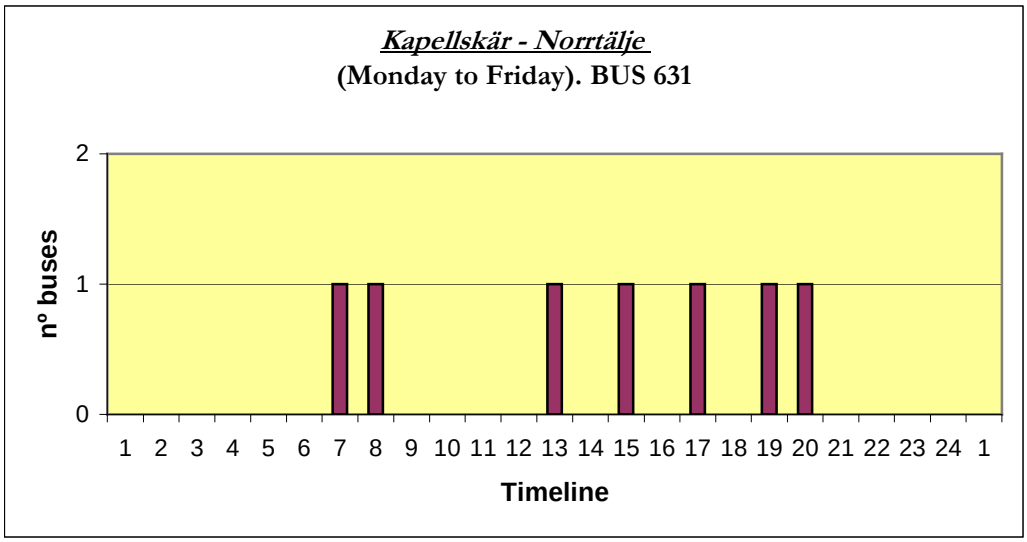
6 buses in total

Figure AI.6: Number of buses Norrtälje - Kapellskär from Monday to Friday, line 631.

Kapellskär-Nörrtalje (Monday-Friday). BUS 631	
Timeline	**Frequency (minutes)**
01:00 - 02:00	-
02:00 - 03:00	-
03:00 - 04:00	-
04:00 - 05:00	-
05:00 - 06:00	-
06:00 - 07:00	-
07:00 - 08:00	**60**
08:00 - 09:00	280
09:00 - 10:00	280
10:00 - 11:00	280
11:00 - 12:00	280
12:00 - 13:00	280
13:00 - 14:00	120
14:00 - 15:00	120
15:00 - 16:00	140
16:00 - 17:00	140
17:00 - 18:00	85
18:00 - 19:00	85

19:00 - 20:00	90
20:00 - 21:00	-
21:00 - 22:00	-
22:00 - 23:00	-
23:00 - 24:00	-
24:00 - 01:00	-

Table AI.6: Frequency of buses Kapellskär - Norrtälje from Monday to Friday, line 631.



7 buses in total

Figure AI.7: Number of buses Kapellskär - Norrtälje from Monday to Friday, line 631.

Connections of Rimbo and Norrtälje with other localities by bus services:

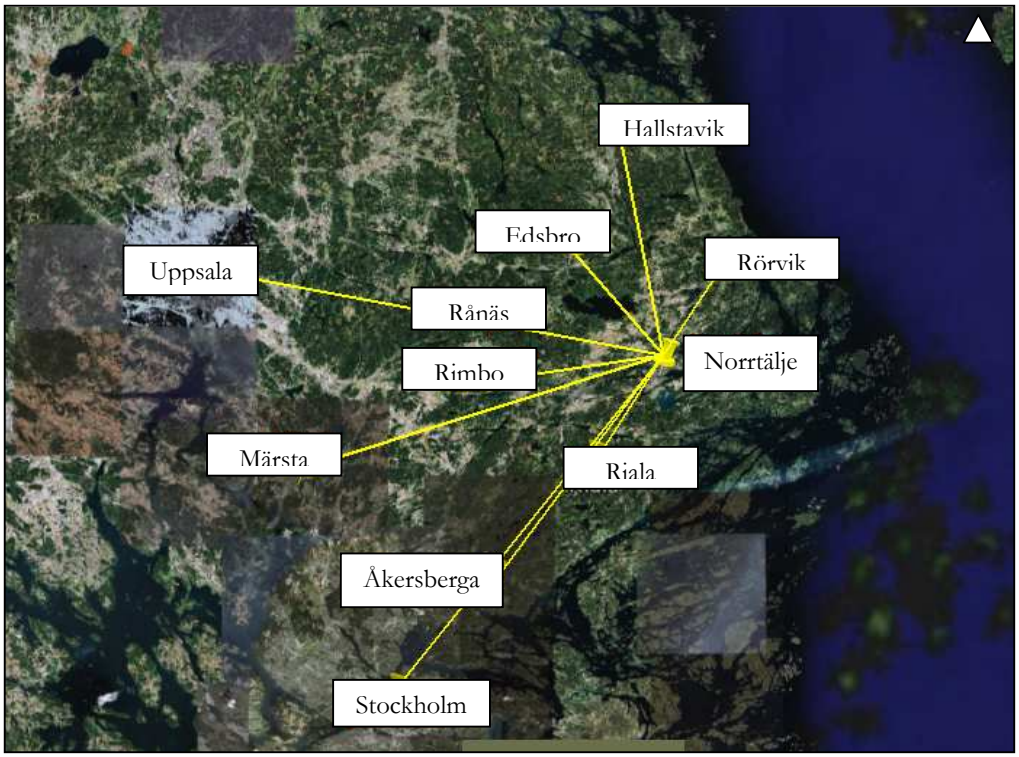


Figure AI.8: Connections of Norrtälje by bus services.

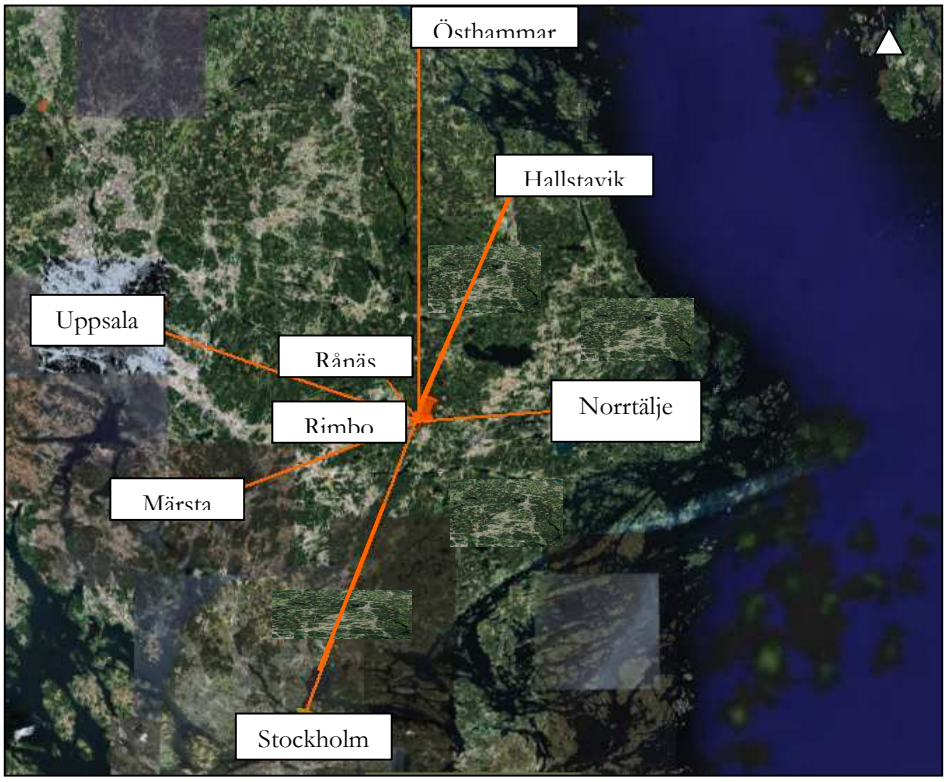


Figure AI.9: Connections of Rimbo by bus services.

APPENDIX II: Calculation of the Capacity in the existing bus lines.

- **BUS LINE 676**

Nörrtalje-Stockholm (Monday-Friday). BUS 676		
Timeline	**nº buses/hour**	**Capacity = seats*nº buses**
01:00 - 02:00	1	59
02:00 - 03:00	0	0
03:00 - 04:00	0	0
04:00 - 05:00	1	59
05:00 - 06:00	7	413
06:00 - 07:00	14	**826**
07:00 - 08:00	11	649
08:00 - 09:00	6	354
09:00 - 10:00	4	236
10:00 - 11:00	4	236
11:00 - 12:00	4	236
12:00 - 13:00	4	236
13:00 - 14:00	4	236
14:00 - 15:00	4	236
15:00 - 16:00	4	236
16:00 - 17:00	4	236
17:00 - 18:00	4	236
18:00 - 19:00	3	177
19:00 - 20:00	3	177
20:00 - 21:00	2	118
21:00 - 22:00	2	118
22:00 - 23:00	2	118
23:00 - 24:00	1	59
24:00 - 01:00	1	59
TOTAL:	**90**	**5,310**
		Total capacity/day

Table AII.1: Capacity of the line Norrtälje-Stockholm, from Monday-Friday, line 676.

$$Capacity/\ hour = nº\ seats * nº\ buses/hour \qquad \textit{(Equation AII.1)}$$

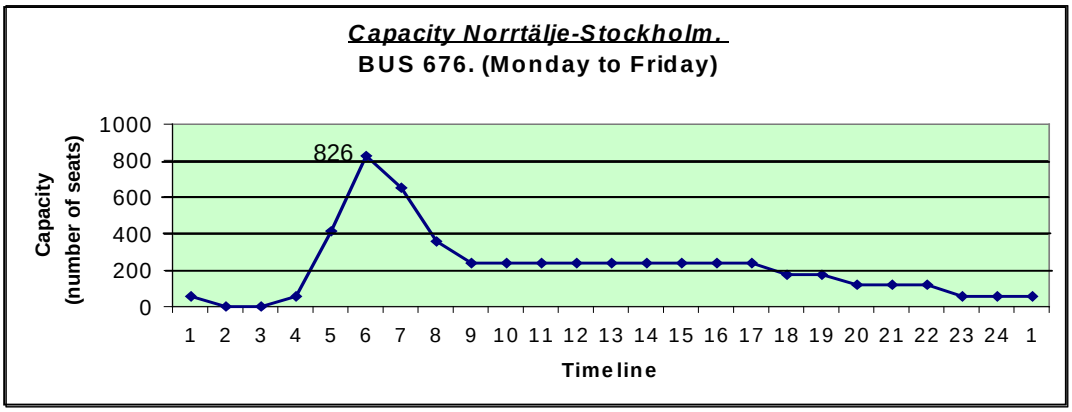


Figure AII.1: Capacity in bus line 676 Norrtälje - Stockholm.

Stockholm-Nörrtalje (Monday-Friday). BUS 676		
Timeline	**nº buses/hour**	**Capacity = seats*nº buses**
01:00 - 02:00	1	59
02:00 - 03:00	1	59
03:00 - 04:00	0	0
04:00 - 05:00	0	0
05:00 - 06:00	3	177
06:00 - 07:00	4	236
07:00 - 08:00	5	295
08:00 - 09:00	4	236
09:00 - 10:00	4	236
10:00 - 11:00	4	236
11:00 - 12:00	4	236
12:00 - 13:00	4	236
13:00 - 14:00	4	236
14:00 - 15:00	6	354
15:00 - 16:00	10	590
16:00 - 17:00	**12**	**708**
17:00 - 18:00	8	472
18:00 - 19:00	5	295
19:00 - 20:00	4	236
20:00 - 21:00	3	177
21:00 - 22:00	2	118
22:00 - 23:00	2	118
23:00 - 24:00	2	118
24:00 - 01:00	1	59
TOTAL:	**92**	**5,487** Total capacity/day

Table AII.2: Capacity of the line Stockholm- Norrtälje, from Monday-Friday, line 676.

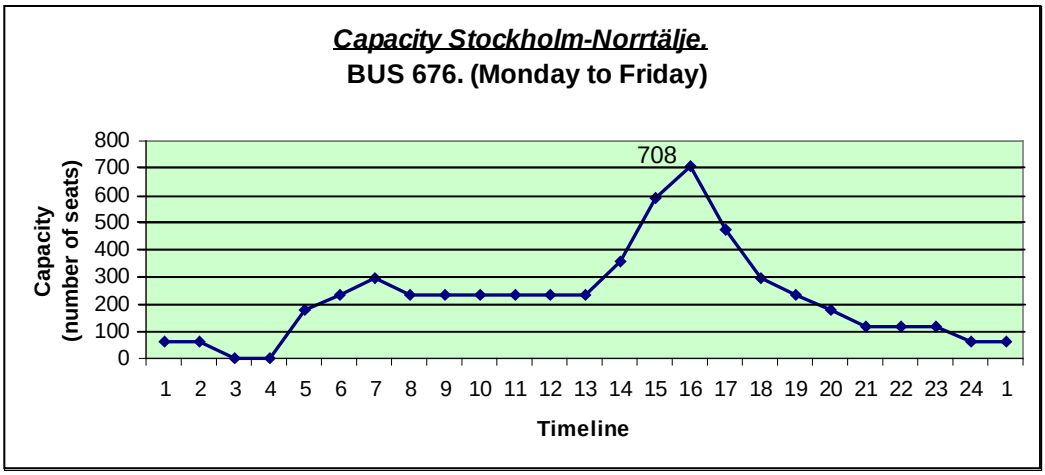


Figure AII.2: Capacity in bus line 676 Stockholm - Norrtälje.

- **BUS LINE 639**

Stockholm-Rimbo (Monday-Friday). BUS 639		
Timeline	**nº buses/hour**	**Capacity = seats*nº buses**
01:00 - 02:00	0	0
02:00 - 03:00	0	0
03:00 - 04:00	0	0
04:00 - 05:00	0	0
05:00 - 06:00	1	59
06:00 - 07:00	2	118
07:00 - 08:00	0	0
08:00 - 09:00	1	59
09:00 - 10:00	0	0
10:00 - 11:00	1	59
11:00 - 12:00	0	0
12:00 - 13:00	0	0
13:00 - 14:00	0	0
14:00 - 15:00	2	118
15:00 - 16:00	3	177
16:00 - 17:00	**4**	**236**
17:00 - 18:00	2	118
18:00 - 19:00	2	118
19:00 - 20:00	1	59
20:00 - 21:00	0	0
21:00 - 22:00	0	0
22:00 - 23:00	0	0
23:00 - 24:00	0	0
24:00 - 01:00	0	0
TOTAL:	**19**	**1,121**
		Total capacity/day

Table AII.3: Capacity of the line Stockholm- Rimbo, from Monday-Friday, line 639.

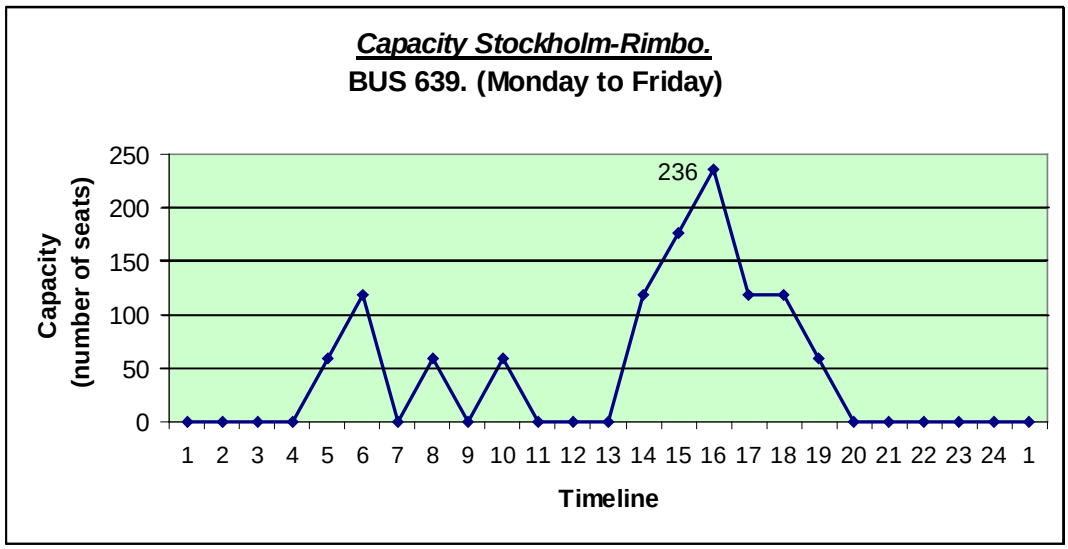


Figure AII.3: Capacity in bus line 676 Stockholm - Rimbo.

Rimbo-Stockholm (Monday-Friday). BUS 639		
Timeline	**nº buses/hour**	**Capacity = seats*nº buses**
01:00 - 02:00	0	0
02:00 - 03:00	0	0
03:00 - 04:00	0	0
04:00 - 05:00	0	0
05:00 - 06:00	1	59
06:00 - 07:00	2	118
07:00 - 08:00	**4**	**236**
08:00 - 09:00	2	118
09:00 - 10:00	0	0
10:00 - 11:00	1	59
11:00 - 12:00	0	0
12:00 - 13:00	1	59
13:00 - 14:00	0	0
14:00 - 15:00	1	59
15:00 - 16:00	1	59
16:00 - 17:00	2	118
17:00 - 18:00	0	0
18:00 - 19:00	0	0
19:00 - 20:00	0	0
20:00 - 21:00	1	59
21:00 - 22:00	0	0
22:00 - 23:00	0	0
23:00 - 24:00	0	0
24:00 - 01:00	0	0
TOTAL:	**16**	**944**
		Total capacity/day

Table AII.4: Capacity of the line Rimbo- Stockholm, from Monday-Friday, line 639.

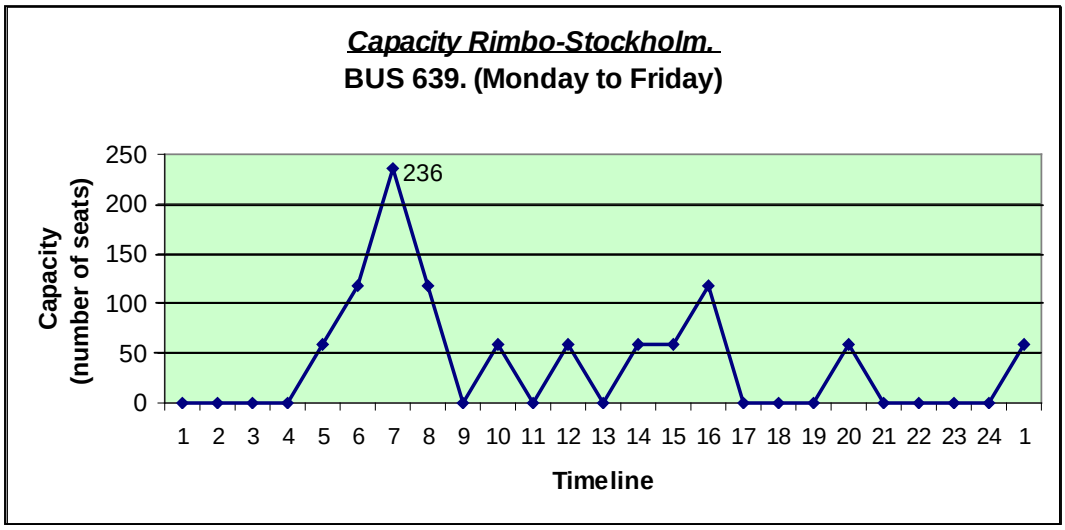


Figure AII.4: Capacity in bus line 639 Rimbo-Stockholm.

- **BUS LINE 631**

Nörrtalje-Kapellskär (Monday-Friday). BUS 631		
Timeline	**nº buses/hour**	**Capacity = seats*nº buses**
01:00 - 02:00	0	0
02:00 - 03:00	0	0
03:00 - 04:00	0	0
04:00 - 05:00	0	0
05:00 - 06:00	0	0
06:00 - 07:00	0	0
07:00 - 08:00	**1**	**59**
08:00 - 09:00	0	0
09:00 - 10:00	0	0
10:00 - 11:00	0	0
11:00 - 12:00	0	0
12:00 - 13:00	**1**	**59**
13:00 - 14:00	0	0
14:00 - 15:00	**1**	**59**
15:00 - 16:00	0	0
16:00 - 17:00	**1**	**59**
17:00 - 18:00	0	0
18:00 - 19:00	**1**	**59**
19:00 - 20:00	**1**	**59**
20:00 - 21:00	0	0
21:00 - 22:00	0	0
22:00 - 23:00	0	0
23:00 - 24:00	0	0
24:00 - 01:00	0	0
TOTAL:	**6**	**354**
		Total capacity/day

Table AII.5: Capacity of the line Norrtälje-Kapellskär, from Monday-Friday, line 631.

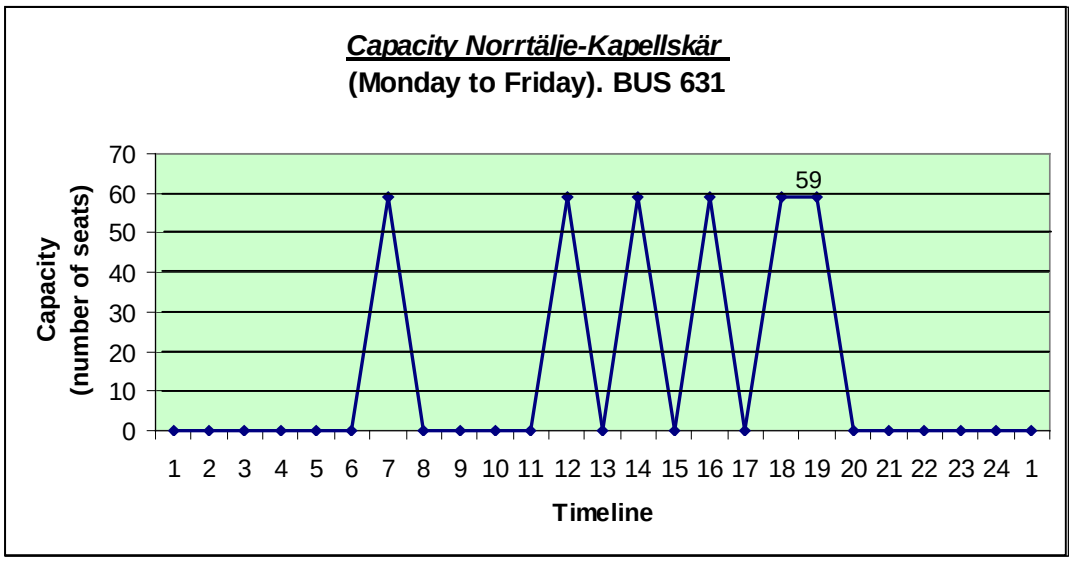


Figure AII.5: Capacity in bus line 631 Norrtälje – Kapellskär.

Kapellskär-Nörrtalje (Monday-Friday). BUS 631		
Timeline	**nº buses/hour**	**Capacity = seats*nº buses**
01:00 - 02:00	0	0
02:00 - 03:00	0	0
03:00 - 04:00	0	0
04:00 - 05:00	0	0
05:00 - 06:00	0	0
06:00 - 07:00	0	0
07:00 - 08:00	**1**	**59**
08:00 - 09:00	**1**	**59**
09:00 - 10:00	0	0
10:00 - 11:00	0	0
11:00 - 12:00	0	0
12:00 - 13:00	0	0
13:00 - 14:00	**1**	**59**
14:00 - 15:00	0	0
15:00 - 16:00	**1**	**59**
16:00 - 17:00	0	0
17:00 - 18:00	**1**	**59**
18:00 - 19:00	0	0
19:00 - 20:00	**1**	**59**
20:00 - 21:00	**1**	**59**
21:00 - 22:00	0	0
22:00 - 23:00	0	0
23:00 - 24:00	0	0
24:00 - 01:00	0	0
TOTAL:	**0**	**413**
		Total capacity/day

Table AII.6: Capacity of the line Kapellskär- Norrtälje, from Monday-Friday, line 631.

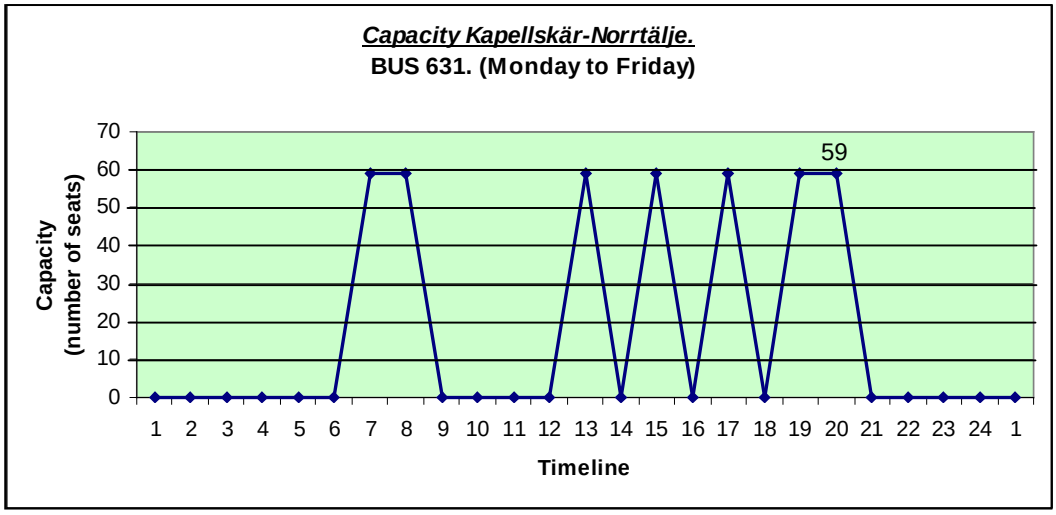


Figure AII.6: Capacity in bus line 631 Kapellskär - Norrtälje.

APPENDIX III: Trains' timetables (Results 1).

In this appendix all the resulting from the simulation timetables are shown, for each alternative and for each scenario:

Alternative 1 (Solna–Åkersberga-Norrtälje)	**Alternative 2a** (Stockholm-Märsta-Norrtälje)	**Alternative 2b** (Stockholm-Arlanda-Norrtälje)
100% capacity passenger trains	100% capacity passenger trains + 10% capacity freight trains	100% capacity passenger trains
200% capacity passenger trains	200% capacity passenger trains + 25% capacity freight trains	200% capacity passenger trains
	200% capacity passenger trains + 50% capacity freight trains	

Table AIII.1: New timetable scenarios simulated in RailSys®.

(In this printable version of the Project, only the new passenger trains for the chosen best alternative from a passenger traffic perspective are shown in Appendix III. The rest of the timetable´s results for all the simulated route alternatives and trains are shown in the full version of the Appendices available digitally on request).

The timetables have been obtained for weekdays (which are the most congested), and the times shown in the timetables are the departing times.

The symbol " | " in the timetables means that the train passes by the station where it is showed, without stopping at that station.

The symbol " x " in the timetables means that the train does stop in that station but the stopping time is just not shown. Just the stopping times in the most important stations are shown.

The new proposed passenger trains are shown in red colour.

- NEW TRAINS. **Alternative 2b: Stockholm – Arlanda airport – Norrtälje**. ***(100% capacity of passenger trains).***

Direction: Norrtälje to Stockholm.

ALTERNATIVE 2b: Stockholm – Arlanda airport – Norrtälje. *(100% capacity of passenger trains)* - Direction: Norrtälje to Stockholm – NEW TRAINS										
TRAIN:	**501;X50-3**	**503;X50-3**	**505;X50-3**	**507;X50-3**	**509;X50-3**	**511;X50-3**	**513;X50-3**	**515;X50-3**	**517;X50-3**	**1;X50-3**
From:										
Norrtälje	05:00:00	05:33:00	06:02:00	06:17:00	06:21:00	06:50:00	07:02:00	07:17:00	07:36:00	07:52:00
Rimbo	05:09:00	05:42:00	06:11:00	06:26:00	06:30:00	06:59:00	07:11:00	07:26:00	07:45:00	08:01:00
Arlanda central	05:23:00	05:56:00	06:25:00	06:40:00	06:44:00	07:13:00	07:25:00	07:40:00	07:59:00	|
Upplands Väsby	05:34:00	06:07:00	06:36:00	06:51:00	06:55:00	07:24:00	07:36:00	07:51:00	|	|
Rotebro	|	|	|	|	|	|	|	|	|	|
Norrviken	|	|	|	|	|	|	|	|	|	|
Häggvik	|	|	|	|	|	|	|	|	|	|
Sollentuna	|	|	|	|	|	|	|	|	|	|
Helenelund	|	|	|	|	|	|	|	|	|	|
Ulriksdal	|	|	|	|	|	|	|	|	|	|
Solna	|	|	|	|	|	|	|	|	|	|
Karlberg	|	|	|	|	|	|	|	|	|	|
Stockholms Central	5:50	6:23	6:52	7:07	7:11	7:40	7:52	8:07	8:23	8:42

Table AIII.1: ALTERNATIVE 2b: Stockholm – Arlanda – Norrtälje. (100% capacity of passenger trains). Direction: Norrtälje to Stockholm. New trains.

TRAIN:	**519;X50-3**	**521;X50-3**	**523;X50-3**	**525;X50-3**	**527;X50-3**	**529;X50-3**	**531;X50-3**	**533;X50-3**	**535;X50-3**	**537;X50-3**
From:										
Norrtälje	08:06:00	08:35:00	09:03:00	09:31:00	10:03:00	10:30:00	11:00:00	11:30:00	12:00:00	12:30:00
Rimbo	08:15:00	08:44:00	09:12:00	09:40:00	10:12:00	10:39:00	11:09:00	11:39:00	12:09:00	12:39:00
Arlanda central	08:29:00	08:58:00	09:26:00	09:54:00	10:26:00	10:53:00	11:23:00	11:53:00	12:23:00	12:53:00
Upplands Väsby	08:40:00	09:09:00	09:37:00	10:05:00	10:37:00	11:04:00	11:34:00	12:04:00	12:34:00	13:04:00
Rotebro	|	|	|	|	|	|	|	|	|	|
Norrviken	|	|	|	|	|	|	|	|	|	|
Häggvik	|	|	|	|	|	|	|	|	|	|
Sollentuna	|	|	|	|	|	|	|	|	|	|

Helenelund	|	|	|	|	|	|	|	|	|	|	|
Ulriksdal	|	|	|	|	|	|	|	|	|	|	|
Solna	|	|	|	|	|	|	|	|	|	|	|
Karlberg	|	|	|	|	|	|	|	|	|	|	|
Stockholms Central	8:57	9:26	9:53	10:21	10:53	11:20	11:50	12:20	12:50	13:20	

Table AIII.2: ALTERNATIVE 2b: Stockholm – Arlanda – Norrtälje. (100% capacity of passenger trains). Direction: Norrtälje to Stockholm. New trains.

TRAIN:	**539;X50-3**	**541;X50-3**	**543;X50-3**	**545;X50-3**	**547;X50-3**	**549;X50-3**	**551;X50-3**	**553;X50-3**	**555;X50-3**	**557;X50-3**
From:										
Norrtälje	13:00:00	13:30:00	14:00:00	14:29:00	15:00:00	15:29:00	16:00:00	16:29:00	17:00:00	17:30:00
Rimbo	13:09:00	13:39:00	14:09:00	14:38:00	15:09:00	15:38:00	16:09:00	16:38:00	17:09:00	17:39:00
Arlanda central	13:23:00	13:53:00	14:23:00	14:52:00	15:23:00	15:52:00	16:23:00	16:52:00	17:23:00	17:53:00
Upplands Väsby	13:34:00	14:04:00	14:34:00	15:03:00	15:34:00	16:03:00	16:34:00	17:03:00	17:34:00	18:04:00
Rotebro	|	|	|	|	|	|	|	|	|	|
Norrviken	|	|	|	|	|	|	|	|	|	|
Häggvik	|	|	|	|	|	|	|	|	|	|
Sollentuna	|	|	|	|	|	|	|	|	|	|
Helenelund	|	|	|	|	|	|	|	|	|	|
Ulriksdal	|	|	|	|	|	|	|	|	|	|
Solna	|	|	|	|	|	|	|	|	|	|
Karlberg	|	|	|	|	|	|	|	|	|	|
Stockholms Central	13:50	14:20	14:50	15:19	15:50	16:19	16:50	17:19	17:50	18:20

Table AIII.3: ALTERNATIVE 2b: Stockholm – Arlanda – Norrtälje. (100% capacity of passenger trains). Direction: Norrtälje to Stockholm. New trains.

TRAIN:	559;X50-3	561;X50-3	563;X50-3	565;X50-3	567;X50-3	569;X50-3	571;X50-3
From:							
Norrtälje	18:00:00	18:31:00	19:00:00	19:31:00	20:00:00	21:00:00	22:00:00
Rimbo	18:09:00	18:40:00	19:09:00	19:40:00	20:09:00	21:09:00	22:09:00
Arlanda central	18:23:00	18:54:00	19:23:00	19:54:00	20:23:00	21:23:00	22:23:00
Upplands Väsby	18:34:00	19:05:00	19:34:00	20:05:00	20:34:00	21:34:00	22:34:00
Rotebro	|	|	|	|	|	|	|
Norrviken	|	|	|	|	|	|	|
Häggvik	|	|	|	|	|	|	|
Sollentuna	|	|	|	|	|	|	|
Helenelund	|	|	|	|	|	|	|
Ulriksdal	|	|	|	|	|	|	|
Solna	|	|	|	|	|	|	|
Karlberg	|	|	|	|	|	|	|
Stockholms Central	18:50	19:21	19:50	20:21	20:50	21:50	22:50

Table AIII.4: ALTERNATIVE 2b: Stockholm – Arlanda – Norrtälje. (100% capacity of passenger trains). Direction: Norrtälje to Stockholm. New trains.

- NEW TRAINS. **<u>Alternative 2b:</u> Stockholm – Arlanda airport – Norrtälje**. ***(100% capacity of passenger trains).***
  Direction: Stockholm to Norrtälje.

<u>ALTERNATIVE 2b</u>: Stockholm – Arlanda airport – Norrtälje. *(100% capacity of passenger trains)* - Direction: Stockholm to Norrtälje – NEW TRAINS										
TRAIN:	**500;X50-3**	**502;X50-3**	**504;X50-3**	**506;X50-3**	**508;X50-3**	**510;X50-3**	**512;X50-3**	**514;X50-3**	**516;X50-3**	**518;X50-3**
From:										
Stockholm Central	05:04:00	05:35:00	06:03:00	06:33:00	07:02:00	07:18:00	07:48:00	08:03:00	08:33:00	09:18:00
Karlberg	|	|	|	|	|	|	|	|	|	|
Solna	|	|	|	|	|	|	|	|	|	|
Ulriksdal	|	|	|	|	|	|	|	|	|	|
Helenelund	|	|	|	|	|	|	|	|	|	|

Sollentuna	|	|	|	|	|	|	|	|	|	|	|
Häggvik	|	|	|	|	|	|	|	|	|	|	|
Norrviken	|	|	|	|	|	|	|	|	|	|	|
Rotebro	|	|	|	|	|	|	|	|	|	|	|
Upplands Väsby	5:22	5:53	6:21	6:51	|	7:36	8:06	8:21	8:53	9:36	
Arlanda central	5:34	6:05	6:33	7:03	07:31:00	7:48	8:18	8:33	9:03	09:48:00	
Rimbo	5:48	6:19	6:47	7:17	07:44:00	8:02	8:32	8:47	9:16	10:01:00	
Norrtälje	5:56	6:27	6:55	07:25:41	7:52	8:10	8:40	8:55	09:24:41	10:09	
To:											

Table AIII.5: ALTERNATIVE 2b: Stockholm – Arlanda – Norrtälje. (100% capacity of passenger trains). Direction: Stockholm to Norrtälje. New trains.

TRAIN:	**520;X50-3**	**522;X50-3**	**524;X50-3**	**526;X50-3**	**528;X50-3**	**530;X50-3**	**532;X50-3**	**534;X50-3**	**536;X50-3**	**538;X50-3**
From:										
Stockholm Central	09:33:00	10:03:00	10:33:00	11:00:00	11:30:00	12:00:00	12:30:00	13:00:00	13:20:00	13:40:00
Karlberg	|	|	|	|	|	|	|	|	|	|
Solna	|	|	|	|	|	|	|	|	|	|
Ulriksdal	|	|	|	|	|	|	|	|	|	|
Helenelund	|	|	|	|	|	|	|	|	|	|
Sollentuna	|	|	|	|	|	|	|	|	|	|
Häggvik	|	|	|	|	|	|	|	|	|	|
Norrviken	|	|	|	|	|	|	|	|	|	|
Rotebro	|	|	|	|	|	|	|	|	|	|
Upplands Väsby	9:51	10:21	10:51	11:18	11:48	12:18	12:48	13:18	13:38	13:58
Arlanda central	10:03:00	10:33	11:03	11:30	12:00	12:30	13:00	13:30	13:50	14:10
Rimbo	10:16:00	10:47	11:17	11:44	12:14	12:44	13:14	13:44	14:04	14:24
Norrtälje	10:24	10:55	11:25	11:52	12:22	12:52	13:22	13:52	14:12	14:32
To:										

Table AIII.6: ALTERNATIVE 2b: Stockholm – Arlanda – Norrtälje. (100% capacity of passenger trains). Direction: Stockholm to Norrtälje. New trains.

TRAIN:	540;X50-3	542;X50-3	544;X50-3	546;X50-3	548;X50-3	550;X50-3	552;X50-3	554;X50-3	556;X50-3	558;X50-3
From:										
Stockholm Central	14:00:00	14:20:00	14:40:00	15:00:00	15:20:00	15:40:00	16:00:00	16:15:00	16:30:00	16:45:00
Karlberg	|	|	|	|	|	|	|	|	|	|
Solna	|	|	|	|	|	|	|	|	|	|
Ulriksdal	|	|	|	|	|	|	|	|	|	|
Helenelund	|	|	|	|	|	|	|	|	|	|
Sollentuna	|	|	|	|	|	|	|	|	|	|
Häggvik	|	|	|	|	|	|	|	|	|	|
Norrviken	|	|	|	|	|	|	|	|	|	|
Rotebro	|	|	|	|	|	|	|	|	|	|
Upplands Väsby	14:18	14:38	14:58	15:18	15:38	15:58	16:18	16:33	16:48	17:03
Arlanda central	14:30	14:50	15:10	15:30	15:50	16:10	16:30	16:45	17:00	17:15
Rimbo	14:44	15:04	15:24	15:44	16:04	16:24	16:44	16:59	17:14	17:29
Norrtälje	14:52	15:12	15:32	15:52	16:12	16:32	16:52	17:07	17:22	17:37
To:										

Table AIII.7: ALTERNATIVE 2b: Stockholm – Arlanda – Norrtälje. (100% capacity of passenger trains). Direction: Stockholm to Norrtälje. New trains.

TRAIN:	560;X50-3	562;X50-3	2;X50-3	564;X50-3	566;X50-3	568;X50-3	570;X50-3	572;X50-3	574;X50-3	576;X50-3
From:										
Stockholm Central	17:00:00	17:15:00	17:31:00	17:33:00	17:55:00	18:15:00	18:35:00	18:55:00	19:25:00	19:55:00
Karlberg	|	|	|	|	|	|	|	|	|	|
Solna	|	|	|	|	|	|	|	|	|	|
Ulriksdal	|	|	|	|	|	|	|	|	|	|
Helenelund	|	|	|	|	|	|	|	|	|	|
Sollentuna	|	|	|	|	|	|	|	|	|	|
Häggvik	|	|	|	|	|	|	|	|	|	|
Norrviken	|	|	|	|	|	|	|	|	|	|
Rotebro	|	|	|	|	|	|	|	|	|	|
Upplands Väsby	17:18	17:33	|	17:51	18:13	18:33	18:53	19:13	19:43	20:13
Arlanda central	17:30	17:45	|	18:03	18:25	18:45	19:05	19:25	19:55	20:25

Rimbo	17:44	17:59	18:22:00	18:17	18:39	18:59	19:19	19:39	20:09	20:39
Norrtälje	17:52	18:07	18:31:00	18:25	18:47	19:07	19:27	19:47	20:17	20:47
To:										

Table AIII.8: ALTERNATIVE 2b: Stockholm – Arlanda – Norrtälje. (100% capacity of passenger trains). Direction: Stockholm to Norrtälje. New trains.

TRAIN:	**578;X50-3**	**580;X50-3**	**582;X50-3**
From:			
Stockholm Central	20:25:00	20:55:00	21:55:00
Karlberg	|	|	|
Solna	|	|	|
Ulriksdal	|	|	|
Helenelund	|	|	|
Sollentuna	|	|	|
Häggvik	|	|	|
Norrviken	|	|	|
Rotebro	|	|	|
Upplands Väsby	20:43	21:13	22:13
Arlanda central	20:55	21:25	22:25
Rimbo	21:09	21:39	22:39
Norrtälje	21:17	21:47	22:47
To:			

Table AIII.9: ALTERNATIVE 2b: Stockholm – Arlanda – Norrtälje. (100% capacity of passenger trains). Direction: Stockholm to Norrtälje. New trains.

- NEW TRAINS. **Alternative 2b: Stockholm – Arlanda airport – Norrtälje**. ***(200% capacity of passenger trains).***

Direction: Norrtälje to Stockholm.

ALTERNATIVE 2b: Stockholm – Arlanda airport – Norrtälje. *(200% capacity of passenger trains)* - Direction: Norrtälje to Stockholm – NEW TRAINS										
TRAIN:	**501;X50-3**	**503;X50-3**	**505;X50-3**	**507;X50-3**	**509;X50-3**	**511;X50-3**	**513;X50-3**	**515;X50-3**	**517;X50-3**	**1;X50-3**
From:										
Norrtälje	05:00:00	05:33:00	06:02:00	06:17:00	06:21:00	06:50:00	07:02:00	07:17:00	07:36:00	07:52:00
Rimbo	05:09:00	05:42:00	06:11:00	06:26:00	06:30:00	06:59:00	07:11:00	07:26:00	07:45:00	08:01:00
Arlanda central	05:23:00	05:56:00	06:25:00	06:40:00	06:44:00	07:13:00	07:25:00	07:40:00	07:59:00	|
Upplands Väsby	05:34:00	06:07:00	06:36:00	06:51:00	06:55:00	07:24:00	07:36:00	07:51:00	|	|
Rotebro	|	|	|	|	|	|	|	|	|	|
Norrviken	|	|	|	|	|	|	|	|	|	|
Häggvik	|	|	|	|	|	|	|	|	|	|
Sollentuna	|	|	|	|	|	|	|	|	|	|
Helenelund	|	|	|	|	|	|	|	|	|	|
Ulriksdal	|	|	|	|	|	|	|	|	|	|
Solna	|	|	|	|	|	|	|	|	|	|
Karlberg	|	|	|	|	|	|	|	|	|	|
Stockholms Central	5:50	6:23	6:52	7:07	7:11	7:40	7:52	8:07	8:23	8:42

Table AIII.10: ALTERNATIVE 2b: Stockholm – Arlanda – Norrtälje. (200% capacity of passenger trains). Direction: Norrtälje to Stockholm. New trains.

TRAIN:	**519;X50-3**	**521;X50-3**	**523;X50-3**	**525;X50-3**	**527;X50-3**	**529;X50-3**	**531;X50-3**	**533;X50-3**	**535;X50-3**	**537;X50-3**
From:										
Norrtälje	08:06:00	08:35:00	09:03:00	09:31:00	10:03:00	10:30:00	11:00:00	11:30:00	12:00:00	12:30:00
Rimbo	08:15:00	08:44:00	09:12:00	09:40:00	10:12:00	10:39:00	11:09:00	11:39:00	12:09:00	12:39:00
Arlanda central	08:29:00	08:58:00	09:26:00	09:54:00	10:26:00	10:53:00	11:23:00	11:53:00	12:23:00	12:53:00
Upplands Väsby	08:40:00	09:09:00	09:37:00	10:05:00	10:37:00	11:04:00	11:34:00	12:04:00	12:34:00	13:04:00
Rotebro	|	|	|	|	|	|	|	|	|	|
Norrviken	|	|	|	|	|	|	|	|	|	|
Häggvik	|	|	|	|	|	|	|	|	|	|
Sollentuna	|	|	|	|	|	|	|	|	|	|

Helenelund	|	|	|	|	|	|	|	|	|	|	|
Ulriksdal	|	|	|	|	|	|	|	|	|	|	|
Solna	|	|	|	|	|	|	|	|	|	|	|
Karlberg	|	|	|	|	|	|	|	|	|	|	|
Stockholms Central	8:57	9:26	9:53	10:21	10:53	11:20	11:50	12:20	12:50	13:20	

Table AIII.11: ALTERNATIVE 2b: Stockholm – Arlanda – Norrtälje. (200% capacity of passenger trains). Direction: Norrtälje to Stockholm. New trains.

TRAIN:	**539;X50-3**	**541;X50-3**	**543;X50-3**	**545;X50-3**	**547;X50-3**	**549;X50-3**	**551;X50-3**	**553;X50-3**	**555;X50-3**	**557;X50-3**
From:										
Norrtälje	13:00:00	13:30:00	14:00:00	14:29:00	15:00:00	15:29:00	16:00:00	16:29:00	17:00:00	17:30:00
Rimbo	13:09:00	13:39:00	14:09:00	14:38:00	15:09:00	15:38:00	16:09:00	16:38:00	17:09:00	17:39:00
Arlanda central	13:23:00	13:53:00	14:23:00	14:52:00	15:23:00	15:52:00	16:23:00	16:52:00	17:23:00	17:53:00
Upplands Väsby	13:34:00	14:04:00	14:34:00	15:03:00	15:34:00	16:03:00	16:34:00	17:03:00	17:34:00	18:04:00
Rotebro	|	|	|	|	|	|	|	|	|	|
Norrviken	|	|	|	|	|	|	|	|	|	|
Häggvik	|	|	|	|	|	|	|	|	|	|
Sollentuna	|	|	|	|	|	|	|	|	|	|
Helenelund	|	|	|	|	|	|	|	|	|	|
Ulriksdal	|	|	|	|	|	|	|	|	|	|
Solna	|	|	|	|	|	|	|	|	|	|
Karlberg	|	|	|	|	|	|	|	|	|	|
Stockholms Central	13:50	14:20	14:50	15:19	15:50	16:19	16:50	17:19	17:50	18:20

Table AIII.12: ALTERNATIVE 2b: Stockholm – Arlanda – Norrtälje. (200% capacity of passenger trains). Direction: Norrtälje to Stockholm. New trains.

TRAIN:	559;X50-3	561;X50-3	563;X50-3	565;X50-3	567;X50-3	569;X50-3	571;X50-3
From:							
Norrtälje	18:00:00	18:31:00	19:00:00	19:31:00	20:00:00	21:00:00	22:00:00
Rimbo	18:09:00	18:40:00	19:09:00	19:40:00	20:09:00	21:09:00	22:09:00
Arlanda central	18:23:00	18:54:00	19:23:00	19:54:00	20:23:00	21:23:00	22:23:00
Upplands Väsby	18:34:00	19:05:00	19:34:00	20:05:00	20:34:00	21:34:00	22:34:00
Rotebro	|	|	|	|	|	|	|
Norrviken	|	|	|	|	|	|	|
Häggvik	|	|	|	|	|	|	|
Sollentuna	|	|	|	|	|	|	|
Helenelund	|	|	|	|	|	|	|
Ulriksdal	|	|	|	|	|	|	|
Solna	|	|	|	|	|	|	|
Karlberg	|	|	|	|	|	|	|
Stockholms Central	18:50	19:21	19:50	20:21	20:50	21:50	22:50

Table AIII.13: ALTERNATIVE 2b: Stockholm – Arlanda – Norrtälje. (200% capacity of passenger trains). Direction: Norrtälje to Stockholm. New trains.

- NEW TRAINS. **<u>Alternative 2b:</u> Stockholm – Arlanda airport – Norrtälje**. ***(200% capacity of passenger trains).***
  Direction: Stockholm to Norrtälje.

<u>ALTERNATIVE 2b</u>: Stockholm – Arlanda airport – Norrtälje. *(200% capacity of passenger trains)* - Direction: Stockholm to Norrtälje – NEW TRAINS										
TRAIN:	**500;X50-3**	**502;X50-3**	**504;X50-3**	**506;X50-3**	**508;X50-3**	**510;X50-3**	**512;X50-3**	**514;X50-3**	**516;X50-3**	**518;X50-3**
From:										
Stockholm Central	05:04:00	05:35:00	06:03:00	06:33:00	07:02:00	07:18:00	07:48:00	08:03:00	08:33:00	09:18:00
Karlberg	|	|	|	|	|	|	|	|	|	|
Solna	|	|	|	|	|	|	|	|	|	|
Ulriksdal	|	|	|	|	|	|	|	|	|	|
Helenelund	|	|	|	|	|	|	|	|	|	|

Sollentuna	|	|	|	|	|	|	|	|	|	|
Häggvik	|	|	|	|	|	|	|	|	|	|
Norrviken	|	|	|	|	|	|	|	|	|	|
Rotebro	|	|	|	|	|	|	|	|	|	|
Upplands Väsby	5:22	5:53	6:21	6:51	|	7:36	8:06	8:21	8:53	9:36
Arlanda central	5:34	6:05	6:33	7:03	07:31:00	7:48	8:18	8:33	9:03	09:48:00
Rimbo	5:48	6:19	6:47	7:17	07:44:00	8:02	8:32	8:47	9:16	10:01:00
Norrtälje	5:56	6:27	6:55	07:25:41	7:52	8:10	8:40	8:55	09:24:41	10:09
To:										

Table AIII.14: ALTERNATIVE 2b: Stockholm – Arlanda – Norrtälje. (200% capacity of passenger trains). Direction: Stockholm Norrtälje. New trains.

TRAIN:	**520;X50-3**	**522;X50-3**	**524;X50-3**	**526;X50-3**	**528;X50-3**	**530;X50-3**	**532;X50-3**	**534;X50-3**	**536;X50-3**	**538;X50-3**
From:										
Stockholm Central	09:33:00	10:03:00	10:33:00	11:00:00	11:30:00	12:00:00	12:30:00	13:00:00	13:20:00	13:40:00
Karlberg	|	|	|	|	|	|	|	|	|	|
Solna	|	|	|	|	|	|	|	|	|	|
Ulriksdal	|	|	|	|	|	|	|	|	|	|
Helenelund	|	|	|	|	|	|	|	|	|	|
Sollentuna	|	|	|	|	|	|	|	|	|	|
Häggvik	|	|	|	|	|	|	|	|	|	|
Norrviken	|	|	|	|	|	|	|	|	|	|
Rotebro	|	|	|	|	|	|	|	|	|	|
Upplands Väsby	9:51	10:21	10:51	11:18	11:48	12:18	12:48	13:18	13:38	13:58
Arlanda central	10:03:00	10:33	11:03	11:30	12:00	12:30	13:00	13:30	13:50	14:10
Rimbo	10:16:00	10:47	11:17	11:44	12:14	12:44	13:14	13:44	14:04	14:24
Norrtälje	10:24	10:55	11:25	11:52	12:22	12:52	13:22	13:52	14:12	14:32
To:										

Table AIII.15: ALTERNATIVE 2b: Stockholm – Arlanda – Norrtälje. (200% capacity of passenger trains). Direction: Stockholm Norrtälje. New trains.

TRAIN:	540;X50-3	542;X50-3	544;X50-3	546;X50-3	548;X50-3	550;X50-3	552;X50-3	554;X50-3	556;X50-3	558;X50-3
From:										
Stockholm Central	14:00:00	14:20:00	14:40:00	15:00:00	15:20:00	15:40:00	16:00:00	16:15:00	16:30:00	16:45:00
Karlberg	|	|	|	|	|	|	|	|	|	|
Solna	|	|	|	|	|	|	|	|	|	|
Ulriksdal	|	|	|	|	|	|	|	|	|	|
Helenelund	|	|	|	|	|	|	|	|	|	|
Sollentuna	|	|	|	|	|	|	|	|	|	|
Häggvik	|	|	|	|	|	|	|	|	|	|
Norrviken	|	|	|	|	|	|	|	|	|	|
Rotebro	|	|	|	|	|	|	|	|	|	|
Upplands Väsby	14:18	14:38	14:58	15:18	15:38	15:58	16:18	16:33	16:48	17:03
Arlanda central	14:30	14:50	15:10	15:30	15:50	16:10	16:30	16:45	17:00	17:15
Rimbo	14:44	15:04	15:24	15:44	16:04	16:24	16:44	16:59	17:14	17:29
Norrtälje	14:52	15:12	15:32	15:52	16:12	16:32	16:52	17:07	17:22	17:37
To:										

Table AIII.16: ALTERNATIVE 2b: Stockholm – Arlanda – Norrtälje. (200% capacity of passenger trains). Direction: Stockholm Norrtälje. New trains.

TRAIN:	560;X50-3	562;X50-3	2;X50-3	564;X50-3	566;X50-3	568;X50-3	570;X50-3	572;X50-3	574;X50-3	576;X50-3
From:										
Stockholm Central	17:00:00	17:15:00	17:31:00	17:33:00	17:55:00	18:15:00	18:35:00	18:55:00	19:25:00	19:55:00
Karlberg	|	|	|	|	|	|	|	|	|	|
Solna	|	|	|	|	|	|	|	|	|	|
Ulriksdal	|	|	|	|	|	|	|	|	|	|
Helenelund	|	|	|	|	|	|	|	|	|	|
Sollentuna	|	|	|	|	|	|	|	|	|	|
Häggvik	|	|	|	|	|	|	|	|	|	|
Norrviken	|	|	|	|	|	|	|	|	|	|
Rotebro	|	|	|	|	|	|	|	|	|	|
Upplands Väsby	17:18	17:33	|	17:51	18:13	18:33	18:53	19:13	19:43	20:13
Arlanda central	17:30	17:45	|	18:03	18:25	18:45	19:05	19:25	19:55	20:25

Rimbo	17:44	17:59	18:22:00	18:17	18:39	18:59	19:19	19:39	20:09	20:39
Norrtälje	17:52	18:07	18:31:00	18:25	18:47	19:07	19:27	19:47	20:17	20:47
To:										

Table AIII.17: ALTERNATIVE 2b: Stockholm – Arlanda – Norrtälje. (200% capacity of passenger trains). Direction: Stockholm Norrtälje. New trains.

TRAIN:	**578;X50-3**	**580;X50-3**	**582;X50-3**
From:			
Stockholm Central	20:25:00	20:55:00	21:55:00
Karlberg	|	|	|
Solna	|	|	|
Ulriksdal	|	|	|
Helenelund	|	|	|
Sollentuna	|	|	|
Häggvik	|	|	|
Norrviken	|	|	|
Rotebro	|	|	|
Upplands Väsby	20:43	21:13	22:13
Arlanda central	20:55	21:25	22:25
Rimbo	21:09	21:39	22:39
Norrtälje	21:17	21:47	22:47
To:			

Table AIII.18: ALTERNATIVE 2b: Stockholm – Arlanda – Norrtälje. (200% capacity of passenger trains). Direction: Stockholm Norrtälje. New trains.

APPENDIX IV: Graphic timetables (Results 2).

In this appendix, the resultant graphic timetables from the simulation are shown. They represent the graphics of the trains' timetables shown in *Appendix III*.

Eeach line in the graphics represents a train. The slope of the lines represents the speed of the trains: the steep it is, the faster the train goes from its origin to its destination.

Table of colours:

- Green colour trains: new additional skip-stop trains during the peak hour.
- Red colour trains: new proposed passenger trains.
- Orange colour trains: all trains that already exist in the railway line Stockholm-Uppsala (including passenger trains and freight trains). All existing trains.
- Purple colour trains: new commuter trains.
- Blue colour trains: new freight trains.

(In this printable version of the Project, only the graphic timetables of all the trains for the chosen best alternative from a passenger traffic perspective are shown. The rest of the timetable´s results for all the simulated route alternatives and trains are shown in the full version of the Appendices available digitally on request).

- ALL TRAINS. **<u>Alternative 2b:</u> Stockholm – Arlanda – Norrtälje**. (100% capacity of passenger trains). Interval of time: from 06:00-09:00 h (peak hour).

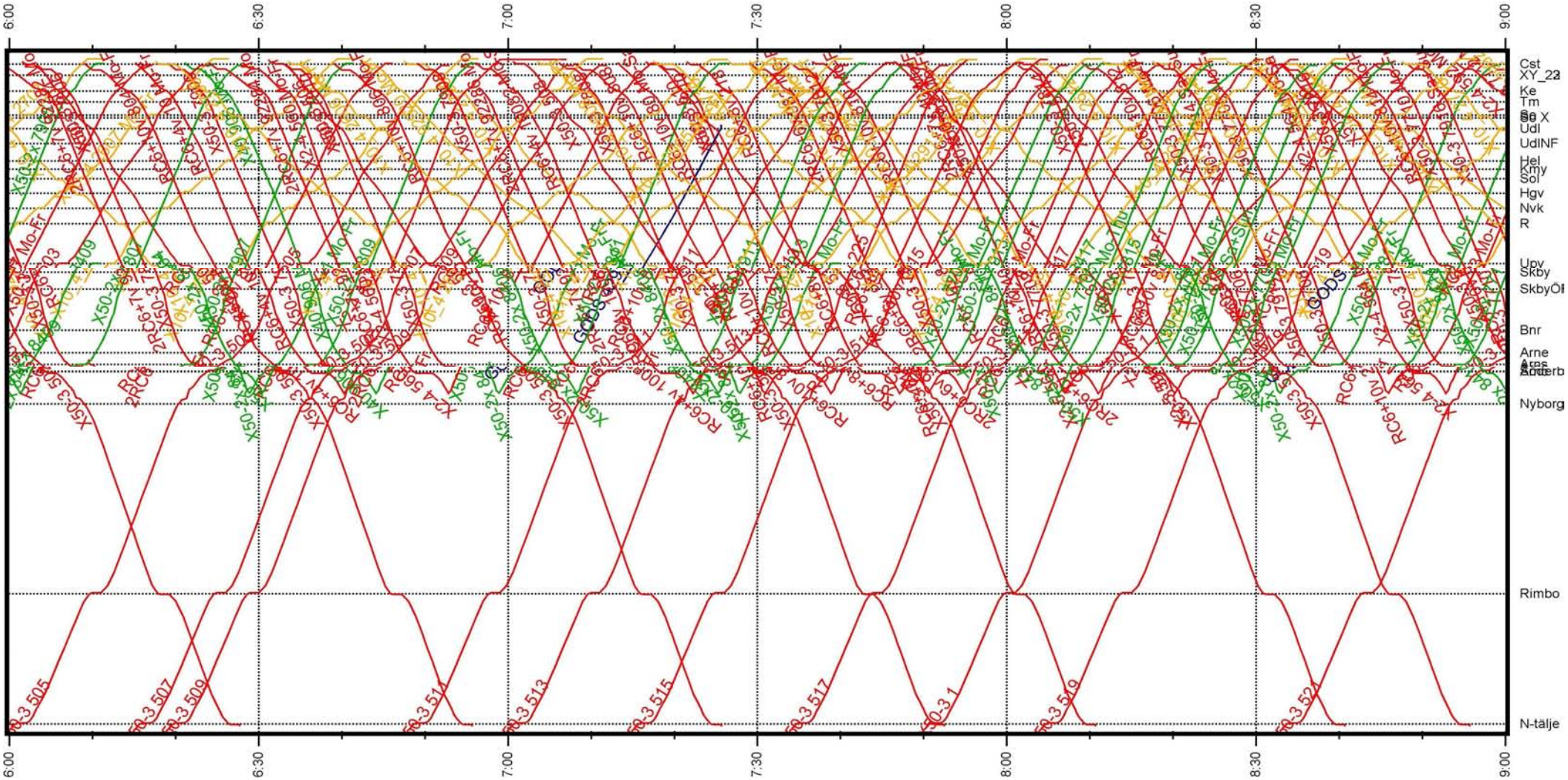


*Figure AIV.1: ALTERNATIVE 2b: **Stockholm – Arlanda – Norrtälje**. (100% capacity of passenger trains). Interval of time: from 06:00-09:00 h (peak hour). All trains.*

New additional skip-stop trains during the peak hours.	New passenger trains: Roslags-express trains.	Existing trains Stockholm-Uppsala (passenger+freight)	New commuter trains.	New freight trains: Kapellskär Cargo trains.

- ALL TRAINS. **<u>Alternative 2b:</u> Stockholm – Arlanda – Norrtälje**. (100% capacity of passenger trains). Interval of time: from 05:00-23:00 h.

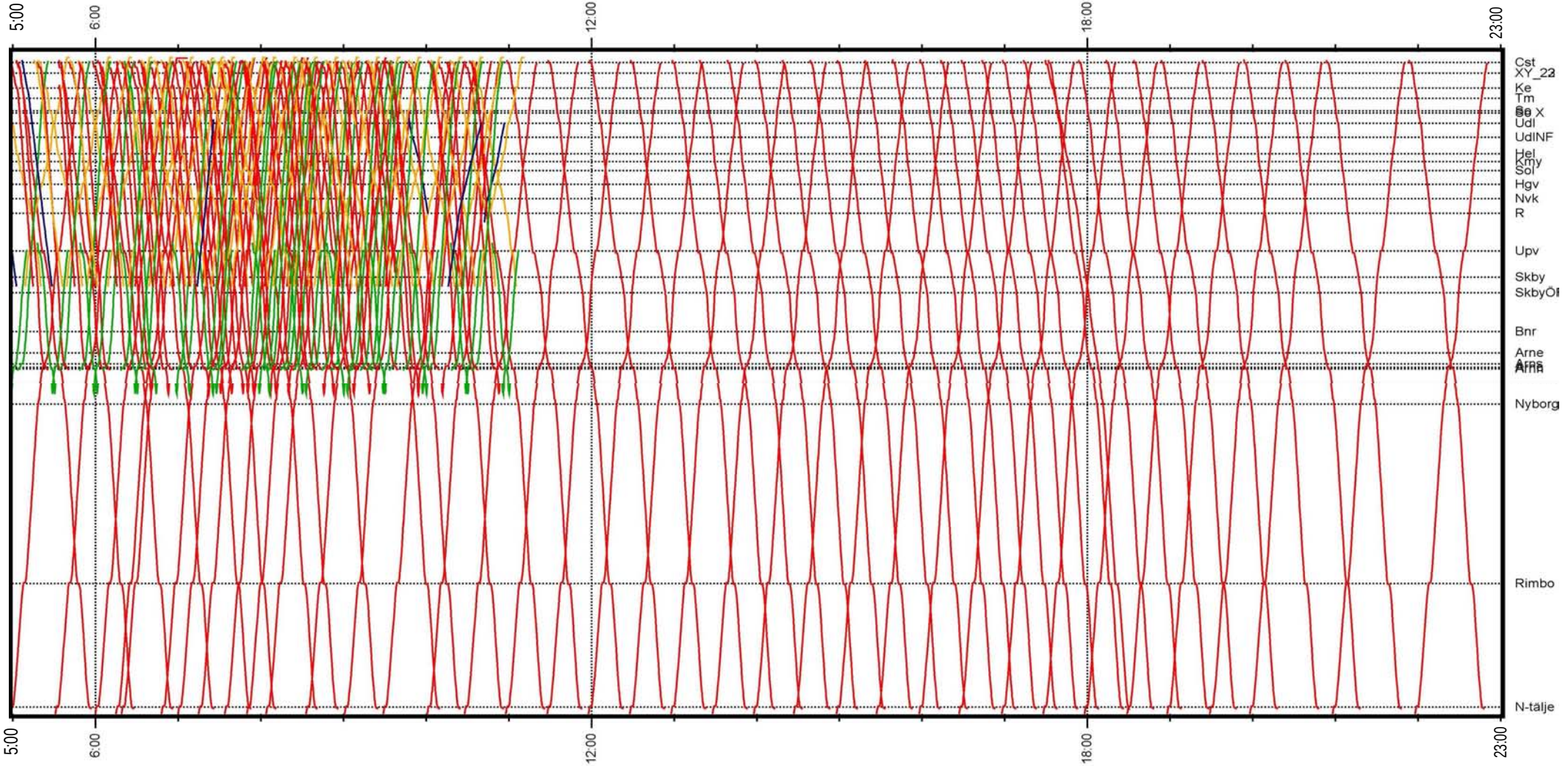


*Figure AIV.2: ALTERNATIVE 2b: **Stockholm – Arlanda – Norrtälje**. (100% capacity of passenger trains). Interval of time: from 05:00-23:00 h . All trains*

New additional skip-stop trains during the peak hours.	New passenger trains: Roslags-express trains.	Existing trains Stockholm-Uppsala (passenger+freight)	New commuter trains.	New freight trains: Kapellskär Cargo trains.

- ALL TRAINS. **<u>Alternative 2b:</u> Stockholm – Arlanda – Norrtälje**. (200% capacity of passenger trains). Interval of time: from 06:00-09:00 h (peak hour).

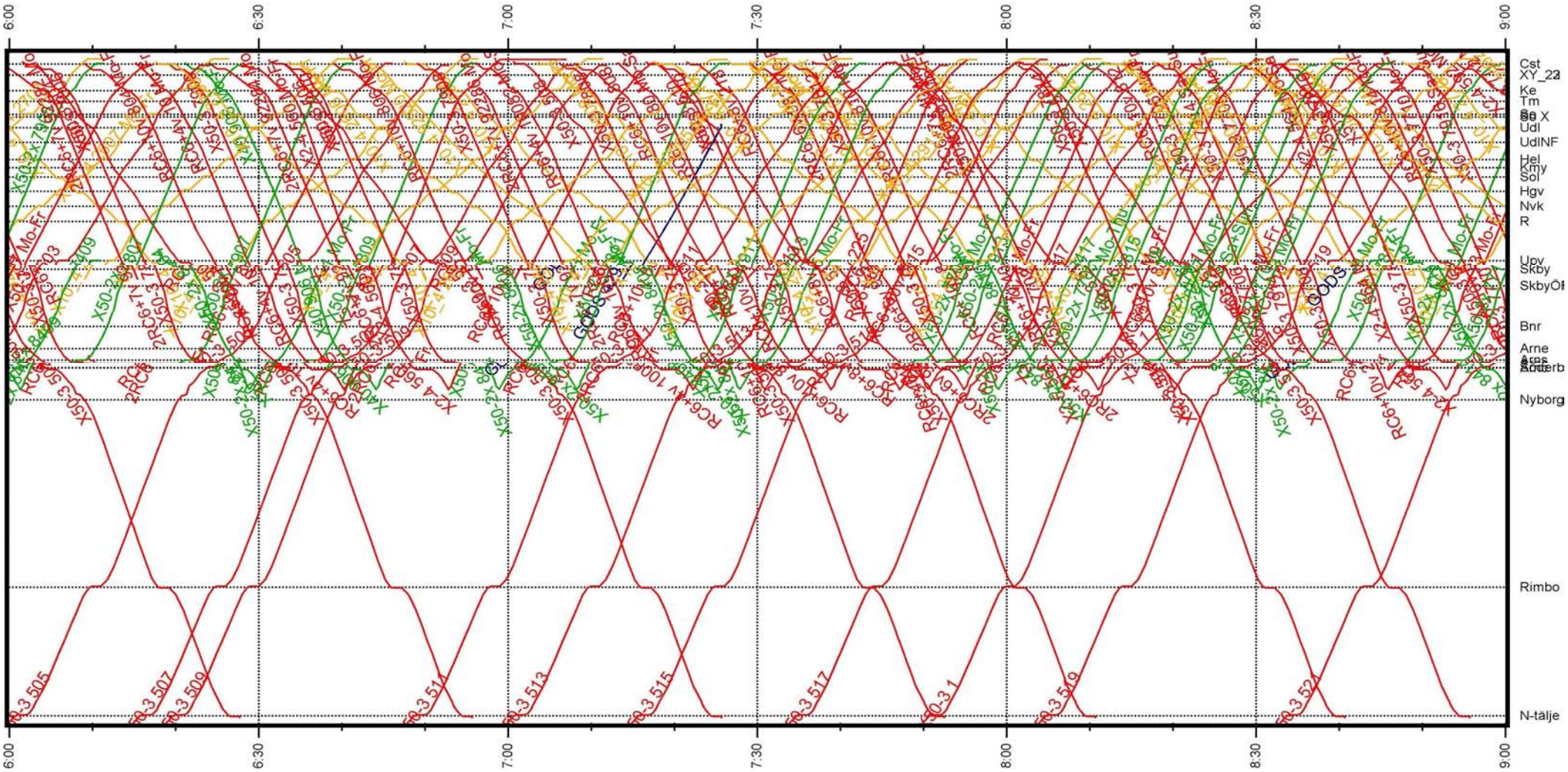


*Figure AIV.3: ALTERNATIVE 2b: **Stockholm – Arlanda – Norrtälje**. (200% capacity of passenger trains). Interval of time: from 06:00-09:00 h (peak hour). All trains.*

New additional skip-stop trains during the peak hours.	New passenger trains: Roslags-express trains.	Existing trains Stockholm-Uppsala (passenger+freight)	New commuter trains.	New freight trains: Kapellskär Cargo trains.

- ALL TRAINS. **<u>Alternative 2b:</u> Stockholm – Arlanda – Norrtälje**. (200% capacity of passenger trains). Interval of time: from 05:00-23:00 h.

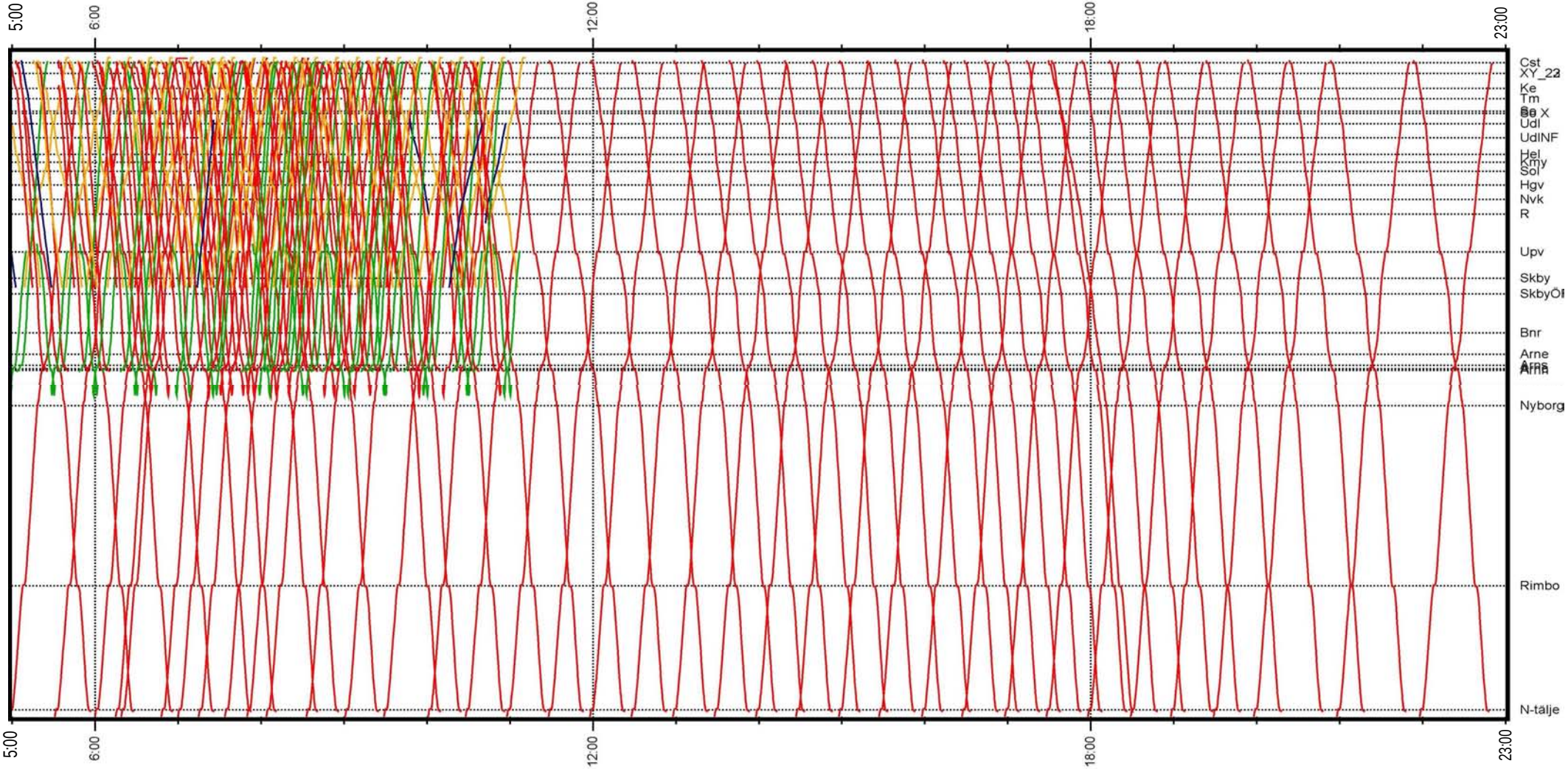


*Figure AIV.4: ALTERNATIVE 2b: **Stockholm – Arlanda – Norrtälje**. (200% capacity of passenger trains). Interval of time: from 05:00-23:00 h . All trains*

New additional skip-stop trains during the peak hours. | New passenger trains: Roslags-express trains. | Existing trains Stockholm-Uppsala (passenger+freight) | New commuter trains. | New freight trains: Kapellskär Cargo trains.

TEC-MT 08-005

LAURA MORENO DEL CAMPO

Evaluation of route alternatives for a new railway line to Norrtälje/Kapellskär from a passenger traffic perspective

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