Evaluation of Route Alternatives for a New Railway By-Pass through the West of Stockholm from an Accessibility Perspective

RAFAEL IBÁÑEZ USACH

KTH Architecture and the Built Environment

Degree Project in Railway Operation
Stockholm, Sweden 2011

TSC-MT 11-013

Evaluation of Route Alternatives for a New Railway By-Pass through the West of Stockholm from an Accessibility Perspective.

Master Thesis

June 2011

Rafael Ibáñez Usach

Division of Transportation and Logistics

KTH Railway Group

Content

Foreword

This report is the result of my thesis work as part of my career for becoming a Civil Engineer. This work has been carried out from January to May 2011 at the Railway Group (Division of Transportation and Logistics) of the Royal Institute of Technology in Stockholm.

I would like to express my sincere gratitude to my supervisors, Anders Lindahl and Bo-Lennart Nelldal for his patience and guidance, as well as my Erasmus friends who have supported me through my stay in Sweden.

But, above all, I thank my parents, my sister and my grandparents for their continued support. Although they do not know it, they are also authors of this report.

Stockholm, June 2011

Rafael Ibáñez Usach

Summary

Railway traffic has undergone important developments during the last years. From local and commuter services to high-speed long-distance routes, through regional services, and forecasts now announce a large increase in traffic demand in the future.

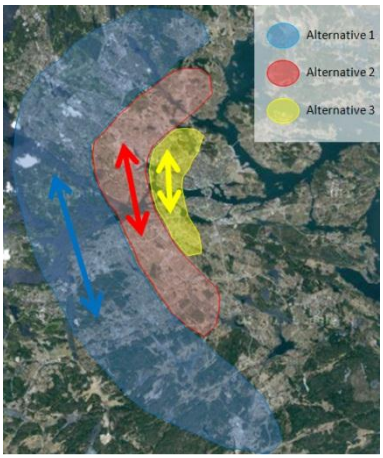
Stockholm has a railway system organized around a big node: Stockholm Central. This station works with all kinds of trains from commuter trains to X2000. However, it has capacity problems due to both the heterogeneity of the traffic, and the large flows of traffic. Despite the fact that new infrastructure is being built in order to separate commuter traffic (City Line), forecasts announce that Stockholm is going to need new railway infrastructure in the future in order to properly cover the demand.

Moreover, Stockholm is undergoing a demographic process which results in the migration of people towards the periphery. In addition, a large part of the workplaces are situated in the suburbs and therefore a lot of trips are being undertaken every day between the suburbs. For most of these trips there is no need to cross the centre of the city, and thus the routes can be potentially subject to change.

Since a lot of people live in the western suburbs, and a lot of workplaces are located in these areas, one possibility would be to build a new railway by-pass through the western parts of Stockholm. Such procedure would enable:

- Diversion of parts of the traffic from Stockholm Central / Stockholm City node.
- Increase in the accessibility between the northern and southern suburbs by reducing travel times.

In this thesis several by-pass alternatives will be assessed from different kinds of railway service perspectives in order to evaluate which of them properly match the objectives above. Thus, an individualized analysis will be made for local/commuter traffic, regional traffic, long-distance-traffic and freight traffic.



Three alternatives have been defined. Their nature and territorial scope is quite different in order to obtain broad-spectrum results. Therefore, Alternative 1 runs through the peripheral suburbs (10-15 km. to the centre), the route of Alternative 2 is located 5-10 km to the centre and Alternative 3 runs through the centre of Stockholm.

The methodology used is different for each kind of service but all of them focus on accessibility and travel times issues.

In order to evaluate effects on local/commuter traffic, a model has been implemented using data with reference to 2030. Moreover, several accessibility indicators have been utilized in order to process the data that has been obtained from the model.

Regional and long-distance-traffic have been assessed by defining new station configuration models. It would allow for a diversion of traffic from Stockholm C. The accessibility from these new stations to Stockholm municipality has been evaluated. In addition, travels between main lines (i.e. the East Coast Line, Mälarbanan and the South/West Main Line) have been studied in order to quantify the changes in travel times.

Finally, the possibility of diverting freight traffic from Stockholm C to the by-pass alternatives will be analyzed.

The studies carried out are focused on accessibility issues, and thus the conclusions of this thesis are partial since a lot of important factors have not been evaluated.

However, the analyses show that by-pass alternatives would make it possible to divert traffic from Stockholm C without deteriorating accessibility and travel times parameters. In addition, Alternatives 1 and 2 are rather beneficial from the perspective of local/commuter and regional accessibility.

	Local/Commuter Traffic	Regional Traffic	Long-Distance traffic	Freight Traffic
Alternative 0				
Alternative 1				
Alternative 2				
Alternative 3				

Negative
Positive aspects
Very Positive

All things taken into consideration, some operation configurations have been proposed in the conclusion chapter.

1 Introduction

In this first chapter a description of this project is made by defining the background, the aim and the methodology followed to achieve the results.

1.1 Background

Due to the crucial role that Stockholm has as Sweden´s administrative, demographic, and economic capital, its railway system absorbs a large part of the Swedish rail traffic. This system, specially its southern part, is currently supporting a large flow of traffic, and because of this, infrastructure is saturated.

Moreover, rail traffic demand has seen an increase in the last years, and forecasts indicate that this trend will continue in the future. This fact is due, among other reasons, to:

- Policy initiatives aimed at promoting the use of the railway; its development has allowed a lot of investment in infrastructure and superstructure.
- Changes in user attitudes, based mainly on the increase of railway competitiveness and on the growing environmental awareness.

In order to improve the capacity in Stockholm´s rail system, several projects have been developed by different institutions.

The City Line is an important project that will enable an increase in the capacity of the Southern/Western Main Line. This project consists of building a new tunnel crossing the centre of Stockholm, and substantially eliminate the bottleneck that currently exists between Stockholm central and Södermalm. This line will be operated by commuter trains. Moreover, regional, long distance, and freight trains will use the old lines.

Other projects are aimed at improving the capacity through changes in signaling and exploitation systems of rails.

The implementation of these projects will cover current demand properly. However, forecasts predict significant growth in demand in the future, and this fact will cause the infrastructure to be congested again.

To anticipate future problems, it is necessary to study different alternatives. These can be structured in three different groups:

- Extend the existing rail lines: this alternative is unrealistic because the current lines run through the centre of Stockholm. This fact makes it very difficult to develop these projects, also it does not pose a long-term solution.

- Improve operating systems and signaling: These developments improve the utilization of the infrastructure without taking up more land. This is undoubtedly the most sustainable solution. However, the implementation of these systems can only increase the capacity to some extent, so other solutions are needed.

- Build new infrastructure: This is the case which will be analyzed in this thesis. The construction of a new railway line should be carefully studied because of the economic implications involved. It should therefore be part of an overall strategy.

The new infrastructure would be a railway by-pass which connects railway main lines and enables diversion of traffic from the city centre. Due to Stockholm´s area morphology, the proper place to situate the new line is the western area. By-pass would have effects on the different railway services. Below an individualized analysis is made for each of them.

Moreover, large cities around the world are undergoing both an increase in their population and a demographic process that produce the migration of the people towards the periphery. It increases the needs for transport between peripheral suburbs. Local and commuter trains have a crucial role in the big cities transport system, and therefore, they have to be able to adapt to the system changes.

Regarding the situation in Stockholm, a lot of important suburbs are located along the periphery. In these districts there are a large number of workplaces and in addition a lot of people live there. These facts produce important traffic flows between suburbs.

However, the railway system is centralized to a large degree and in most cases it is necessary to go through city centre in order to travel between suburbs. Therefore, new infrastructure which connects directly these areas would improve the travel times and thus the accessibility.

Regional railway services have had an increase in importance in the last years. The improvements on railway infrastructure and trains have allowed for an

improvement of the competitiveness of railway mode and, nowadays it is capable of competing with car in several market segments.

A lot of people who live in cities around Stockholm have their workplace in the capital. Therefore, there are an important group of people who travel every day to Stockholm by regional trains. Today, all regional trains stop at Stockholm Central from where customers take local transport in order to reach their workplace. If a new model of peripheral regional stations is organized, the accessibility of customers could be upgraded, since an important part of them have their workplace in the suburbs.

Moreover, regional travels from cities in the north/south to cities in the south/north have to cross Stockholm Central and it penalizes the travel times between cities. New traverse infrastructure through the west would avoid the city centre stretch and would reduce travel times.

A similar problem exists with long distance travels. All arrivals and departures are centralized in Stockholm Central. This results in high speed trains having to cross the city centre, where tracks are highly saturated, and thus their travel times are increased.

Several high speed systems around the world have the stations located out of the city. From these stations, customers travel towards the city by local transport. It enables high speed trains to cross metropolitan areas faster.

Finally, freight trains have to go through Stockholm Central as well. The number of freight trains is quite low, and in addition they can be scheduled in low traffic hours. These facts produce that freight trains are not an important problem from capacity point of view. However, freight trains crossing the city centre causes bad image, especially from the tourism perspective.

Regarding all the explained facts, in this thesis several by-pass alternatives will be studied in order to assess their effects on the railway system.

1.2 Goal

The aim of this project is to define several alternatives for the new line and to carry out an assessment of their effects. The analyses are made supposing 2030 as implantation year of the new line.

The new line has several goals:

- To enable diversion of rail traffic from Stockholm Central and the future Stockholm City in order to avoid capacity problems.
- To improve the accessibility between the northern and southern suburbs in the Stockholm area.

Therefore, the requirements for the alternatives are:

- The alternatives have to connect all the railway main lines and as far as possible link with metro and bus stations.
- They have to include new regional and long-distance stations which allow these kinds of trains to stop there.

For each alternative, the analysis will focus in the evaluation of accessibility changes. The studies will be made separately for each kind of supply, i.e. commuter, regional, long-distance and freight.

Finally, the results will be analyzed in order to provide recommendations about the alternatives.

1.3 Methodology

The methods used to obtain information and to carry out the analyses are:

1. Search of information.
    a. Stockholm area features: by searching in existing literature data about population, workplaces, development projects, natural reserves, etc.
    b. Stockholm railway infrastructure: obtaining data about today´s network and planned projects.
    c. Stockholm railway operation: services, travel times, frequencies, etc.

2. Definition of alternatives.
    a. Establishment of influence areas for each alternative.
    b. Individualized analysis of possible localisation for each station.

3. Analysis of accessibility and travel times effects.
    a. To model the network in 2030 by defining travel times and frequency in the new stretches.
    b. Definition of proper accessibility indicators
    c. Individualized analysis for each kind of supply: commuter, regional, long-distance and freight.

4. The final step consists of a conclusions report, as well as making recommendations about the project.

1.4 Scope

The construction of a railway line running through a metropolitan area involves a huge investment and notably modifies the transport system.

Therefore, it is important to remark that the analyses carried out along this thesis are focused on accessibility and then the conclusions are partial. Other studies must be made in order to get an overall evaluation of the different alternatives.

2 Stockholm´s Railway System

2.1 Introduction

Nowadays, the railway system in Stockholm is an important part of the public transport system. A lot of people use the railway to commute or they use the train to reach regional destinations.

In spite of the fact that private car is the most used mode of traffic today, several facts forecast a good future for the railway. Road congestion and environmental issues produce a bad image of the car to people and induce them to study alternative modes.

The railway has two important development fronts. The first of them is the long-distance services, due to high speed trains having revolutionized this market and railway is able to compete with other modes of traffic; such as flights or private car.

The other front is the development of the railway in the large metropolitan areas. A large part of the pollution in roads is produced in the vicinity of the cities, where the congestion is much more frequent. A dense and efficient local and commuter railway system could induce a population to change their transport habits and they would get environmental friendly cities. In order to reach these objectives, politicians are giving a boost to the railway mode and a great number of new projects have seen daylight.

Even though Stockholm has a largely used network, some issues have to be studied to avoid crucial problems in the near future. Today´s network is strongly radial, i.e. all the lines converge in one central point at the centre of the city. It involves the node at Stockholm Central / T-Centralen being highly saturated and it is necessary to make huge investments to extend the infrastructure in this densely populated area.

Moreover, it is important to remark that in a parallel way, large cities are undergoing a demographic process which produces the migration of the people towards peripheral areas. It creates new flows between the suburbs which are growing into great importance.

The local government is developing tram projects in order to improve the transverse connectivity and reduce the congestion in the centre of the city. However, these projects have in most of the cases local effects, i.e. improve the situation only in a small part of the metropolitan area, and its effects involve exclusively the local traffic. Recent studies such as Stockholm Central 2050 (Nelldal, Lindfeldt and Fröidh, 2010), inform about the necessity of new infrastructure in the near future in order to avoid congestion in the city centre.

In this chapter, network components that interact with alternatives studied are described. Moreover, the improvements planned for 2030 are included since they will be included in posterior analyses.

2.2 Local and Commuter System

2.2.1. Metro

Three different lines of metro are at work in Stockholm today. They are largely used for local trips and connect most parts of the city. Some improvements will be made before 2030 like the change of the signaling system. However, they will not vary the travel times so much since metro lines have a high frequency today.

Figure 2.1 shows a sketch of the metro network and the travel times to/from T-Centralen. Below, there is information about the different lines.

Figure 2.1. Today´s Stockholm Metro System (2011). Source: www.sl.se

-The Green Line

The Green Line is the oldest one. It was in 1950 that the first part between Slussen and Hökarängen was opened. Today, it has three distinct lines that connect the western to southeast suburbs. In fact, it has one branch in the north to Hässelby and three branches in the south to Hagsätra, Farsta Strand and Skarpnäck. The total length of these lines is 66,6 km but due to the common central part, green line tracks are only 41,3 km long.

Nowadays, the green line supports more than 150 million passengers per year or 500.000 passengers per workday.

-The Red Line

The Red Line runs from the southwest of Stockholm to the northeastern suburbs. It was opened in 1964 and it has two northbound-branches to Mörby Centrum and Ropsten and two southbound-branches to Fruängen and Norsborg. The Red Line is 46.1 km long but it has only 41.2 km of tracks.

More than 140 million passengers per year use the Red Line routes. It amounts to more than 450.000 passengers per workday.

-The Blue Line

Finally, the Blue Line, which runs from the northwestern suburbs to the east of Stockholm´s city centre, is the newest line. The work began in 1975 and the line has two different branches from Kungsträdgården to Hjulsta and Akalla in the north. Its two lines have a length of 30.7 km (25.5 km of tracks).

The Blue Line has 65 millions of customers per year or 200.000 passengers per workday.

Lines		
Green	T17	Åkeshov-Skarpnäck
	T18	Alvik-Farsta Strand
	T19	Hässelby-Hagsåtra
Red	T13	Norsborg-Ropsten
	T14	Fruangen-Morby Centum
Blue	T10	Kungträdgården-Hjulsta
	T11	Kungträdgården-Akalla

		Lines Length (km)	Tracks length (km)	Number of stations	Traffic (pass/year)	Travel Times (min)
Green	T17	19,6	41,3	24	150 millions	42
	T18	18,4		23		38
	T19	28,6		35		58
Red	T13	26,6	41,2	25	140 millions	46
	T14	19,5		19		35
Blue	T10	15,1	25,5	14	65 millions	25
	T11	15,6		12		24

Table 2.1. Metro lines in Stockholm (2011).

2.2.2. Local Trains and Trams

In the last years, light trains have received a major boost from the local government. It has produced the construction of the Tvärbanan through the south of Stockholm and its extension to Solna, which will be finished in 2013.

Moreover, in Stockholm there are several historical light train lines like Lidingöbanan and Nockebybanan.

-Tvärbanan

The newest tram line in Stockholm is known as Tvärbanan or "*Transverse Line*". It started to run in 2000 between Liljeholmen and Gullmarsplan, but in 2002 the stretch Gullmarsplan-Sickla Udde, was opened as well. In addition, the line will reach Solna from Alvik in 2013.

Tvärbanan allows a large number of interchanges between different metro and commuter lines that enable a reduction in travel times between the suburbs in the south and the west. Below, figure 2.2 shows a sketch of the line with the main stations.

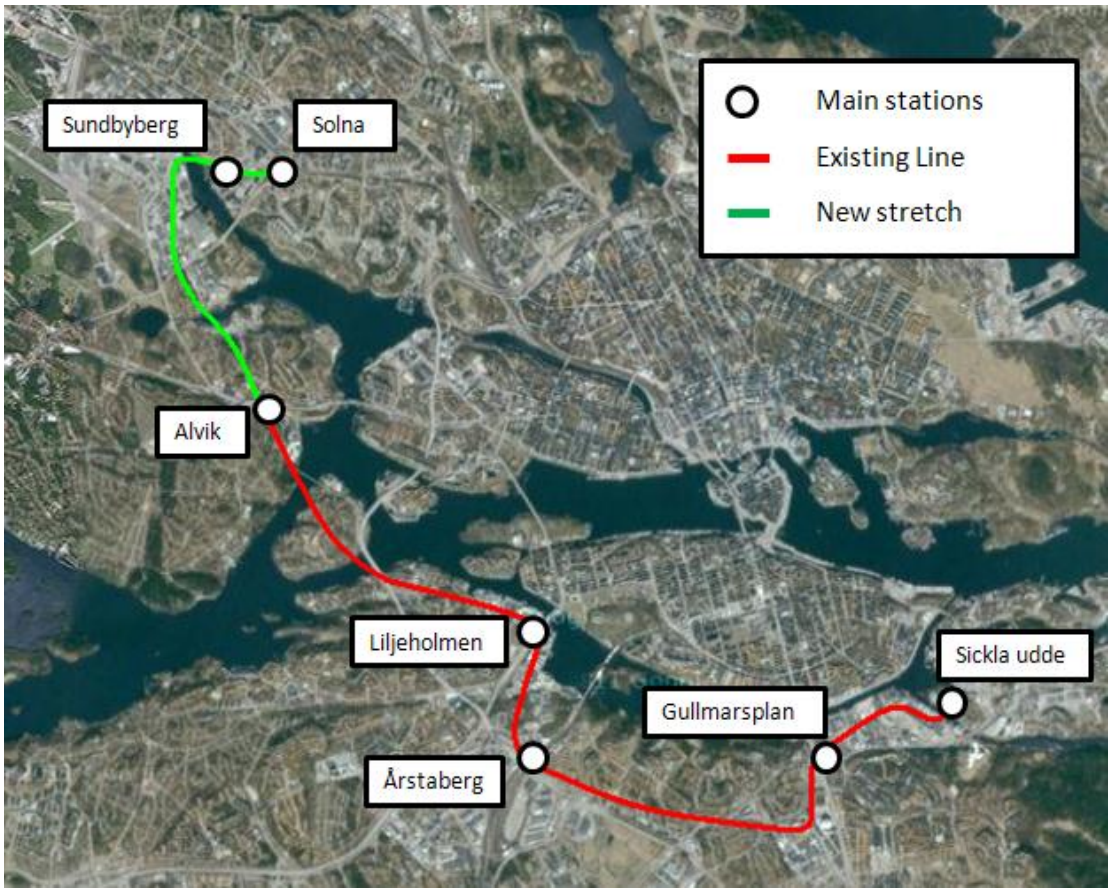


Figure 2.2. Tvärbanan and its extension to Solna.

The stretch between Alvik and Solna (figure 2.2) will enable connecting Tvärbanan with the metro Blue Line and with Commuter trains in Sundbyberg. This segment has seven stations and finishes close to the future National Stadium in Solna.

In addition, there are several tram projects planned. The Tvärbanan extension to Kista and Häggvik is a project which will make it possible to reach important work areas by tram and it would allow for connecting the tram line with the commuter trains towards the suburbs in the north. Moreover, other projects like the southern tram between Flemingsberg and Älvsjö are under investigation. Since they are not being built imminently, these lines are not included in the 2030 network.

-Nockebybanan

This line began its operation in 1914 and was gradually extended to today´s route between Alvik and Nockeby. Nockebybanan enables fast connections between a large residential area and the centre of the city.

It has ten stations and a length of 5.6 kilometers. However, the demand for Nockebybanan is quite small; approximately 10.000 passengers per day.

Nockebybanan is operated by Veolia Transport, but its infrastructure is the property of Storstockholms Lokaltrafik (SL).

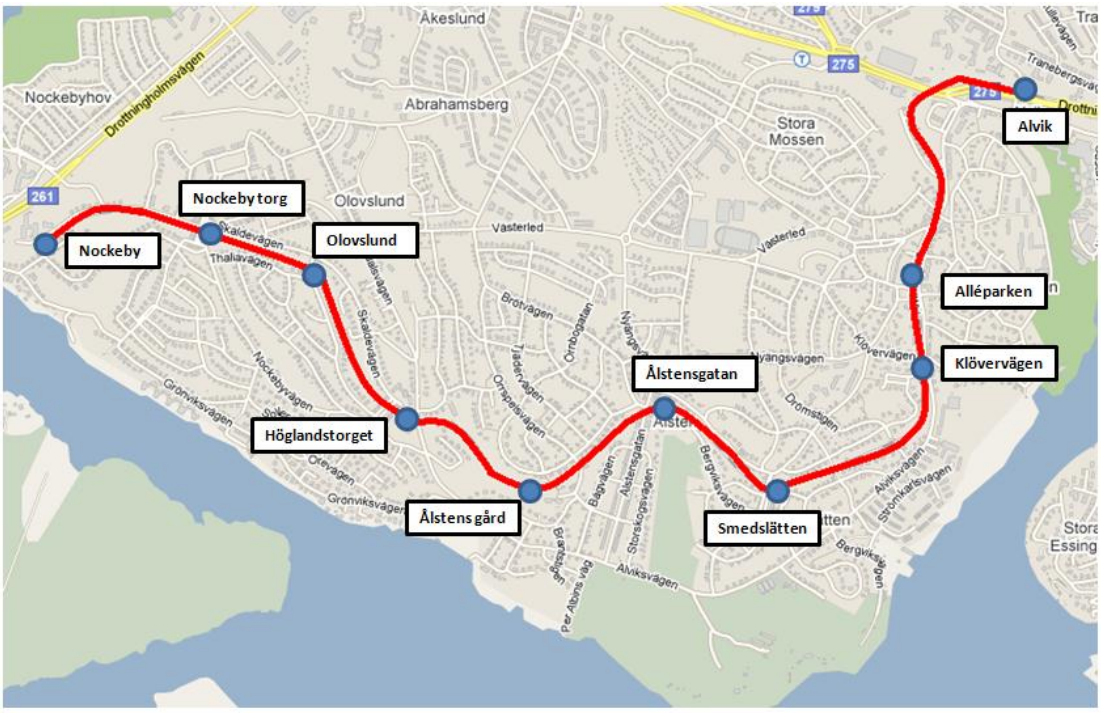


Figure 2.3. Nockebybanan (2011).

-Other Lines

There are some other light rails and trams in Stockholm. They are not included in this chapter since they do not interact with the by-pass. These lines are:

- Lidingöbanan
- City - Spårvägen
- Saltsjöbanan

2.2.3.-Commuter Lines

Since a great deal of people lives far away from the centre of Stockholm, the commuter system is largely used. The commuter rail system began to develop in the second half of the 20th century. Improvements in tracks, rolling stock and stations, allowed increase in both frequency and quality of service.

Nowadays, Stockholm´s commuter rail system encompasses three lines:

- Bålsta-Nynäshamn (J35): This line runs through Stockholm central. A train interchange is necessary in Västerhaninge due to lack of proper infrastructure in the southern stations. In the next years, the improvement of infrastructure will enable the elimination of the interchange and the entire line will have a double track. It has a length of 107 kilometers with 27 stations.
- Märsta-Södertälje (J36): It crosses the centre of the city as well. The length of the line is 74 kilometers and there are to be found 24 stations along its tracks.
- Södertälje-Gnesta (J37): This is the shortest one and it stretches merely 30 kilometers. It has 6 stations and it is not possible to reach the centre of Stockholm without changing to line J36.

More than 50% of the railway traffic in Stockholm (metro and tram not included) runs along these lines.

LINES	NAME
Bålsta-Nynäshamn	J35
Märsta-Södertälje	J36
Södertälje-Gnesta	J37

	Lines Length (km)	Tracks length (km)	Number of stations	Travel Times (min)
J35	107	200	27	104
J36	74		24	81
J37	30		6	31

Table 2.2. Commuter lines in Stockholm (2011)

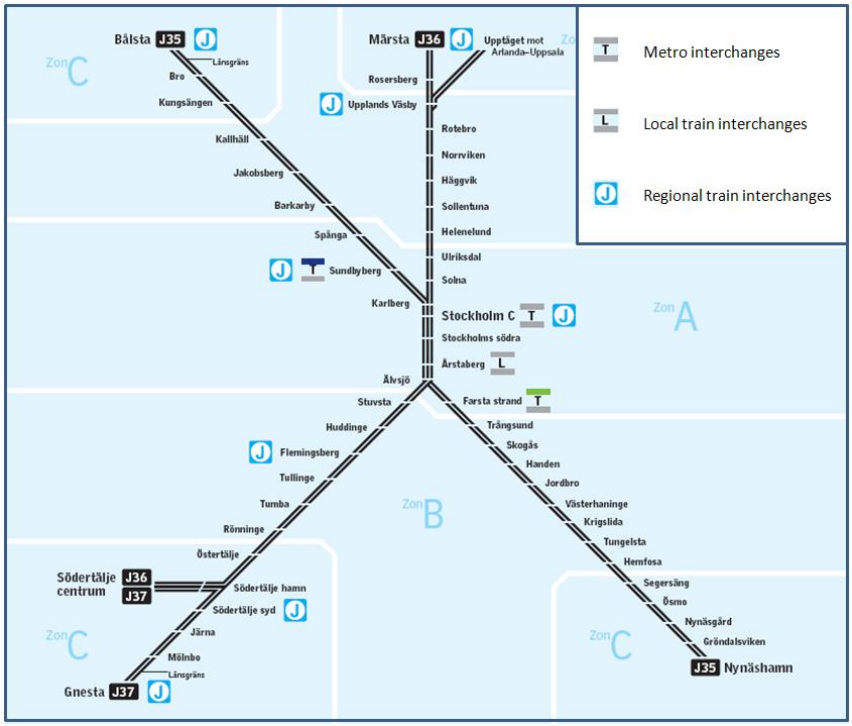


Figure 2.4. Commuter Lines.

One of the most important infrastructure projects developed in Stockholm in recent years is the City Line (see figure 2.5). It will be a new stretch in the commuter network from Tomteboda to Stockholm Södra. The City Line will make it possible to separate commuter traffic and other services and thus, the congestion problem in Stockholm Central will be avoided for the time being.

The project includes two new commuter stations: Odenplan and Stockholm City. Stockholm City will be located under Stockholm Central and exclusively commuter trains will be stopping there. Odenplan will improve the accessibility in Norrmalm and will allow for diversion of customers out of Stockholm City.

Figure 2.5. City Line.

2.2.4.-Roslagsbanan

Roslagsbanan was one of the first electrified lines that opened in Europe. The line runs through Roslagen, in the northern parts of Stockholm. Along the time, some parts of the line have closed, but the rest of the stretches are largely used today.

It is a narrow track gauge (891 millimeters) and has three different branches. The longest branch runs from Stockholms Östra to Kårsta in the north. In Djurholms Ösby, a second branch was created, which nowadays finishes in Österskär. In the same way, the third branch changes its direction in Roslags Näsby. In the table 2.3 there is information about the lines.

Today, some stretches are simple track, but plans for doubling the tracks to Täby and Åkersberga have been made. In addition, the line is to be improved to 120 km/h. These improvements will be implanted in 2030, and thus they are included in posterior analyses.

LINES	NAME
Stockholms östra – Kårsta	27
Stockholms östra – Österskär	28
Stockholms östra – Näsbypark	39

	Lines Length (km)	Tracks length (km)	Number of stations	Travel Times (min)
27	41,5	65	23	54
28	29,5		20	41
29	11,5		12	20

Table 2.3. Roslagsbanan Lines.

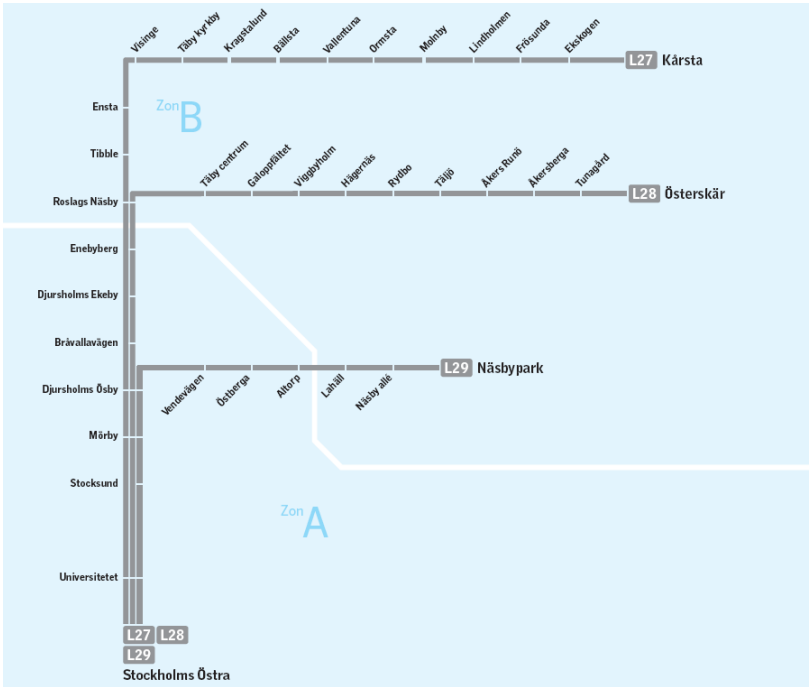


Figure 2.6. Sketch of Roslagsbanan Lines.

2.3. The Regional Railway System

The regional services have been on the increase in importance throughout the years. Today, a lot of people travel every day from important cities in Mälardalen area to Stockholm metropolitan area.

New regional services like Eskilstuna – Stockholm have had important territorial and transport effects. A deep analysis of these effects can be consulted in *Introduction of Regional High Speed Trains* (Fröidh 2003).

All regional trains stop in Stockholm Central from where all the departures towards Mälardalen cities are made. In addition, there are two complementary regional stations in Stockholm´s metropolitan area. They are located in Sundbyberg (Mälarbanan) and Flemingsberg (The South Main Line). A sketch of the regional station system is represented in figure 2.7.

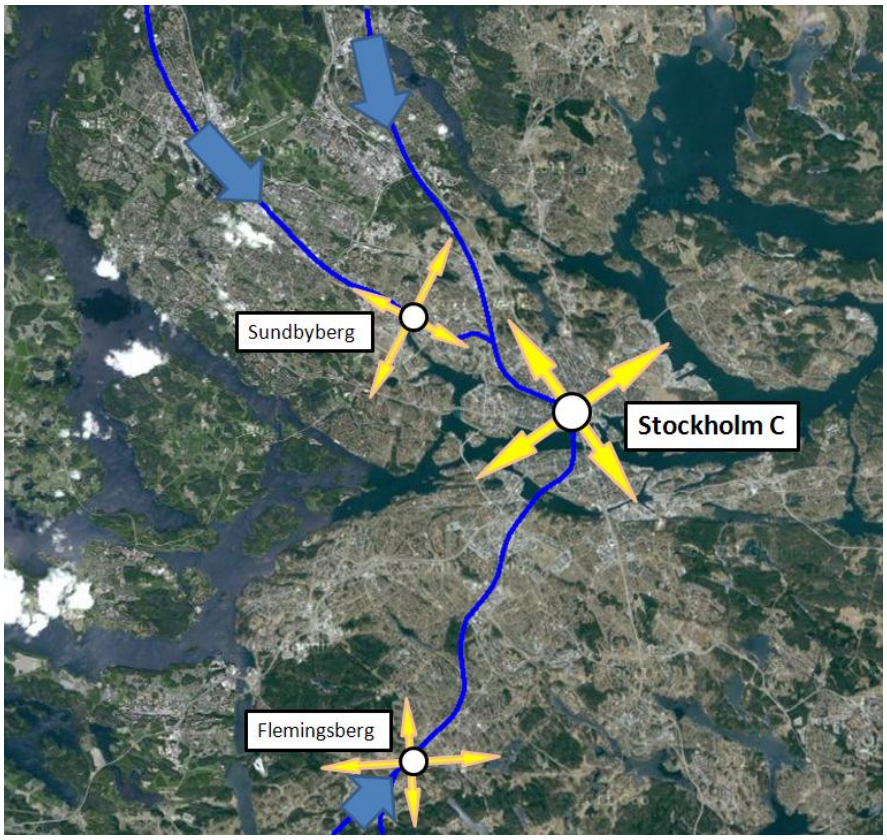


Figure 2.7. Today regional station system in Stockholm´s area.

The regional services operating today are included in the table 2.4. In most of the cases it is necessary to change trains at Stockholm Central in order to travel between two cities situated on different main lines. This is because the traffic flows between all these cities are not large and thus a direct service between them is not necessary. In figure 2.8 the lines used for regional trains to/from Stockholm are displayed.

Lines	
Stockholm	Eskilstuna
Stockholm	Gävle
Stockholm	Norrköping/Linköping
Stockholm	Västerås/Örebro/Hallsberg
Stockholm	Katrineholm/Hallsberg
Stockholm	Uppsala/Sala/Borlange

Table 2.4. Regional services to/from Stockholm

The increase of the population in Mälardalen valley could produce an increase in these flows and thus it would be necessary to plan new services.

However, the main problem in the regional system is the congestion in Stockholm Central. This problem will be temporally avoided with the City Line (which will be capable of diverting commuter traffic to Stockholm City station), but forecasts indicate that it will be saturated again in 30 years.

There are no planned projects to get to grips with this problem, since new transverse tram lines are not able to schedule regional trains. The alternatives studied in this thesis could be a solution for the congestion in Stockholm Central, and thus it will be studied in a subsequent chapter.

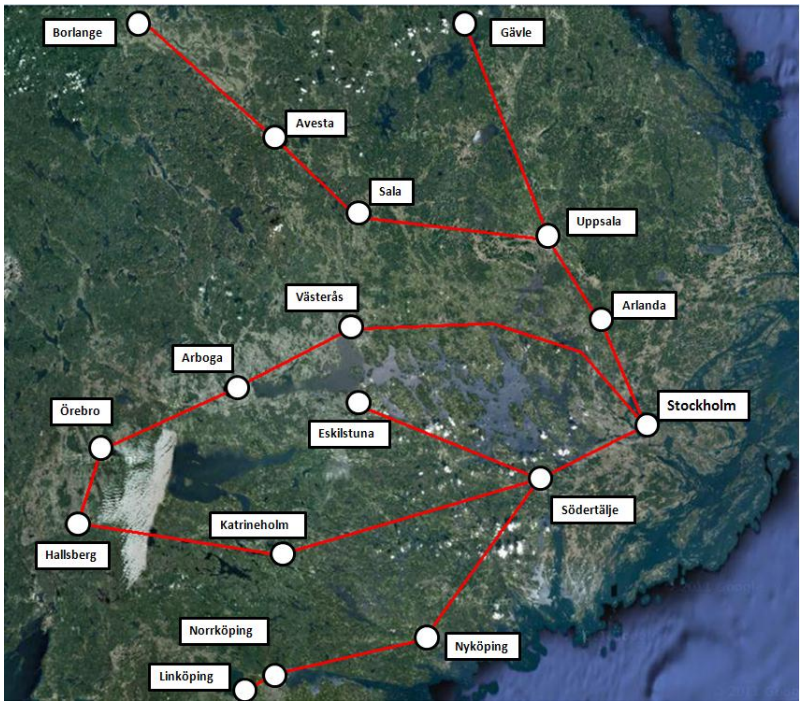


Figure 2.8. Regional lines to/from Stockholm.

2.4. The Long Distance Railway System.

Long distance travels are becoming really important in the national transport system. A lot of investments and investigations are being done in order to equip Sweden with an efficient high speed railway. Nowadays, X2000 services are operating and they develop a crucial role in the travels between the Swedish main nodes: Stockholm, Gothenburg and Malmö/Copenhagen. In some cases they are more used than other modes.

For the construction of a new high-speed line there are two different principles that can be applied. The traditional railway principle consists of locating the station at the centre of the city. It often allows having a good connectivity with the rest of the public transport network, however, trains are forced to run through the centre of the cities and travel times could suffer heavily.

On the other hand, the motorway principle consists of building a by-pass through the periphery of the city. It allows for the trains to run faster than in other cases, and then the travel times are reduced. Another advantage of this model is that capacity conflicts in the central station are avoided.

In Stockholm, all the arrivals and departures are made to/from Stockholm Central. The problems explained in the section on regional traffic are completely valid for long-distance, since they share Stockholm Central as the unique main station. Moreover, long-distance travels often have different motivation than regional travels. People utilize long distance services sporadically or periodically (once a week; once a month), and the connectivity with the suburbs is not that important. In figure 2.9 the lines used by X2000 trains today are displayed.

As explained above, a lot of high-speed projects have been planned in Sweden. In addition, new trains like Gröna Tåget have been developed in order to improve the system. In figure 2.10 there is a sketch of the high-speed network in 2030.

However, there are no planned projects that modify the Stockholm situation (all high-speed trains go through Stockholm Central). In 2030, Stockholm´s high-speed system will follow the traditional network principle and in this thesis the possibility of changing the model will be assessed.

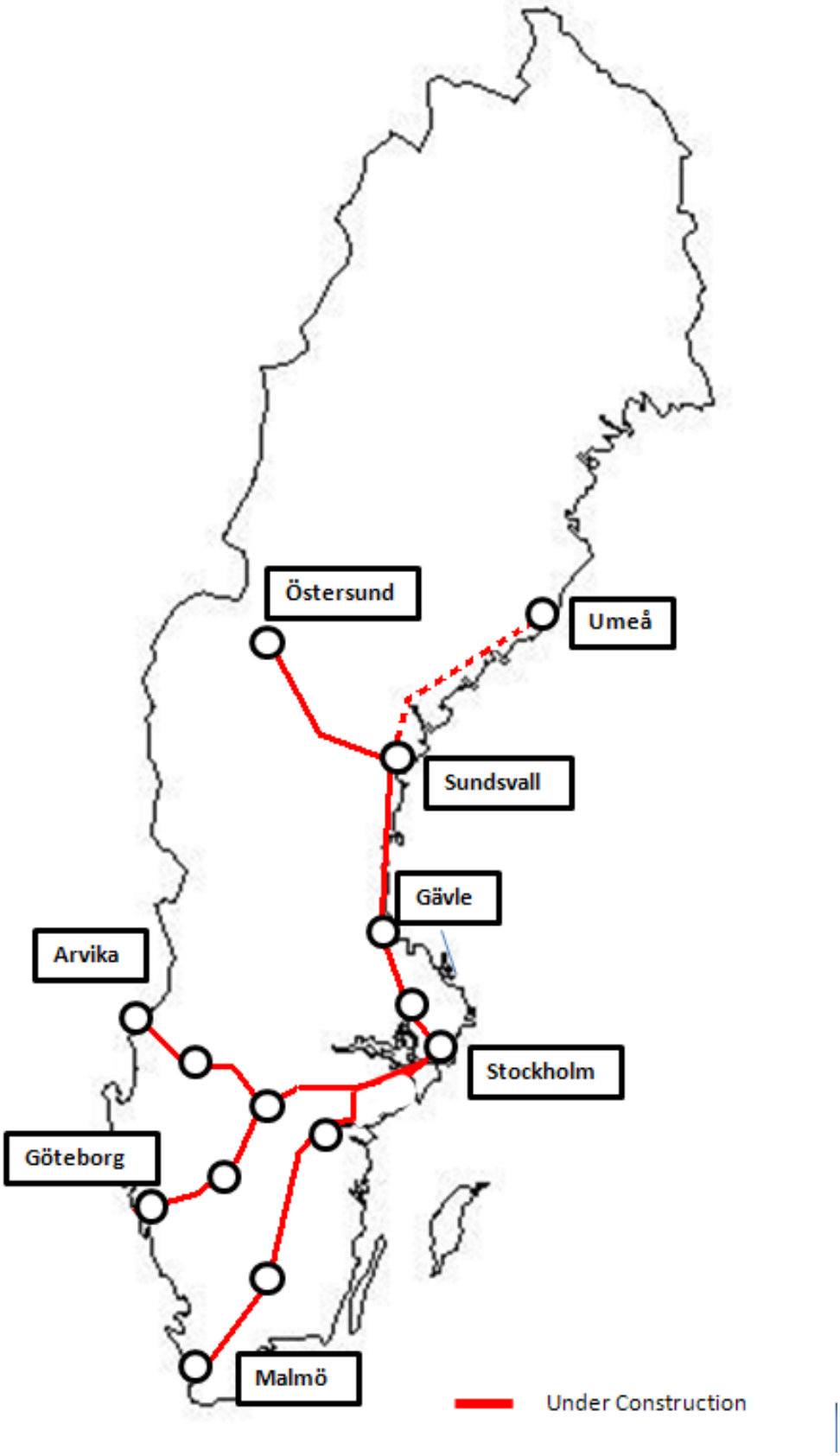


Figure 2.9. X2000 services to/from Stockholm.

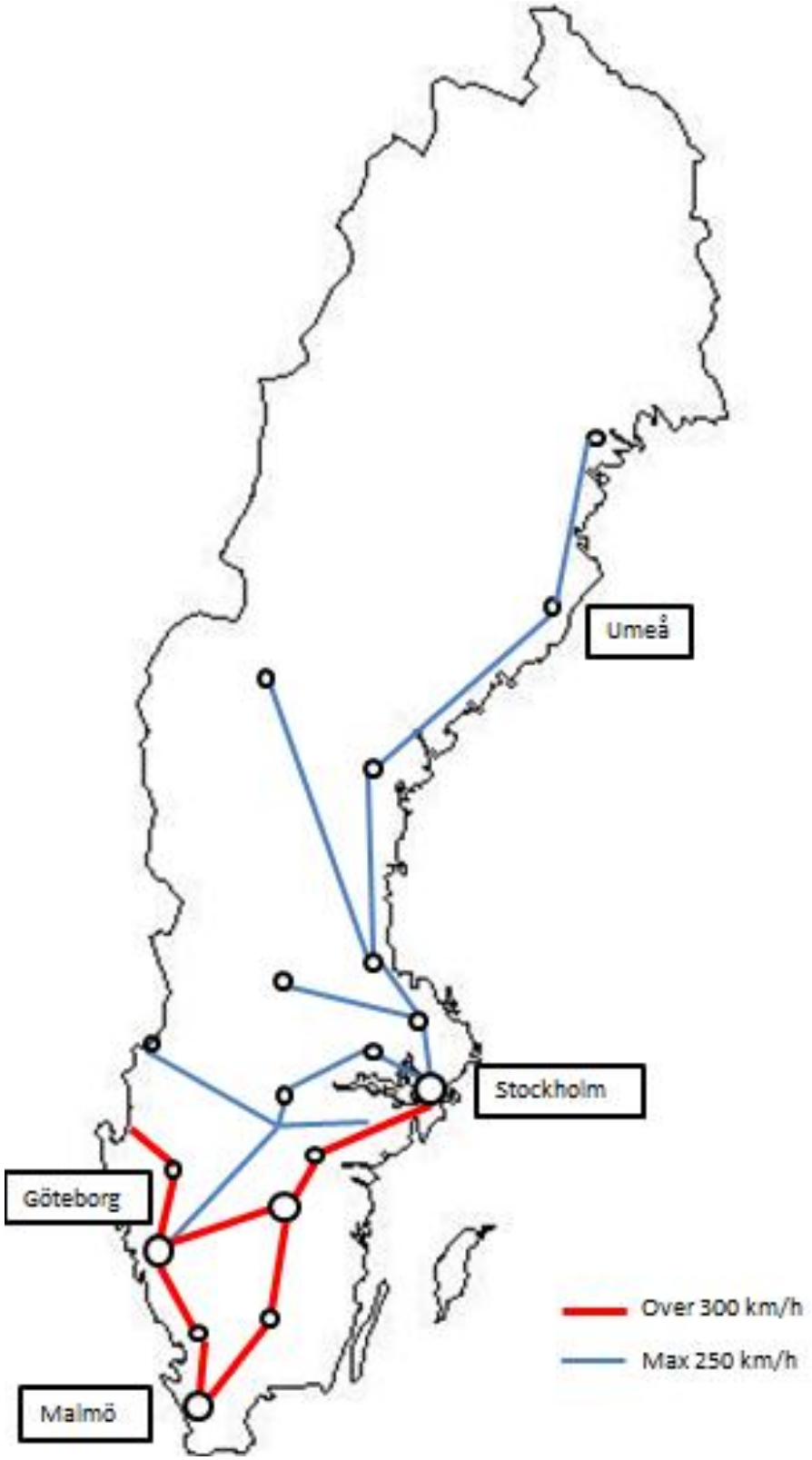


Figure 2.10.High-Speed services in Sweden (2030).

2.5. The Freight Railway System.

One of the main objectives of the European transport policies is to increase intermodality in freight transport. The railway plays a crucial role in intermodal systems and an efficient freight railway is necessary in order to achieve a competitive intermodal system. Therefore, it is important to have good connectivity between ports and main railway lines.

In 2030, Stockholm will have two ports operating. They are Kapellskär in the north and Norvik in the South. Nowadays, Kapellskär does not have connection with the rail network, however, Norvik which is situated close to Nynäshamn, can be connected to the network easily.

Besides, in 2030, there will be two big terminals in the Stockholm area. Rosersberg is a new terminal that is located at Sigtuna. This terminal is next to the The East Coast Line. On the The South Main Line there is another terminal in Årsta, which is the main terminal today. Figure 2.11 shows main freight transport nodes in the Stockholm area.

Today freight trains have to cross the centre of Stockholm, i.e. Stockholm Central, since this route is the unique option. In the future, flows between north and south terminals could become larger, and the traffic through the city would be a problem. By-pass could be a route alternative for freight traffic. This option will be studied in posterior chapters.

Figure 2.11.Freight transport in Stockholm area (2030).

3 Definition of alternatives

3.1.-Introduction

In this chapter, the different alternatives will be defined. Three routes through the west of Stockholm will be established. The differences between them are mainly the length and the territorial scope of each one.

From now on the alternatives will be 1, 2 and 3. In figure 3.1, there is a sketch of the areas where each alternative will be located.

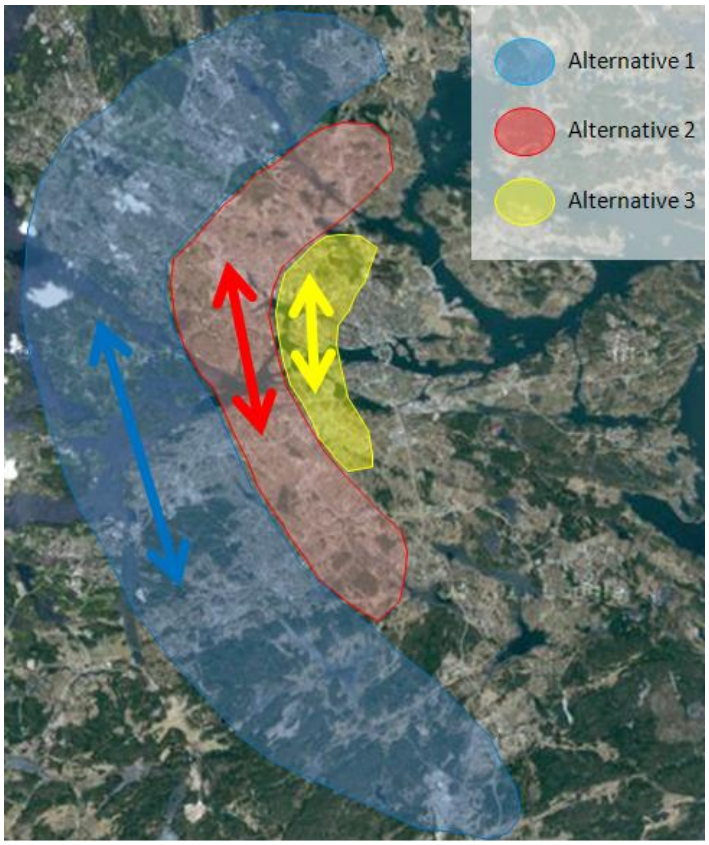


Figure 3.1. Approximate area where different alternatives will be studied

There are big length differences between the alternatives. It allows for evaluation of several options for the same project (west by-pass). Each option will have different effects on the railway system, thus it will make it possible to study a wide variety of effects.

The **exterior** alternative (1) covers a large area which lets all main lines in the Stockholm area interconnect, such as The South Main Line or Mälarbanan. It is approximately 60 kilometers long and some stretches have to be built by tunnel.

The **interior** alternative (2) is a lot shorter than the previous one, but it runs through a densely urbanized area. Therefore, the construction of the infrastructure could be complicated. It presents some stretches that run parallel to others rail lines, and thus the interferences between them have to be analyzed.

Finally, the third option or **central (3)** option is located in the centre of the city. Despite being the shortest alternative, the construction would be quite complicated due to the congested areas that it crosses. Moreover, this alternative presents operational difficulties due to the huge flows of railway traffic that runs in these areas. In addition, Alternative 3 does not modify Stockholm´s railway model, i.e., a central model where all the main lines cross the centre of the city.

Below, there is a deep study for each one of the alternatives trying to establish the number and the localizations of the stations.

3.2.- Alternative 1

Alternative 1 has a length of approximately 60 kilometers. It is quite long but it allows for a connection with the by-pass with all the railway main lines:

- Nynäshamn line
- The South Main Line
- Mälarbanan
- The East Coast Line
- Roslagsbanan

In addition, the route allows connecting the new line with the existing metro lines. Therefore, this alternative is the most proper from a connectivity point of view and it provides a lot of possibilities for interchange.

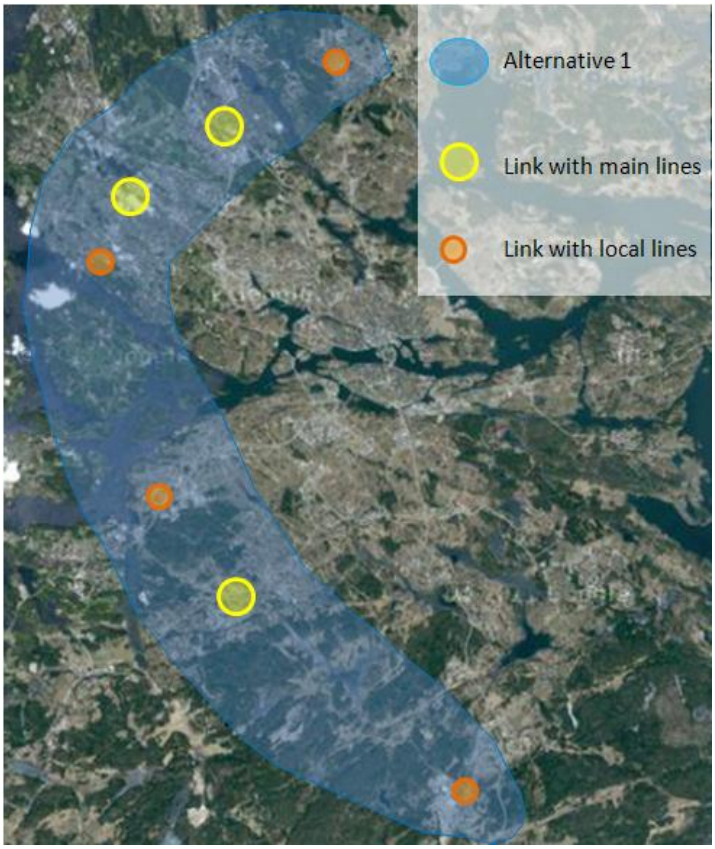


Figure 3.2. Exterior alternative. Study area and approximate location of some stations.

The main stations on the line will connect with junctions to existing main lines (The South Main Line, Mälarbanan and The East Coast Line). Therefore, these stations have to be able to operate with regional and long distance services.

It is mandatory to situate stations in some points:

- Junctions with the railway main lines: 5 stations
  - Nynäshamn line (commuter station)
  - The South Main Line (commuter, regional and long-distance station)
  - Mälarbanan (commuter, regional and long-distance station)
  - The East Coast Line (commuter, regional and long-distance station)
  - Roslagsbanan (commuter station)
- Junctions with metro lines: 2 stations
  - Red line (commuter station)
  - Green line (commuter station)

Therefore, we have *a priori* situated the approximate location for 7 stations.

3.2.1. Station 1: Connection with Nynäshamn line

The new station will be just for commuter trains. On the Nynäshamn line there are some possible locations for the new station. All of them are commuter stations of the Stockholm-Nynäshamn line (J35). Selected stations are:

1.-Trångsund-Skogås: both Trångsund and Skogås have a commuter station. They are a district of Huddinge municipality and have 25.000 inhabitants approximately. In addition, Länna, a commercial employer area, is situated in this district. The areas around the stations are densely urbanized, and it is quite difficult to get extra space to build new infrastructure.

2.-Handen: This is the most important population node in Haninge municipality. At this place we can find a commercial centre known as Haninge Centrum, and the Södertörns Högskola campus. Moreover, an important bus station, which provides services to several southern suburbs, is situated next to the existing station.

Most of the districts of Haninge are quite close to Handen (Brandbergen, Vega, and Jordbro) and the total combined population amounts to around 40.000 inhabitants.

Even though the station is situated between an urbanized area and a lake; it is possible to extend the infrastructure, since we can find available land 100 meters to the south. However, this available space has a high environmental value and its utilization would need a deep study.

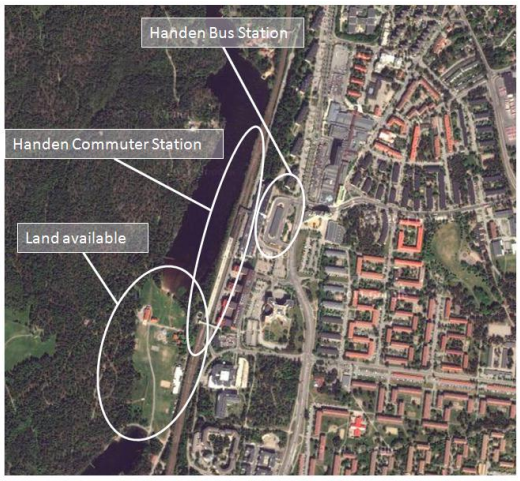


Figure 3.3. Handen commuter and bus stations

3.-Västerhaninge: It is a locality in the municipality of Haninge. Västerhaninge has a population of 18.000 inhabitants. This town is mainly residential and has some tourist destinations. The station was built in 1997 and there is undeveloped land to extend the infrastructure.

At this point, regarding the available information, the most proper location for station number 1 is selected:

LOCATION OF THE STATION	ADVANTAGES	DISADVANTAGES
Skogås	- Largely populated 22000 inhabitants - Employer commercial area in Länna	-Lack of space for new infrastructure
Handen	- Largely populated 40000 inhabitants - Important bus station - Södertörns Högskolan - Haninge commercial centre - Haninge government centre - Tourist destination - Land available - Jordbro Industrial park	- Environment with high value
Västerhaninge	- Land available - Jordbro Industrial park	- Lack of potential customers next to the station

In view of all, Handen has been selected, and it will be station number 1.

Station 1 (link Nynäshamn Line – By-pass): Handen

3.2.2. Station 2: Connection with The South Main Line.

A new station has to able to work with commuter, regional and long-distance trains. Two locations will be evaluated to locate the by-pass station in the The South Main Line. The proposal areas are:

- Huddinge
- Flemingsberg

Both, Flemingsberg and Huddinge are part of Huddinge Municipality. This municipality is the second most populated area at Stockholm´s Län and it has around 95000 inhabitants.

There are two commuter stations in Huddinge and Flemingsberg which are part of the the South Main Line. Many regional trains call in Flemingsberg station as well.

1.-Huddinge: The area around Huddinge station has a population of 30000 inhabitants approximately. Next to the station there is a large bus station which serves to several localities in south Stockholm. In addition, a big commercial centre (Huddinge Centrum) is located in the same place. It is difficult to find available land close to the today´s station due to that area is densely urbanized. Therefore, it would be quite hard to build the joints and extra infrastructure needed to connect The South Main Line with new By-pass.

2.-Flemingsberg: Flemingsberg is both residential and work area. At this place, the southern Stockholm´s main hospital is located as well as Södertörns Högskola campus. A total of 22000 inhabitants live in the vicinity of Flemingsberg Station. It is possible to extend the infrastructure next to the station thus there are some undeveloped pieces of land. Apart from that, there is a parking zone next to the station that was built 15 years ago. Nowadays, Flemingsberg is covering both commuter and regional services.

LOCATION OF THE STATION	ADVANTAGES	DISADVANTAGES
Huddinge	-Large population around the station (40000 inh.) -Important bus station -Commercial centre (Huddinge Centre)	-Densely urbanized area -Great difficulty in getting land
Flemingsberg	-Södertörns Högskola campus -South Stockholm´s main hospital (Huddinge Sjukhus) -Available land to extend infrastructure -Parking area in operation -Work area	-Population living close to the station is less than in Huddinge

The hospital and the university generate a lot of trips every day. In addition, due to the link between The South Main Line and the new By-pass will be crucial in

the project, the availability of undeveloped land it is necessary. Therefore, Flemingsberg is the most proper option to locate this station.

Station 2 (link The South Main Line – By-pass): Flemingsberg

3.2.3. Station 3: Connection with Metro Red Line.

The new station will be just for commuter trains. The Red line of Stockholm´s metro network runs in this area through Skärholmen borough, which pertains to Stockholm municipality. Specifically, Skärholmen and Sätra stations will be assessed as candidates to locate the By-pass station.

1.-Sätra: Sätra is a suburb located in the borough of Skärholmen. It is mainly a residential area where less than 10.000 inhabitants live. The availability of land is quite limited.

2.-Skärholmen: It has a population of 20.000 inhabitants. Close to the station, one of the most important commercial areas in Sweden is located. This commercial zone, where there are shops like IKEA and malls like Heron City, generates a large flow of passengers every day. It is possible to get undeveloped land 200 meters north of the stations. However, the new line probably will need to run by a tunnel at this point due to the presence of highways (E-4) and a lot of building structures.

In addition, the road by-pass, which is under construction, begins at this point. It would make the building project of the new station difficult.

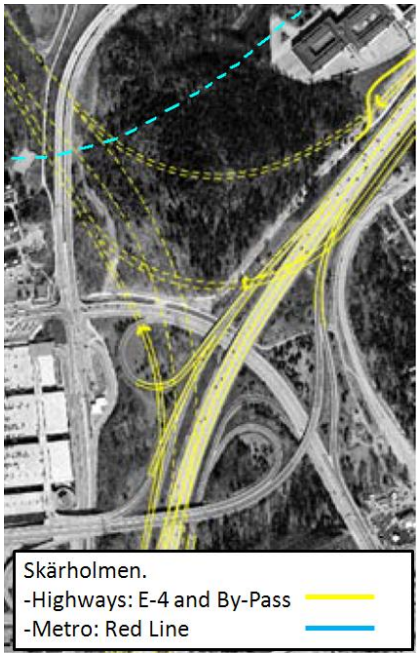


Figure 3.4. Skärholmen. Today and future infrastructure.

LOCATION OF THE STATION	ADVANTAGES	DISADVANTAGES
Sätra		-Low population -Densely urbanized area -Great difficulty in getting land
Skärholmen	-Large population close to the station - Important commercial centre -Possibility of extend infrastructure	- A lot of infrastructure in the same point: highways, tunnels, etc.

The most proper place to locate the station is Skärholmen. However, to project and to build more infrastructures at this important node could be quite difficult.

Station 3 (link metro red line – By-pass): Skärholmen

3.2.4.-Station 4: Connection with Metro Green line.

The new station will be only for commuter trains. This link has to be made in the area around Hässelby-Vällingby borough. It has a population of 65.000 inhabitants and it is mainly a residential area. Nevertheless, some industrial parks are located in this area.

In particular, the area around Hässelby and Vällingby stations will be assessed as building sites for the new station

1.-Hässelby: It is a suburb of Stockholm which has a residential function. Around 25.000 inhabitants live in its localities. Despite the fact that the area next to the station is densely urbanized, it is possible to acquire land to extend the infrastructure.

2.-Vällingby: This suburb was founded in the fifties as a dormitory-working area. However, it has evolved into a residential area where around 30.000 inhabitants live. In addition, an important commercial area is located next to the metro station and a lot of cultural events take place in Vällingby every year. There are no pieces of land undeveloped in the areas around the station, so, if the new station is built here, it has to be by a tunnel. Moreover, an important bus station is located next to the metro station.

LOCATION OF THE STATION	ADVANTAGES	DISADVANTAGES
Hässelby	- Large population (25000 inhabitants) - Availability of land	
Vällingby	- Large population (30000) - Commercial area - Important bus station	- The new infrastructure has to run by tunnel

Despite the construction difficulties that Vällingby presents, the advantages such as good connection opportunities (bus station) or travel generating activities, suggest that the best option to locate the station to is Vällingby.

Station 4 (link metro green line – By-pass): Vällingby

3.2.5. Station 5: Connection with Mälarbanan.

The new station will have to be able to work with commuter, regional and long-distance trains. The link between Mälarbanan and the West By-pass will be crucial in the possibilities of the new infrastructure. Therefore, some junctions have to be built in order to allow proper interchanges between lines; thus, the requirements of space are important. In this case the possibilities to locate the new station are Barkarby and Spånga.

1.-Spånga: It is a locality with a small population and mainly residential function. The area around the railway station is urbanized and it is not possible to build new infrastructure on the ground level.

2.-Barkarby: It is a district of Järfälla municipality where there live around 10.000 inhabitants. When the improvements in Mälarbanan finish, Barkarby will be an essential transport node where interchanges between bus and railway will be made. Moreover, there is a big piece of available land which can be built on, but it is important to take in account that an important node of the future road by-pass is being built already today in the same area.

In addition there is a large industrial park close to the station (Lunda).

LOCATION OF THE STATION	ADVANTAGES	DISADVANTAGES
Spånga	-No important infrastructure built (non congested area)	- Little population - Lack of space on ground level
Barkarby	- Larger potential customers - Lunda industrial park - Important bus station - Land available	- A lot of infrastructure in the same point. Future node of the road by-pass

All things taken into consideration, Barkarby has been selected. Its features are suitable for erecting the Western Stockholm main station.

Station 5 (link Mälarbanan – By-pass): Barkarby

3.2.6. Station 6: Connection with The East Coast Line.

The new station has to able to work with commuter, regional and long-distance trains. This station will allow interchanges between the new by-pass and the The East Coast Line and it will be one of the crucial nodes in the infrastructure. Therefore, the new station has to be big enough to support a large number of passengers and trains.

However, two of the three options that we are going to assess only have very little land available. Therefore, the junctions and other complementary infrastructure will have to be built by a tunnel.

The three candidates for locating this station are:

1.-Häggvik: It is a locality of Sollentuna where around 5000 inhabitants live. The area has several main infrastructures and thus it has a lack of land to build the new station. However, one of the most important advantages to locate the station at Häggvik is the tongue of land free of water that allows easy building of the new tracks towards Roslagen.

2.-Sollentuna: The area around Sollentuna station has an approximate population of 15.000 inhabitants. Notwithstanding the fact that the area has a residential function, large work areas like Kista are quite close to the station and it is possible to reach them by bus or by tram when the extension of Tvärbanan will be operating.

Moreover, if the new station is built in Sollentuna, it will have to be by a tunnel owing to the fact that there is no land available in the vicinity.

3.-Helenelund/Kista: Nowadays, there is a commuter station in front of Kista work area which name is Helenelund. Kista is one of the biggest work areas in the Stockholm region and thus generates a large number of daily trips. In the future, the tram line from Alvik will have a stop in Kista that will complement today´s supply. It is possible to find available land close to the Helenelund station.

LOCATION OF THE STATION	ADVANTAGES	DISADVANTAGES
Häggvik	-Suitable point to extend the infrastructure towards Roslagen.	- Lack of space on ground level - A lot of infrastructure in the same point. Future node of the road by-pass
Sollentuna	- Larger population (15000 inh.) - Quite close to Kista area	- Lack of space on ground level
Kista	-Large work area - Land available	-The presence of metro and the future tram might be enough to cover demand

In accordance with all points, Kista option is the most proper to locate the new station. However, we will study the interferences between different kinds of public transport to evaluate the feasibility of a new station in Kista.

Station 6 (link The East Coast Line – By-pass): Kista

3.2.7. Station 7: Connection with Roslagsbanan.

The new station will be exclusively for commuter trains. Due to the different narrow gauge, it is not necessary to build junctions between the lines. Two options will be evaluated: Roslags Näsby and Täby. Since there is no available land on ground, the future station has to be built by a tunnel for all options.

1.-Roslags Näsby: It is a part of Täby municipality and it is dominated by single-family houses. Therefore, the population in the area is low. The main advantage to building the station here is that two branches of Roslagsbanan could be covered in one point, since after Roslags Näsby station the line is separated into two branches.

2.-Täby: It is a locality situated in the municipality of Täby. Approximately 30.000 inhabitants live around the station area. Täby is an important suburb and accordingly there are commercial and public

services in the selected area. At this point, Roslagsbanan has two branches and the idea would be to construct the new station between Tibble (Vallentuna branch) and Täby Centrum (Åkersberga branch).

LOCATION OF THE STATION	ADVANTAGES	DISADVANTAGES
Roslags Näsby	-Both, Vallentuna and Åkersberga branches stop at this station	- Little population - Lack of space on ground level - Just residential function
Täby	- Large number of potential customers - Commercial area (Täby Centrum)	- Two branches - Lack of space on ground level

So, the most appropriate candidate is Täby, albeit the project will be expensive.

Station 7 (link Roslagsbanan – By-pass): Täby

3.2.8. Extra commuter stations.

Until now, we have established the location for seven stations for Alternative 1. Since the new line is to have commuter services, it is advisable to locate stations every 2-4 km. Due to the nature of the new line, which has to work mainly as a complement for existing lines, the distance between stations has been increased to 5-7 kilometers.

In figure 3.5 and table 3.1, the location and the distance between stations are shown. The stretches between Flemingsberg-Handen and Vällingby-Skärholmen are rather long and it could be a possibility to locate commuter stations between each pair.

	Distance to next stop	Distance from start
Handen	12,4	0
Flemingsberg	7	12,4
Skärholmen	11,1	19,4
Vällingby	4,6	40,5
Barkarby	6	45,1
Kista	7	51,1
Täby	0	58,1

Table 3.1. Main stations in alternative 1. Regional and long distance stations in bold letters.

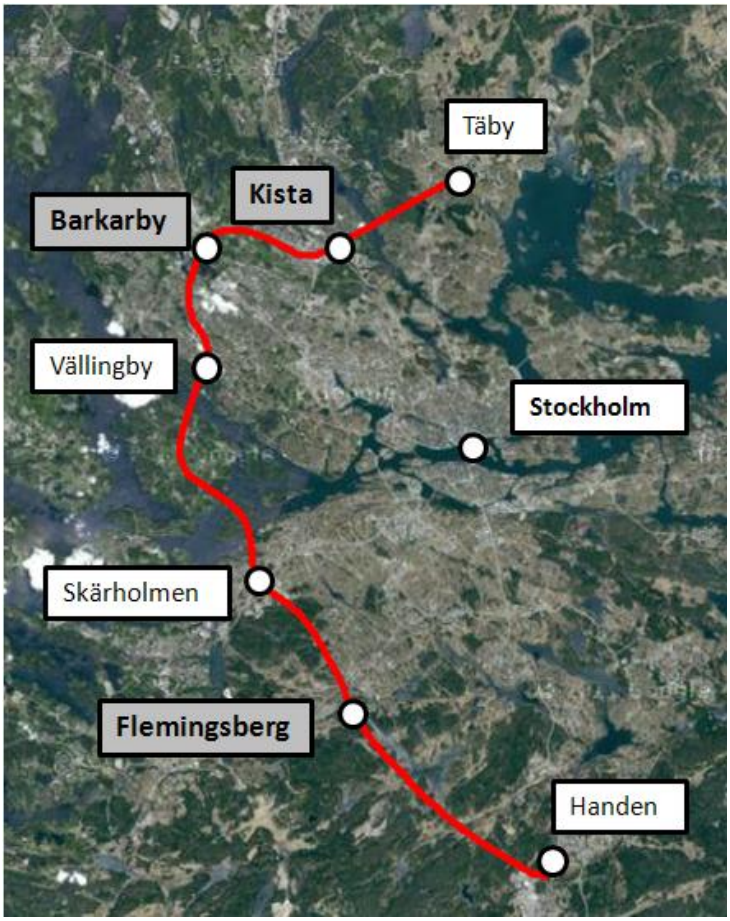


Figure 3.5. Alternative 1. Linking stations. Regional and long distance stations in bold letters.

Complementary station 1: Between Handen and Flemingsberg

The stretch between Handen and Flemingsberg runs through Orlången Nature Reserve, where there are no outstanding human settlements. Therefore, it is not necessary to create a new station in this area, since it would increase the travel time between Handen and Flemingsberg without increasing the accessibility.

Complementary station 2: Between Skärholmen and Vällingby

The new station would be located on the Island of Lovön. This island has no notable population and it has a high environmental value. However, Ekerö municipality, which is situated close to Lovön in the south, has no good connections with Stockholm. Thus, this would be an opportunity to improve Ekerö accessibility.

The connection between Ekerö and a new station at Lovön would be made by bus. In consequence, it would be necessary to create new bus lines to link the two of them.

Figure 3.6. Lovön Station

3.2.9. Route

Therefore, the final configuration of Alternative 1 will encompass 8 stations. The sketch and the distances between the stops are shown below.

	Distance to next stop (km)	Distance from start (km)
Handen	12,4	0
Flemingsberg	7	12,4
Skärholmen	4,2	19,4
Lovön	6,9	23,6
Vällingby	4,6	40,5
Barkarby	6	45,1
Kista	7	51,1
Täby	0	58,1

Table 3.2. Stations of alternative 1. Regional and long distance stations in bold.

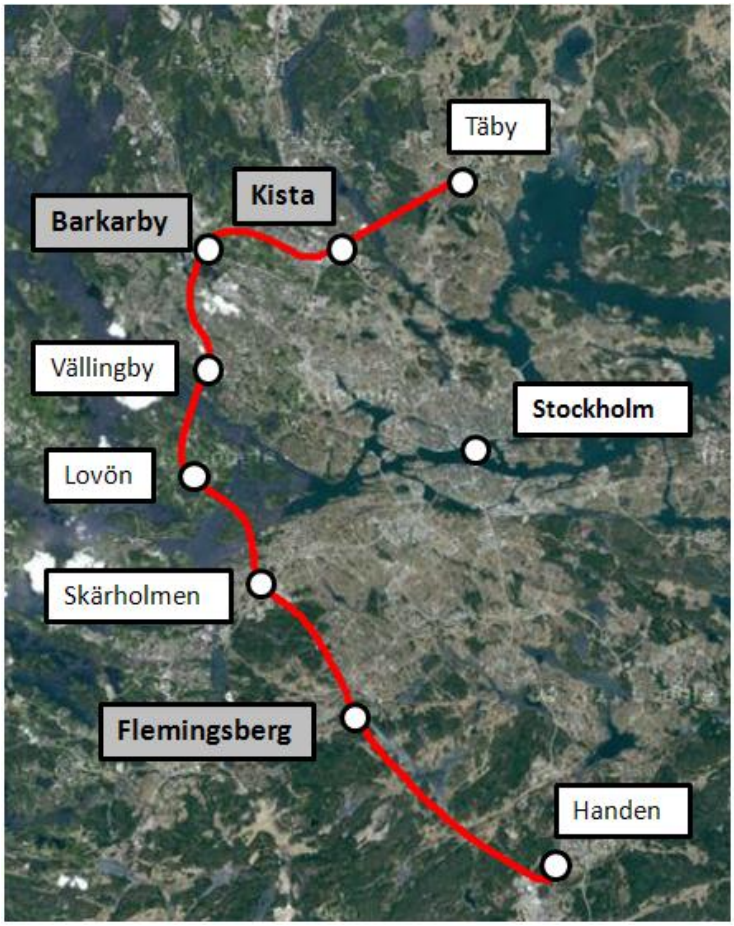


Figure 3.7. Exterior alternative. Definitive route.

3.3.- Alternative 2

The second alternative concerns a short ring through the western parts of Stockholm centre. The stations will be located between 5 and 10 kilometers from the centre of Stockholm. It means that this alternative would have to be built mostly by tunnel for the reason that it crosses densely urbanized areas.

There are several stations that have to be included in the alternative. Those are the ones which allow interchanges with the main lines, i.e. junctions with:

- The South Main Line – Nynäshamn Line (commuter, regional and long-distance trains)
- Mälarbanan (commuter, regional and long-distance trains)
- The East Coast Line (commuter, regional and long-distance trains)
- Roslagsbanan (commuter trains)
- Metro´s red line (commuter trains)
- Metro´s green line (commuter trains)

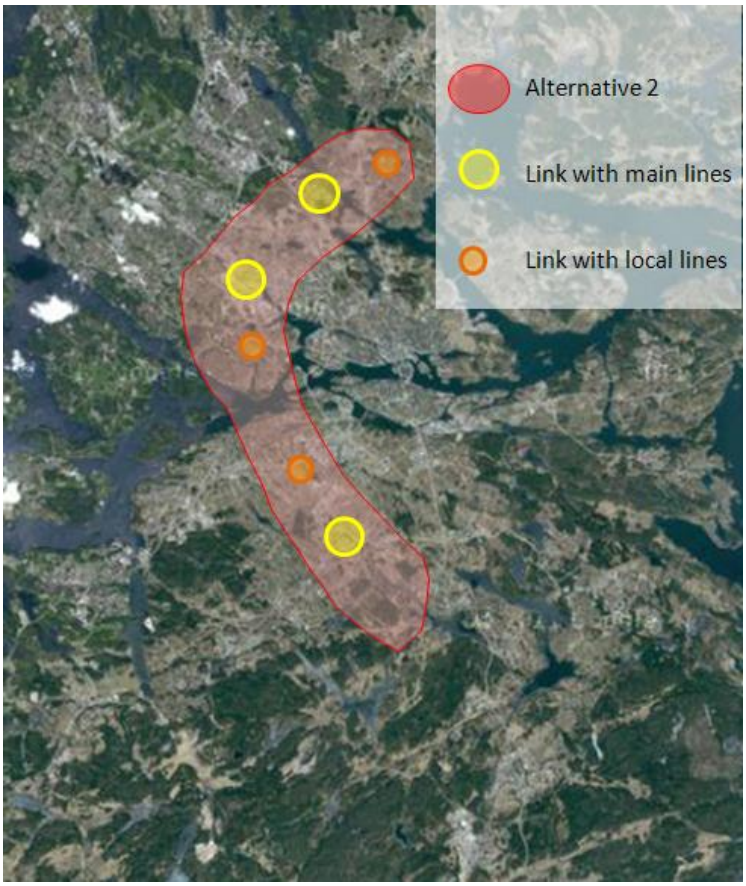


Figure 3.8. Alternative2. Study area and approximate location of some stations.

Below the location of the stations will be established in the same way that was done with the first alternative.

3.3.1. Station 1: Link with The South Main Line / Nynäshamn line

A new station has to able to work with commuter, regional and long-distance trains. The most suitable location to this end is the station in Älvsjö. There are several reasons:

- Älvsjö is an important place where Stockholm International Fairs is situated.
- The commuter trains depot is located next to the station.
- Both Nynäshamn Line and The South Main Line share Älvsjö as their station
- It would be a good place for diverting regional and long distance traffic from Stockholm Central since it is just 6 kilometers to the north of Älvsjö.

Another option is to build two stations, one on the Nynäshamn Line and another one in The South Main Line. For example, those stations might be situated in

Farsta Strand and Huddinge. However, this alternative would be pretty much more expensive and it does not improve the effects.

Seeing it is necessary to construct some junctions between lines and the station it has to be able to support a large number of trains per day, the requirements of space are noticeable. It is possible to find some pieces of land undeveloped next to the station (figure 3.9), but since the large space required, some parts of the project would have to be built by a tunnel.

In conclusion, the first station which will connect a new by-pass and the the South Main Lines will be situated in Älvsjö.

Figure 3.9. Älvsjö

Station 1 (link The South Main Line – By-pass): Älvsjö

3.3.2. Station 2: Link with Metro Red line

The new station will be earmarked for commuter trains only. There are several candidates to locate the station. The new by-pass would cross two metro Red line branches, i.e. the branch to Norsborg and the one to Fruängen.

The Norsborg branch is longer towards the south than the Fruängen branch; consequently, the first one is able to cover a larger number of potential customers.

Two alternatives will be assessed:

- Telefonplan
- Aspudden

1.-Telefonplan: This station is situated in Hägersten borough. Next to the station is the University College of Arts and a lot of construction and urban projects are being developed in the area. Telefonplan is located on the Fruängen branch of the red line.
Moreover, there is available land to build the station on ground level.
2.-Aspudden: It is a station located in Aspudden borough. This is a residential borough but there are some work centres as well. In addition, Aspudden is a Norsborg branch station, thus it is able to attract more passengers.

LOCATION OF THE STATION	ADVANTAGES	DISADVANTAGES
Telefonplan	-University College of Arts -Growing area. Several projects are being studied.	-Little population - Fruängen branch (shorter than Norsborg branch)
Aspudden	- Norsborg branch (longer than Fruängen branch)	- Little population - Mostly residential borough

To sum up, both Telefonplan and Aspudden, present advantages and disadvantages, and a priori they are adequate for locating the station. However, Telefonplan has a huge developmental potential, hence it will be our choice.

Station 2 (link Metro red line – By-pass): Telefonplan

3.3.3. Station 3: Link with Metro´s Green line

The new station will set aside for commuter trains only. The Metro Green line runs from the centre of Stockholm towards the west. The new by-pass would cross the Green line in the area around Alvik. Therefore, Alvik station and Stora Mossen station will be evaluated in this chapter as possible locations for this link.

From the point of view of local transport, it is important to take into account the circumstance that the tram (Tvärbanan) will run parallel to the by-pass in this area. Due to this fact, both the tram and the new by-pass could overlap, i.e. cover the same market sector.

1.-**Alvik:** Nowadays, Alvik is a pivotal point in the Stockholm local transport system. Here, both Nockebybanan and Tvärbanan begin. Tvärbanan is being extended towards the north to Solna. In the station vicinity, there are mainly simple-family houses and there are no remarkable working areas. Since, it is not necessary to build joints between lines, the most proper solution is to locate the new station underground.

2.-**Stora Mossen:** It is a station situated close to Alvik. Stora Mossen does not have a large number of potential customers, and it does not have connections with other lines of the system (except the metro Green line). However, next to Stora Mossen station there is land available for building the station.

LOCATION OF THE STATION	ADVANTAGES	DISADVANTAGES
Alvik	-Tvärbanan station -Nockebybanan station -Large potential as local transport node	-New by-pass could compete with Tvärbanan
Stora Mossen	-Land available to build the station on the ground	-Little customers potential

Alvik presents important advantages from accessibility standpoint. Since most of the Alternative 2 route would have to run under ground, the availability of undeveloped land is not a crucial factor. So, Alvik is the option chosen.

Station 3 (link Metro green line – By-pass): Alvik

3.3.4. Station 4: Link with Mälarbanan

This station has to be able to support commuter, regional and long distance trains. Moreover, junctions between the new line and Mälarbanan will be necessary. Those facts make it indispensable to have a large area to build infrastructure. The zone studied does not have enough available land on the ground level, thus the future station will be built under ground.

Sundbyberg has been selected to house the new station. There are no other feasible options since Mälarbanan´s closest stations (Spånga and Karlsberg), are outside of the study area.

Sundbyberg has around 35.000 inhabitants and all its territory has an urban nature. However, Sundbyberg is not a dormitory suburb, seeing it has a large number of workplaces. This fact produces important flow of commuters every day.

Nevertheless, as happens in Alvik, the extension of Tvärbanan is being constructed in this area. Therefore, we will have to study how both, a new by-pass and tram could interact.

Station 4 (link Mälarbanan– By-pass): Sundbyberg

3.3.5. Station 5: Link with The East Coast Line

Linking a station with The East Coast Line, as previous one, has to support several railway services like commuter and regional. Moreover, junctions between existing and new lines are necessary as well. Thus, it is essential to have enough land to build new infrastructure.

The new line could connect with The East Coast Line at two different points: Solna towards the east and Ulriksdal towards the north. Below, the options are deep- analyzed to assess their advantages and disadvantages.

1.-Solna: It is undoubtedly the most proper location from an accessibility and supply perspective, since it is an important suburb of Stockholm that generates a lot of travels every day.
Solna is a municipality where around 65.000 inhabitants live. Råsunda, Hagalund and Huvudsta districts, where most of the people live, are situated close to Solna commuter station. In addition, Solna Centrum, where both an important commercial area and a metro station are located, is situated close to Solna commuter station.
The extension of the tram line (Tvärbanan) will have a stop next to Solna railway station.
A large depot of commuter trains is located next to the station. The depot area could be transformed into the new station but would presuppose a remarkable modification in the railway operation in Stockholm.

2.-Ulriksdal: It is a commuter station situated a kilometer towards the north of Solna station. The area around the station has not many buildings and it is possible to get a big piece of undeveloped land next to today´s commuter station. Moreover, Ulriksdal station is close to the commuter trains depot area.
In addition, the location is ideal for extension of the new line towards Roslagsbanan.

LOCATION OF THE STATION	ADVANTAGES	DISADVANTAGES
Solna	-Tvärbanan station -Big residential area - Large number of workplaces -Large potential as local transport node - Proximity to train depot	-New by-pass could compete with Tvärbanan - Lack of space available. However trains depot could be transformed
Ulriksdal	-Land available to build a big station on the ground -Large potential as regional/long distance station due to available land - Ideal to extend the by-pass towards east,	- Non metro or tram connections - Little population around the station.

In conclusion, both options present interesting advantages. However, Ulriksdal will be selected. The most important reason is the available land that could be used to build the new regional / long distance station. In addition, Ulriksdal is not distant to the centre of Stockholm and thus it could work quite well as a northbound distance node.

Moreover, Solna has many local transport equipments so, building the new station there, does not improve the supply very much. We have to take into account that we are to locate a new by-pass station in Sundbyberg, and it should be enough to cover the Sundbyberg-Solna demand.

Station 5 (link The East Coast Line – By-pass): Ulriksdal

3.3.6. Station 6: Link with Roslagsbanan – Metro Red Line

This station would be the end of the line and would have only commuter function. Therefore, junctions between lines are not necessary (in addition, the lines have different track gauge). There is only one Roslagsbanan station in the area studied. It is Mörby and it presents a lot of good features.

The station of Mörby is situated in Danderyd municipality, more specifically next to the hospital (Danderyd Sjukhus). In the same area there are a metro station (Danderyd Sjukhus; Red line) and an important bus station. From this station, a lot of bus lines go to the northern suburbs. There is lack of space on ground level and not so many people live in the proximity of the station.

Station 6 (link Roslagsbanan – By-pass): Mörby

3.3.7. Route

The second alternative will encompass 6 stations: Älvsjö, Telefonplan, Alvik, Sundbyberg, Ulriksdal and Mörby. The figure and the table below show the sketch and the distances between stations.

	Distance to next stop (km)	Distance from start (km)
Älvsjö	3	0
Telefonplan	4	3
Alvik	4,2	7
Sundbyberg	3,4	11,2
Ulriksdal	2,7	14,6
Mörby	0	17,3

Table 3.3. Stations of alternative 2. Regional and long distance stations in bold.

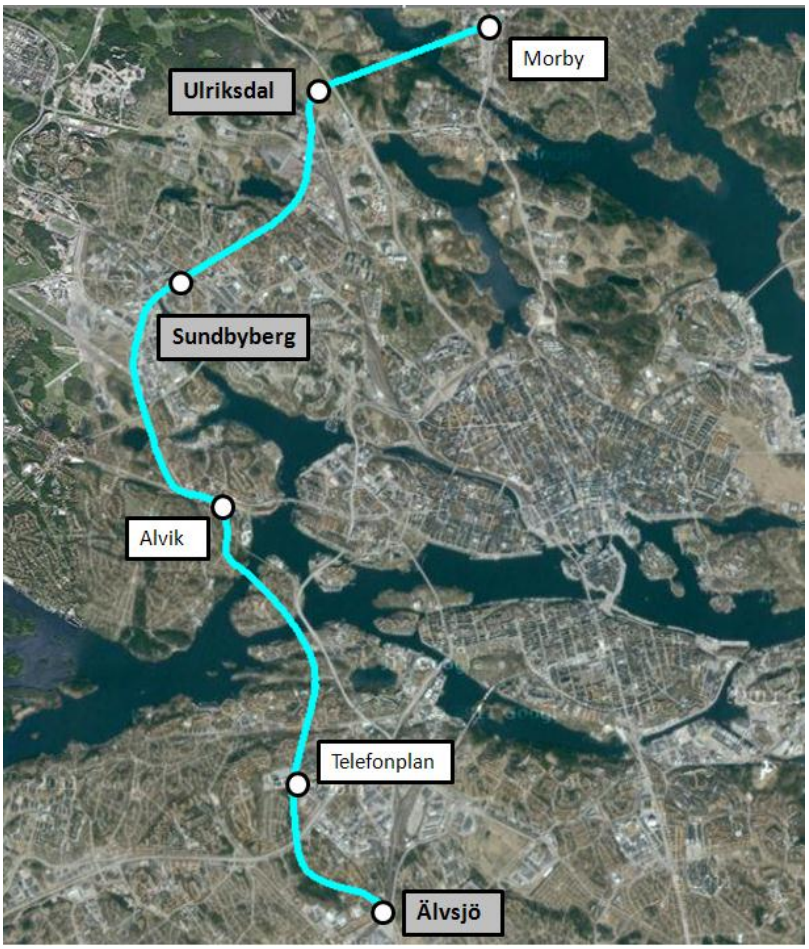


Figure 3.10. Interior Alternative. Definitive route.

3.4.- Alternative 3

Finally, the third alternative would run through Stockholm municipality. This option is the shortest one and it would serve mainly to reduce the traffic at Stockholm Central station, since, a priori, it does not improve very much the travel times in the direction south-north.

This alternative will have four stations, but only two of them would have regional and long distance functions. These two stations will link the new line with the main railway lines in Stockholm, i.e. The South Main Line in the south and Mälarbanan-The East Coast Line in the north.

We are going to include two commuter stations as well. They would allow customer interchange between the new line and metro lines.

Figure 3.11. Alternative 3. Study area and approximate location of some stations

Below, as was undertaken with the other alternatives, an analysis of possible locations for the stations will be made.

3.4.1. Station 1: Link with The South Main Line / Nynäshamn Line

As explained above, this station would be able to operate with commuter, regional and long distance trains. Moreover, it is necessary to connect the new line with The South Main Line in order to allow for trains changing the line. Due to these facts, a big surface area will be required.

Two different locations for the station will be evaluated: Älvsjö and Årstaberg. Although Älvsjö has been studied in the previous alternative (Alternative 2), Årstaberg has to be studied here.

> 1.-Älvsjö: it is an important place where the Stockholm International Fairs is situated. A commuter train depot is located next to the station as well, and it could be used to build the new infrastructure. Moreover, it is possible to find some pieces of undeveloped land next to the station, but since a large space is required, some parts of the project would have to be built by a tunnel.
> 2.-Årstaberg: Nowadays, it is possible to find a commuter stop in Årstaberg and a Tvärbanan station. In addition, next to the station, an important freight terminal is situated which provides services to the adjacent industrial park. There is a strip of available land between The South Main Line and the terminal that could be used to locate the future station. However, it could be that it is not enough and as a consequence it would be necessary to obtain a larger surface area.

LOCATION OF THE STATION	ADVANTAGES	DISADVANTAGES
Älvsjö	-Stockholm International Fairs -Commuter trains depot (it could be transformed in the new station)	-It is further from Stockholm´s centre than Årstaberg -Lack of connections with other lines
Årstaberg	-Connection with Tvärbanan -Large freight terminal -Big industrial park next to the station -It is closer from Stockholm´s centre than Älvsjö	- A lot of infrastructure (highways, tracks) built in this area

All these facts taken together, Årstaberg is the most proper option.

Station 1 (link The South Main Line – By-pass): Årstaberg

3.4.2. Station 2: Link with Metro Red Line

On the way towards the north the new line crosses Liljeholmen. It is a district in southern Stockholm where metro lines 13 and 14 (Red) and Tvärbanan have a stop. Since Liljeholmen has good connections with the local railway system; it would be a good option to construct a commuter station here.

Hornstull in Södermalm would be another option, but it offers worse connectivity with the public transport system.

Station 2 (link Metro Red Line – By-pass): Liljeholmen

3.4.3. Station 3 Link with Metro Green and Blue Lines

There is a possibility to link with both, the green and the blue line if we locate the station in Fridhemsplan. This fact entails diverting the route towards the centre, but improves noticeably the number of potential customers.

Moreover, there are some different possibilities like Thorildsplan (green line) or Stadshagen (blue line) but they are small metro stations that would not contribute significantly to the improvement of services.

If we locate the station in Fridhemsplan, the building work will be complicated, and it would be by tunnel. Since Fridhemsplan is situated in the centre of the city, the cost of the project would be rather high, and thus the effects of constructing the new station have to be very positive to make it feasible.

Station 3 (link Metro Green and Blue Lines – By-pass): Fridhemsplan

3.4.4. Station 4 Link with Mälarbanan and The East Coast Line

Owing to the fact that we have located the previous station in Fridhemsplan, there are two places on the northern main lines where the future northern main station could be situated. They are Solna and Tomteboda.

> 1.-Solna: Today there is a good commuter station at this place. In addition, there are plans to upgrade the station. Therefore, it could be a good place to locate a new station which operates with commuter, regional and long-distance services.
> However, the connection between by-pass and the existing line would have to be made in Tomteboda in order to avoid the building of parallel lines.
> From the regional traffic perspective, the combination of Sundbyberg in Mälarbanan and Solna in The East Coast Line would be quite interesting in view of the fact that there are two good stations already built.

2.-Tomteboda: Future Citybanan runs from Tomteboda to Odenplan, so all the trains from the north have to pass through its tracks. Today there is a big rail post terminal in Tomteboda which takes up a large surface area. If this post terminal is moved to another place, the available space will be ideal for locating the future station.
Moreover, the freight line that runs towards the harbor in Värtan, connects with main lines in Tomteboda. Owing to the fact that the freight traffic will be eliminated in this line, the free tracks could be improved to extend the by-pass towards Roslagsbanan.

LOCATION OF THE STATION	ADVANTAGES	DISADVANTAGES
Solna	-There is a good station built, and there are plans for re-built it. -Area next to the station is densely populated. -Under the point of view of regional services Solna and Sundbyberg could be an interesting combination	-The by-pass would connect in Tomteboda, 2 kilometers towards south.
Tomteboda	-Connection with Citybanan -Possibility to extend By-pass towards Roslagsbanan	-It is necessary to move the post terminal to other place -There is not a commuter station in Tomteboda today.

Since Solna has already a developed infrastructure and due to the large population who lives in this area, it has been selected as the most proper location. In this way, the connection will take place in Tomteboda, but the station will be located in Solna.

Station 4 (link Mälarbanan and The East Coast Line – By-pass): Solna

3.4.5. Route.

Alternative 3 has four stations. Below, figure 3.12 and table 3.4 display the sketch of the route and the distances between stations.

	Distance to next stop (km)	Distance from start (km)
Årstaberg	2	0
Liljeholmen	3,5	2
Fridhemsplan	3,5	5,5
Solna	0	9,5

Table 3.4. Stations of alternative 3. Regional and long distance stations in bold.

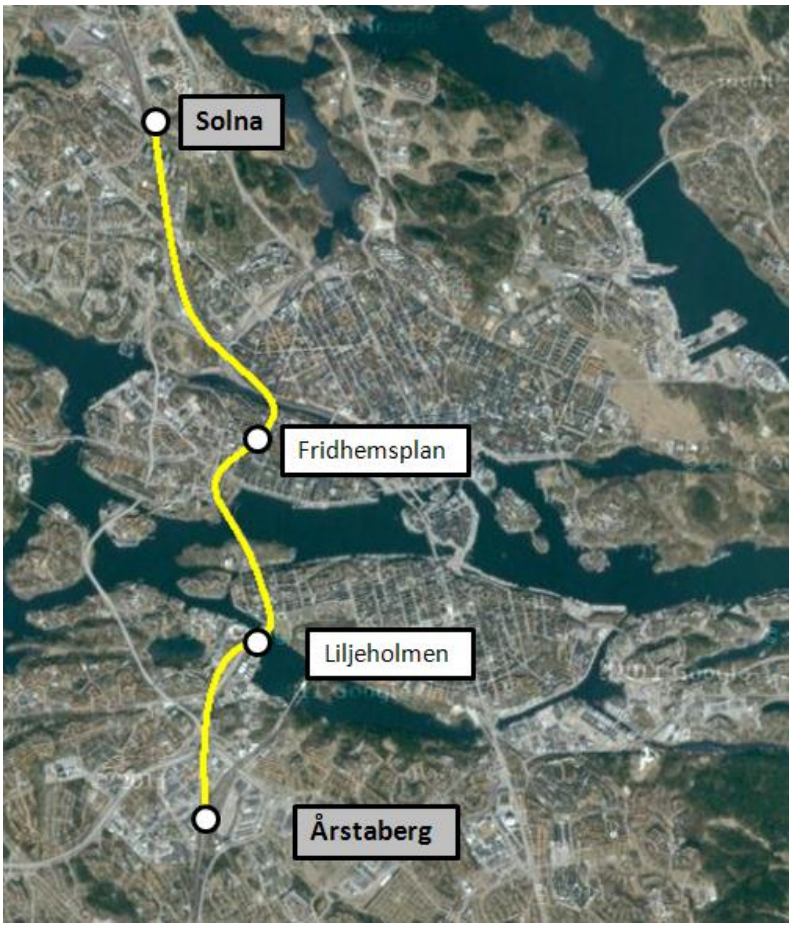


Figure 3.12. Central Alternative. Definitive route.

4 Analysis of Effects on Local Traffic

4.1 Introduction

In this chapter, the effects that alternatives would have on the railway local traffic system in Stockholm are analyzed. This analysis will be made on the basis of accessibility considerations which have been widely used to evaluate the project alternatives.

To do this, it is important to evaluate travel times and how they would change if each alternative is built. Moreover, workplaces and population have been used to establish the relative importance of each area in the territory.

This thesis will focus on some destinations that have great significance in the commuter system, i.e. places that generate large flows of commuter traffic for the reason that they are work areas. Travel times analysis is made in the rush hour (7:00-9:00am) since it is when the network has major traffic flows.

The travel times will be analyzed in 2030. Since we have data about travel times in today´s network, we have to modify them to get admissible values for 2030. It means that we have to take into account the improvements in the network like new signaling systems, new trains, improved infrastructure, etc.

These improvements will increase, in some cases, the capacity, the frequency and the service speed of the lines, and for this reason the travel times will be reduced. In this thesis, travel times will be modified by the use of corrector factors.

Moreover, new infrastructure will be operating in 2030 like for example Citybanan or new Tvärbanan lines. The travel times and the frequency of these lines have been obtained from the respective document projects.

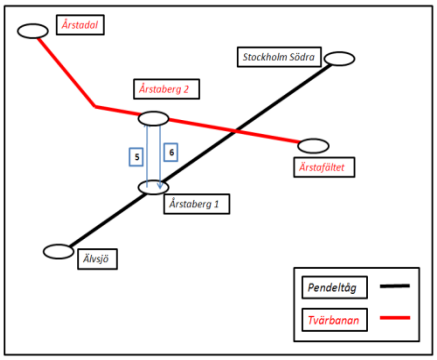
4.2 Model. Stockholm´s Local Railway Network in 2030.

4.2.1. Introduction

To analyze the effects on the local railway system the network has been modeled. This model includes the next lines:

- Stockholm commuter lines: J35; J36; J37; including Citybanan
- Stockholm metro lines: red; green; blue.
- Tvärbanan: extension towards Solna included
- Nockebybanan
- Roslagsbanan

They are the lines which interact with the different by-pass alternatives. The lines are modeled as a nodal network where each station is represented as a node. In addition, the connections between the different lines are included. All this information can be represented by a connection matrix, which represents both the "real" (physical network connections, i.e. nodes linked by tracks) and the "virtual" (interchanges between lines, represented in the model by waiting times). Below, figure 4.1 shows a sketch of the model.



	Stockholm Södra	Årstaberg 1	Älvsjö	Årstafältet	Årstaberg 2	Årstadal
Stockholm Södra	0	**3**	0	0	0	0
Årstaberg 1	**3**	0	**3**	0	5	0
Älvsjö	0	**3**	0	0	0	0
Årstafältet	0	0	0	0	**1**	0
Årstaberg 2	0	5	0	**1**	0	**2**
Årstadal	0	0	0	0	**2**	0

Figure 4.1. Model sketch and connections matrix example.

The figure above represents a connections matrix. The bold numbers (red and black) represent the real connections. For example, the travel time between Årstaberg and Älvsjö is 3 minutes.

Moreover, the shaded numbers represent the connections or interchanges between the lines. In this example, it is possible to change between Pendeltåg and Tvärbanan at Årstaberg. The numbers in the matrix represent the waiting time, i.e. half of the frequency in rush hour.

When the model is defined, i.e. the connections matrix represents the travel times and the frequencies properly, it is possible to obtain the travel times between all the origin-destination pairs by using an adequate algorithm. Moreover, the by-pass alternatives can be included in the network by defining new connections. In this way the different effects can be analyzed.

In order to obtain the shortest path between all origin-destinations pairs, the Floyd – Warshall Algorithm has been implemented in MATLAB.

This algorithm provides only the cost, in this case time, of the shortest route. Therefore, the algorithm does not give information about the route, i.e. the stations visited. This information could be really important in several studies, but it is not our case. Since we want to obtain the effects of the new line; we are going to compare Alternative 0 (without by-pass) with the different by-pass alternatives. Therefore, all changes that the results show are due to new links. The figure below shows the program output for the previous example:

	Stockholm Södra	*Årstaberg 1*	*Älvsjö*	*Ärstafältet*	*Årstaberg 2*	*Årstadal*
Stockholm Södra	0	**3**	0	9,00	8,00	10,00
Årstaberg 1	**3**	0	**3**	6,00	5,00	7,00
Älvsjö	0	**3**	0	9,00	8,00	10,00
Ärstafältet	9,00	6,00	9,00	0	**1**	3
Årstaberg 2	8,00	5,00	8,00	**1**	0	**2**
Årstadal	10,00	7,00	10,00	3	**2**	0

Table 4.1. Algorithm output example.

In Appendix 1, there are both, an explanation about the running of algorithms and the implemented code in MATLAB.

After obtaining the results, some territorial units have been defined in order to compare the alternatives. These units are mainly municipalities in the Stockholm area, but the Stockholm municipality has been divided into 14 districts to obtain more information. The table below shows the defined territorial units and their features.

Territorial Unit	Population 2030	Workplaces 2030
Sigtuna	44900	25152
Upplands-Bro	30600	7571
Upplands-Väsby	48600	14274
Vallentuna	50300	7741
Järfälla	89200	22191
Sollentuna	75100	23417
Danderyd	35300	116242
Österåker	54800	9415
Täby	78200	22227
Sundbyberg	39600	20132
Solna	81000	70777
Kista-Rinkeby (Stockholm)	47382	35086
Spånga-Tensta (Stockholm)	38708	11897
Hässelby-Vällingby (Stockholm)	67182	14010
Bromma (Stockholm)	74513	29386
Kungsholmen (Stockholm)	66095	55362
Norrmalm (Stockholm)	56221	102604
Östermalm (Stockholm)	71171	76307
Gamla Stan (Stockholm)	10121	24580
Södermalm (Stockholm)	122372	76780
Liljeholmen (Stockholm)	46110	29155
Årsta (Stockholm)	19792	3247
Enskede (Stockholm)	33194	23826
Skarpnäck (Stockholm)	44054	8885
Skärholmen (Stockholm)	33655	8143
Hägersten (Stockholm)	36080	6775
Älvsjö (Stockholm)	26704	9660
Vantör (Stockholm)	38783	7498
Farsta (Stockholm)	54564	13705
Botkyrka	111400	21833
Huddinge	112700	40714
Haninge	106400	23984
Salem	25100	2838
Södertälje	103800	44684
Nynäshamn	35300	7003
TOTAL	**2009000**	**1017101**

Table 4.2. Territorial Units defined. Features

4.2.2.- Model Data

To implement the model it is necessary to have some data about the network: travel times and frequencies. If this data is available, it is possible to complete the connections matrix and thereafter run the algorithm.

Since the idea is to represent the network in 2030, it is necessary to take into account the improvements of the network. As explained above, these improvements in the network will be considered by correction factors.

It is important to underline that some improvements, like new trains, are not being assumed. This is for the reason that they affect the entire network and as a consequence, they do not modify the network behavior.

Several railway lines involved in the study will be upgraded before 2030. Mälarbanan will be a four-track line between Tomteboda and Kallhäll. It means that commuter services will be separated from the rest of the trains. It will enable an increase in the capacity and as a result an increase in the service frequency.

Regarding Roslagsbanan, some stretches will be double-track. Particularly, Roslagbanan will be a double-track line from Stockholm to the main nodes: Åkersberga and Vallentuna. These improvements have as main objective to schedule commuter trains every 10 minutes. The project is organized in some phases which will be finished before 2030.

In addition, new infrastructure is included in the model. The transverse tram line (Tvärbanan) will be extended from Alvik to Solna. Since it is in the process of being under construction, the new stations are included in the model.

The City Line is the most important infrastructure project developed in Stockholm in recent years. It will allow for both increasing the capacity of Stockholm Central (Stockholm Central / Stockholm City) and a complete separation from commuter trains in the stretch between Tomteboda and Stockholm Södra. However, forecasts announce that a capacity limit will be reached in decade of the 2030s (Nelldal, Lindfeldt and Fröidh, 2010).

Finally, the signaling system upgrade has been considered for all the lines. The assumption made is that all lines will have ETCS level 2 in 2030. It means that capacity will be increased for the upgraded lines and thus travel times on these lines have been modified.

The travel times assumed in each line are attached in Appendix 2. In addition, the frequencies utilized in the model can be found in the same appendix.

The by-pass alternatives have to be included in the model in order to assess the effects on travel times and accessibility. Therefore, it is necessary to establish travel times in these new stretches.

The methodology used to obtain the travel times in the new links is to compare similar length existing lines. The existing stretches that have been utilized to establish by-pass alternatives travel times are attached in Appendix 3.

The tables 4.3, 4.4, and 4.5 show the travel times assumed for each alternative.

Alternative 1:

Alternative 1	Travel times(min)							
	Handen	**Flemingsberg**	**Skärholmen**	**Lovön**	**Vällingby**	**Barkarby**	**Kista**	**Täby**
Handen		7,8						
Flemingsberg	7,8		4,9					
Skärholmen		4,9		3,6				
Lovön			3,6		4,9			
Vällingby				4,9		3,9		
Barkarby					3,9		4,5	
Kista						4,5		4,9
Täby							4,9	

Table 4.3. Alternative 1. Travel times assumed for commuter trains

Alternative 2:

Alternative 2	Travel times (min)					
	Älvsjö	**Telefonplan**	**Alvik**	**Sundbyberg**	**Ulriksdal**	**Mörby**
Älvsjö		3,3				
Telefonplan	3,3		3,5			
Alvik		3,5		3,6		
Sundbyberg			3,6		3,3	
Ulriksdal				3,3		3,3
Mörby					3,3	

Table 4.4. Alternative 2. Travel times assumed for commuter trains

Alternative 3:

Alternative 3	Travel times (min)			
	Årstaberg	**Liljeholmen**	**Fridhemsplan**	**Solna**
Årstaberg		2,8		
Liljeholmen	2,8		3,1	
Fridhemsplan		3,1		4,8
Solna			4,8	

Table 4.5. Alternative 3. Travel times assumed for commuter trains

4.3.- Analysis of accessibility changes

4.3.1.- Indicators

To compare and evaluate the results, some accessibility indexes have been calculated. Each one allows analyzing different aspects of the network, and thus they are complementary.

- **Location Indicator**: This indicator shows the average weighted travel time between one municipality and all the others defined. The indicator used to represent the weight of each territorial unit could be for example the population, the GDP, or the number of workplaces in each area. Since in this chapter, the analysis is made to local transport, the number of workplaces has been utilized, following the recommendations of Martin et alt (2004).
  Location Indicator is a good tool to evaluate the accessibility differences between central and peripheral areas. Therefore, is interesting to calculate the index for the different alternatives and compare the results.
  The expression of the Location Indicator is:

$$L_i = \frac{\sum_{j=1}^{n} t_{ij}\,\mathrm{gdp}_j}{\sum_{j=1}^{n} \mathrm{gdp}_j}$$

Where:

$$L_i = locationindicator\_node(i)$$

$$t_{ij} = traveltime\_stretch(i, j)$$

$$gdp_j = weight\_indicator\_node(j)$$

- **Daily Accessibility Index**: It is an indicator that enables to quantify the number of inhabitants who are able to reach one destination in less than a determinate time. In this thesis, the time used is 45 minutes due to it is a proper duration for commuter trips.

$$\mathrm{DA}_i = \sum_{j=1}^{n} P_j \delta_{ij}$$

Where:

$$DA_i = daily\_accesibility\_node(i)$$
$$P_j = population\_node(j)$$
$$\delta_{ij} = 1(if\ \_t_{ij} < 45); 0(otherwise)$$

4.3.2.- Alternative 1

To model the alternatives, it is necessary to establish travel times between the new stations. As it is explained above, these travel times are obtained by comparison with existing stretches which have similar length. The travel times assumed are showed in the table 4.3.

It is important to emphasize that Lovön station is not included in the model. The main reason in that nowadays, Ekerö municipality is not included in the railway network, and thus is not possible to compare the different scenarios. However, the accessibility indexes have been calculated separately comparing new travel times with today bus travel times.

After the new stations and the new connections are defined, the new travel times are obtained. Then it is possible to compare the results for the network with and without By-pass. The different indicators have been calculated by defining two different frequencies in the new line in order to evaluate the influence of this factor. In addition it is important to study different frequencies due to other services (like regional or long distance trains) could operate in the line.

The assessed frequencies are:

- 5 trains/hour/direction
- 10 trains/hour/direction

-Location Indicator:

The graph shows the percentage of variation by comparing Alternative 1 with the Alternative 0, i.e. the network without the By-pass. In this case, the indicator shows that peripheral suburbs like Järfalla (west) or Täby (north), get to improve their accessibility more than 20% in the high frequency scenario. The rest of peripheral suburbs improve notably their accessibility as well. However, most of the Stockholm City districts do not vary so much the indicator values. In this group, some important work areas are included like Kista-Rinkeby or Solna.

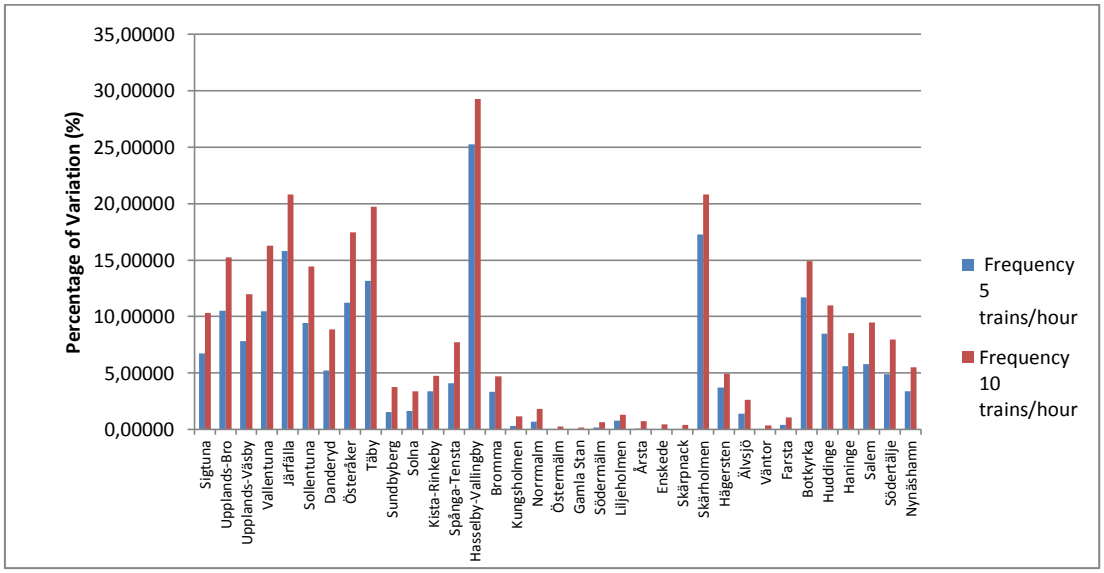


Figure 4.2. Alternative 1 graph. Variation of Location Indicator (%).

It is important to remember that one of the objectives of the new infrastructure (By-pass), is to improve the mobility between south and north suburbs. One of the crucial pieces in this system is the area around Solna and Kista where a lot of workplaces are situated. Despite one of the new stations is located in Kista, this alternative does not get to reduce notably the travel times.

The following maps (figures 4.3 and 4.4) show the same data that the previous graph, i.e. the variation of Location Indicator. The graphical information allows appreciating the spatial effects of the new line.

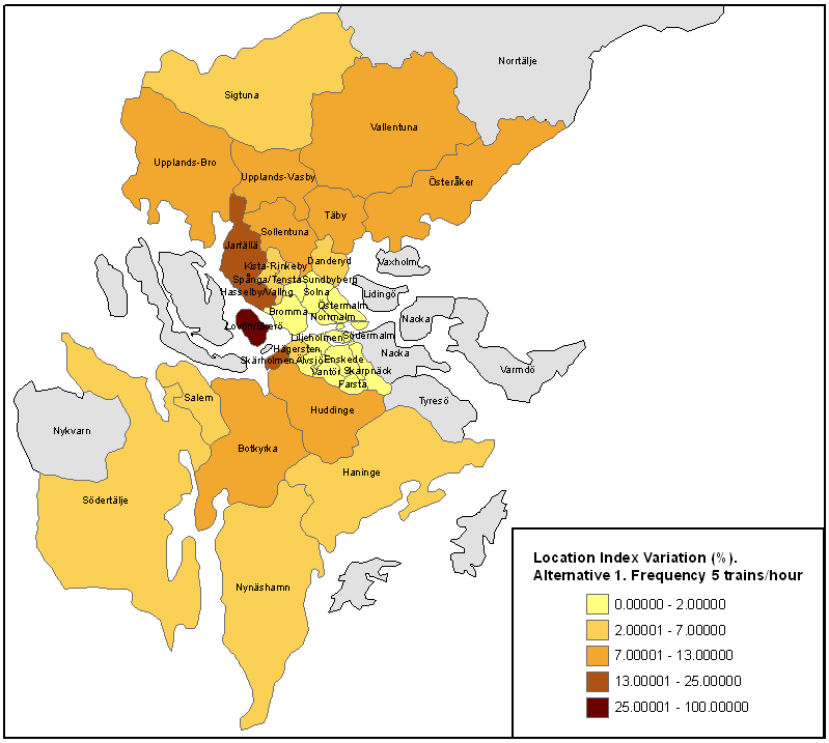


Figure 4.3. Alternative 1. Variation of Location Index in Stockholm area. Frequency 5 trains/ hour.

As we indicated above, the Location Indicator can be interpreted as a measure of the differences between central and peripheral areas, i.e., it is an indicator of the centrality of a determinate area. Following this reasoning, this alternative produces an improvement in the network centrality, since all the peripheral suburbs improve their indicators and the central areas remain in the same situation.

This effect is notably higher in the high frequency scenario (figure 4.4), specially in the north suburbs, where most of the areas increase their accessibility more than 15%.

The values of Location Indicator for Ekerö (represented in maps by Lovön island) are included in the maps. They have been obtained comparing the new travel times (with By-pass) with today bus services. This alternative enables to improve a lot the travel times between Ekerö and the rest of the Stockholm Län.

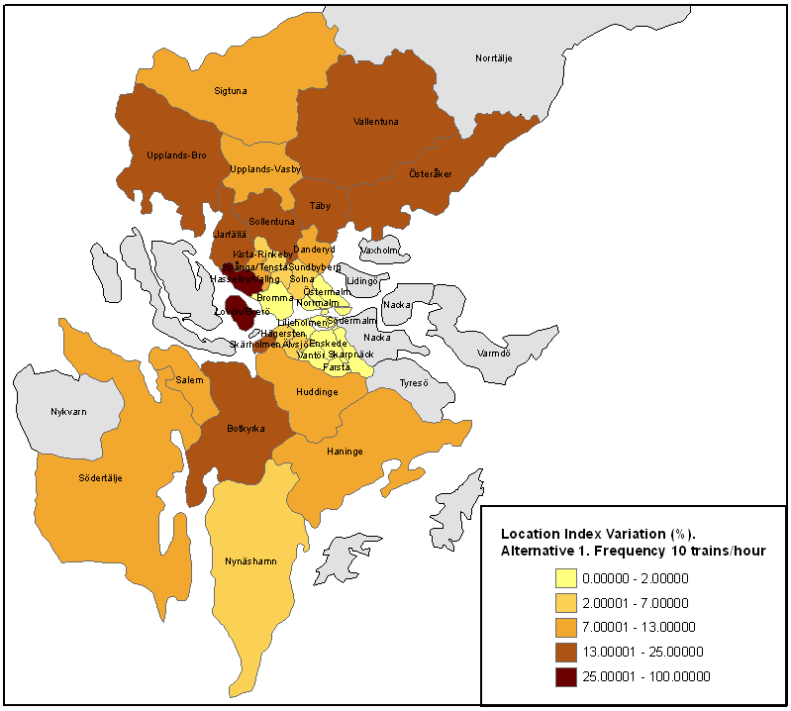


Figure 4.4. Alternative 1. Variation of Location Index in Stockholm area. Frequency 10 trains/ hour.

In order to analyze properly the trips between north and southern suburbs, the indicator has been calculated excluding the central areas. In this way, the results show better the flow between peripheral suburbs.

The indexes have been calculated taking in account the trips between one node and the nodes situated in another side. For example, to calculate the Huddinge indicator, only the north suburbs have been included in the formula.

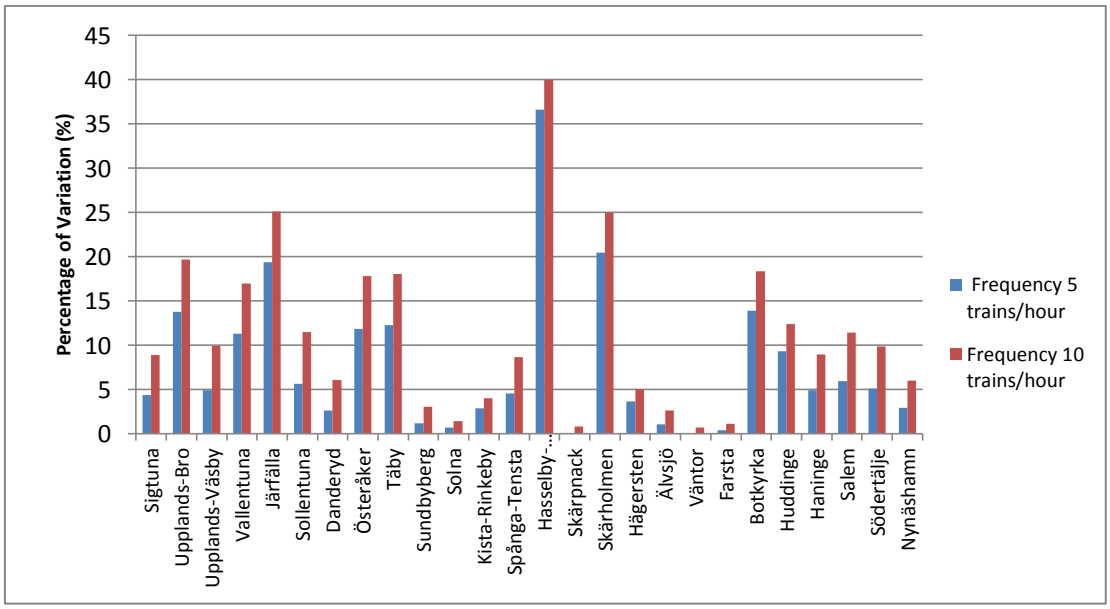


Figure 4.5. Alternative 1. Variation of Location Indicator between north and southern suburbs (%).

The peripheral suburbs present high improvements in their accessibility to the other peripheral suburbs. It is remarkable that northern suburbs obtain better results than the southern suburbs.

In addition, Hässelby – Vällingby and Skärholmen are largely favored due to the presence of a new station in their areas.

However, the districts situated close to Stockholm centre do not vary their indexes so much. This fact is probably due to the existence of metro services in their vicinity which produces hard competition between lines.

Regarding the differences between frequency scenarios, it is worth noting that high frequency (10 trains/hour) improves accessibility considerably. This fact may be seen especially in the northern suburbs.

These facts can be appreciated better in the following figures.

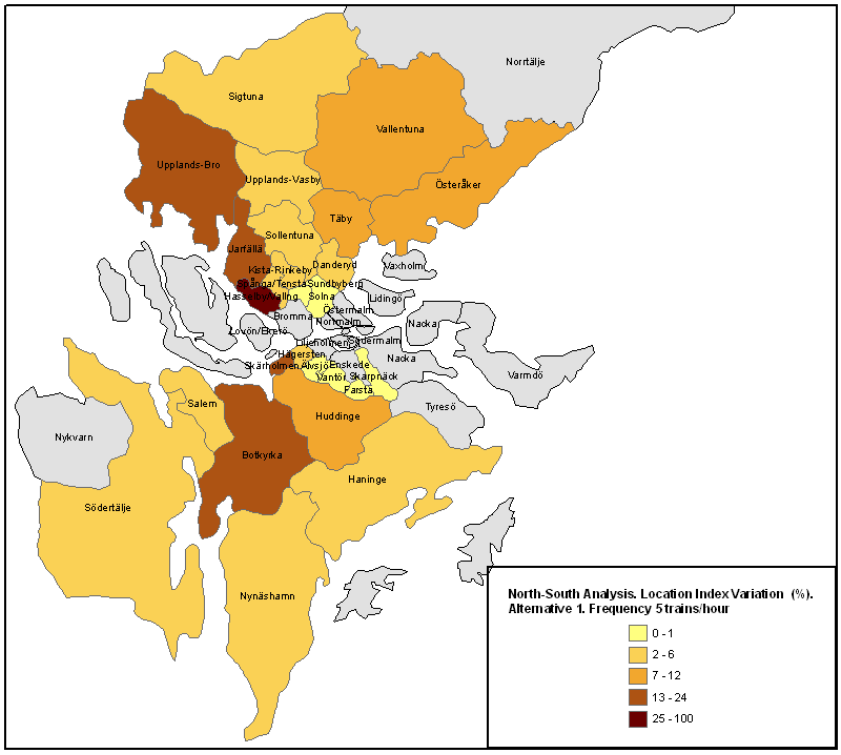


Figure 4.4. Alt 1. Variation of Location Indicator. North-South flows analysis. Frequency 5 trains/hour.

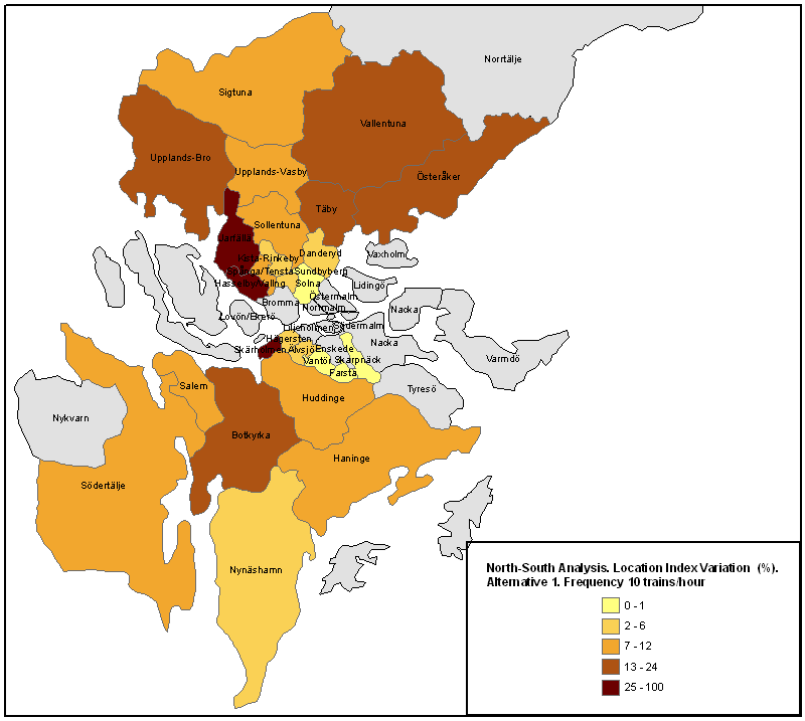


Figure 4.5. Alt 1. Variation of Location Indicator. North-South flows analysis. Frequency 10 trains/hour.

-Daily accessibility index

The Daily accessibility index shows the number of inhabitants that can reach the studied node in less than a determinate time. In this study the time chosen is 45 minutes due to the reasons that were explained above. Figure 4.6 shows the indexes for each scenario studied.

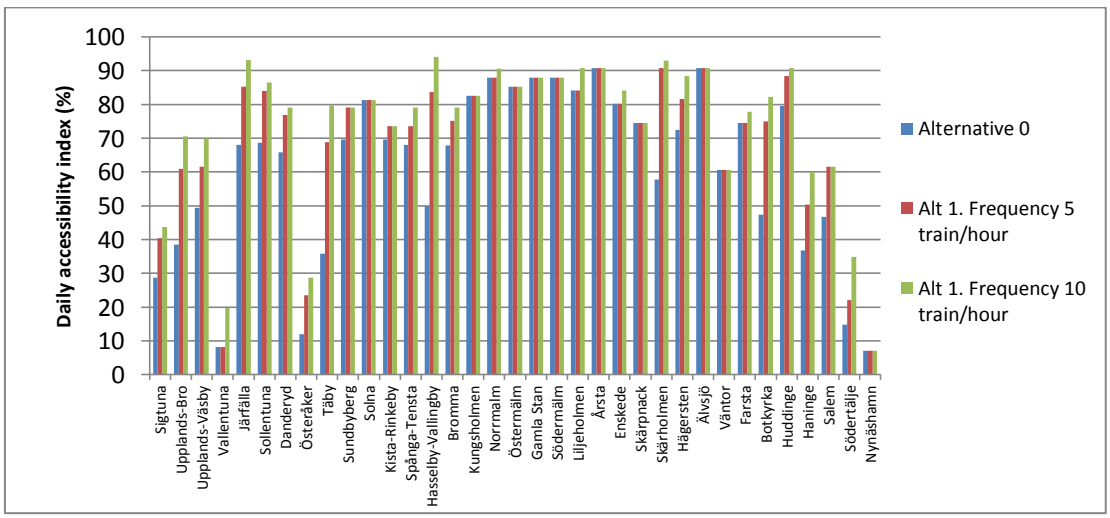


Figure 4.6. Alternative 1. Daily Accessibility Index (%).

As expected, the largest improvements in accessibility have been produced in the peripheral areas. The Stockholm districts have a high percentage of covered inhabitants due to their central location in the system. However, several peripheral areas, like Järfälla or Danderyd, reach values similar to districts situated in the centre of Stockholm. This fact indicates the crucial cohesive role that the new infrastructure would have in the territorial system.

The figure below shows the relative values in respect to alternative 0. It is striking that Vallentuna increases its attended population to a large degree depending on the frequency of the service. This fact is due to the simplicity of the model which presuppose that the entire population chooses the shortest route, despite the fact that the differences in travel times between routes is quite small.

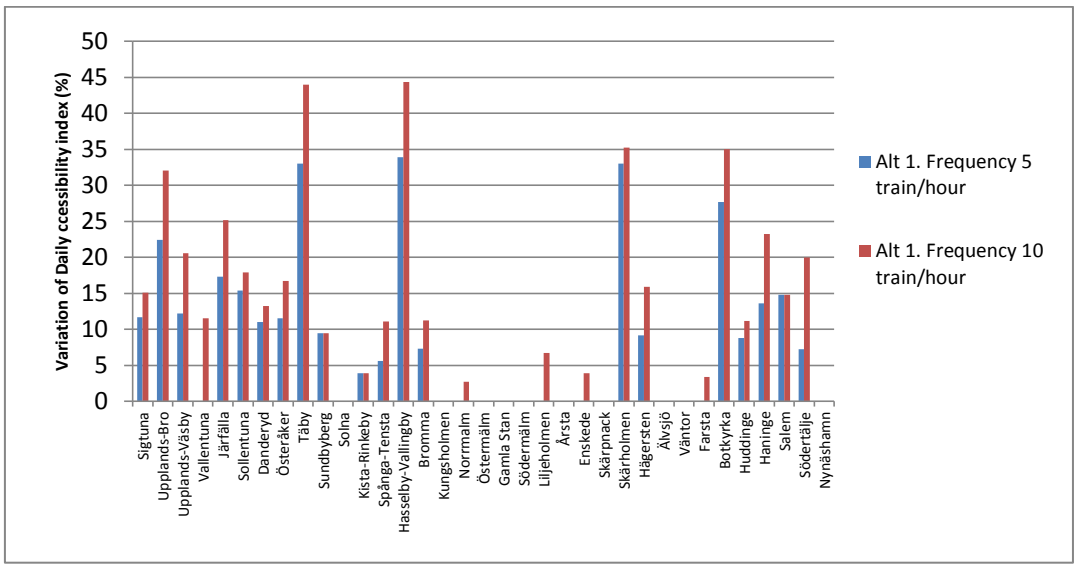
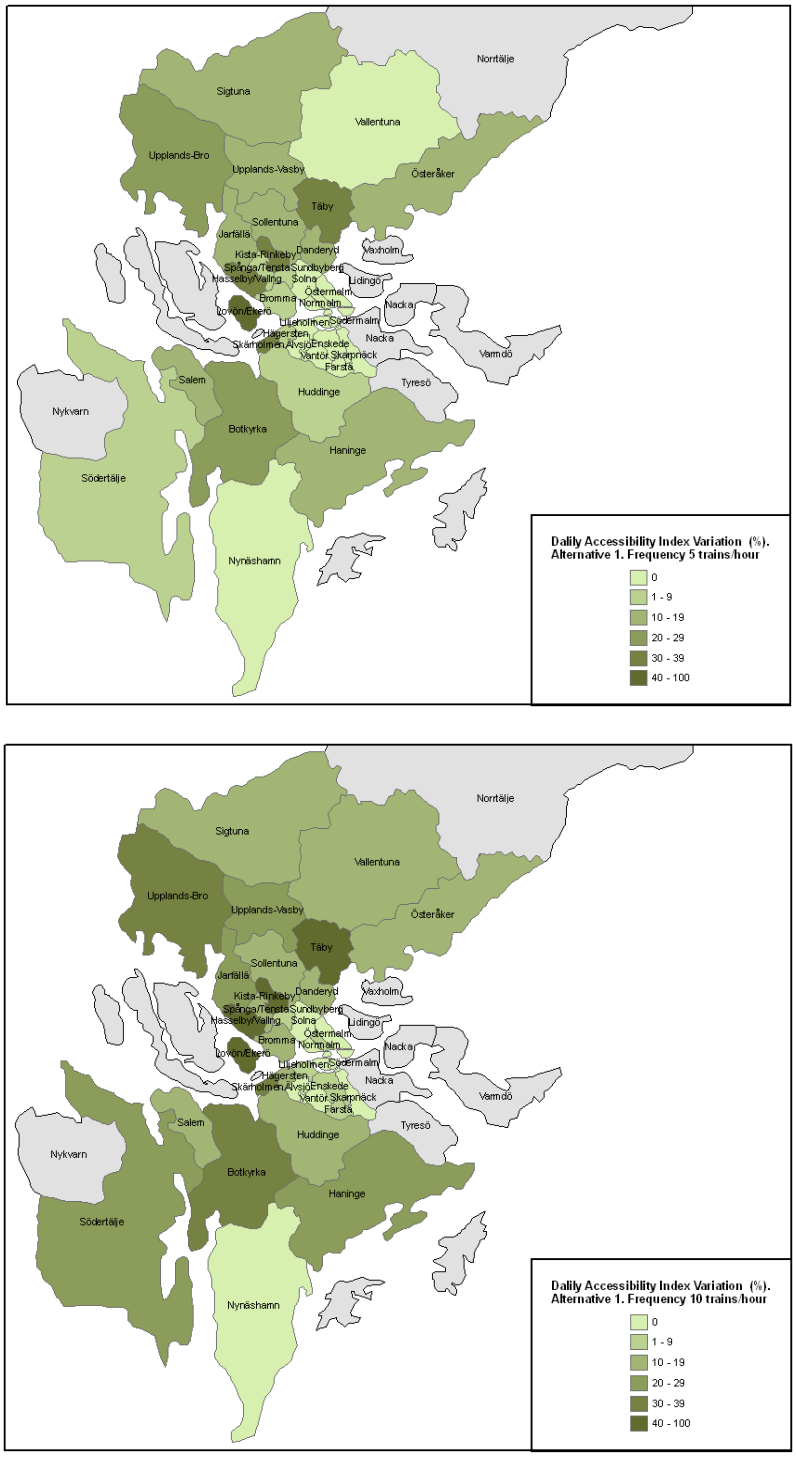


Figure 4.7. Alternative 1. Daily Accessibility Index Variation (%).

The following figures show the variation in the Daily Accessibility Index with respect to Alternative 0. Each one of the figures represents a different frequency scenario.



Figures 4.7 and 4.8. Alternative 1. Daily Accessibility Index Variation.

4.3.3.- Alternative 2

This alternative begins in Älvsjö in the south and it ends in Mörby close to Danderyd Sjukhus. In the route, there are new commuter stations in Telefonplan, Alvik, Sundbyberg and Ulriksdal.

The travel times between the new stations have been obtained as explained above. They can be examined in table 4.4.

-Location Indicator:

In the second alternative, the values are smaller than in the first alternative. However, the improvement in accessibility is more generalized, especially in the northern and western suburbs.

One of the most remarkable facts is the increase in Bromma area where the indicator is reduced to around 15-20%. It is due to the fact that two stations in this alternative (Alvik and Sundbyberg) are located in this district. It is important to take into account that the extension of the Tvärbanan from Alvik to Solna, which runs parallel to the second alternative, is included in the model. Therefore, it is a crucial issue to study how the two lines could co-exist, in order to avoid structural and economic problems.

Moreover, the differences between the frequency scenarios are greater in this alternative than in the first one. It is probably due to the existence of othes rail lines close to the by-pass, which produce a strong competition.

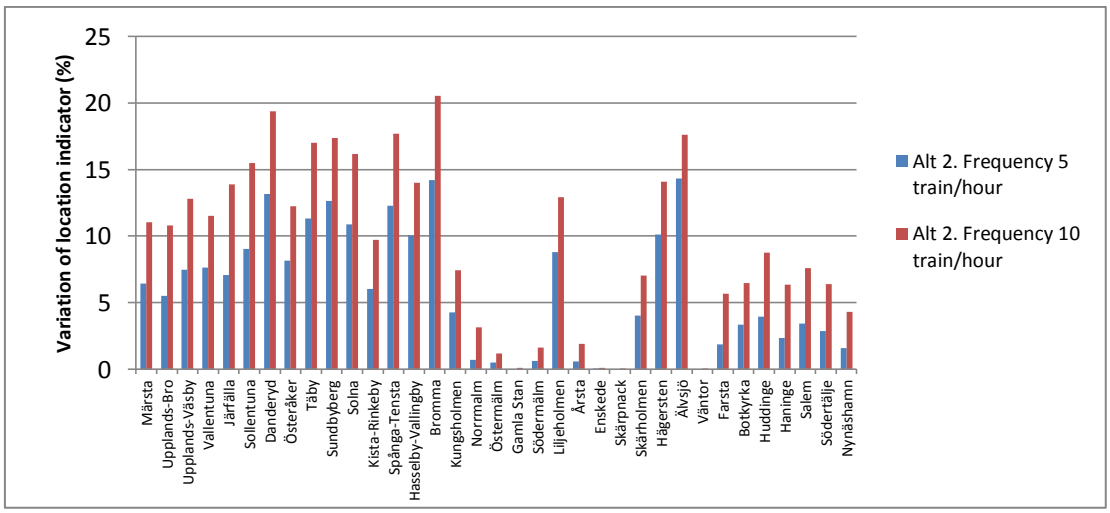


Figure 4.9. Alternative 2 graph. Variation of Location Indicator (%).

It is important to emphasize the difference between the northern/northwesternt and southern suburbs. Although all of them improve their accessibility; the northern districts have obtained larger improvements than the southern suburbs. This fact is owing to the fact that only 2 stations in this alternative are

situated in the south (Älvsjö and Telefonplan), and, in addition, they are situated in areas quite close to the city centre.

Below, the results are displayed in maps, where we can easily appreciate the spatial differences. The "centrality" factor of the new infrastructure, is less important in this alternative for the reason that the stations are located in central areas. However, its effect remains important, since most of the peripheral areas improve their accessibility.

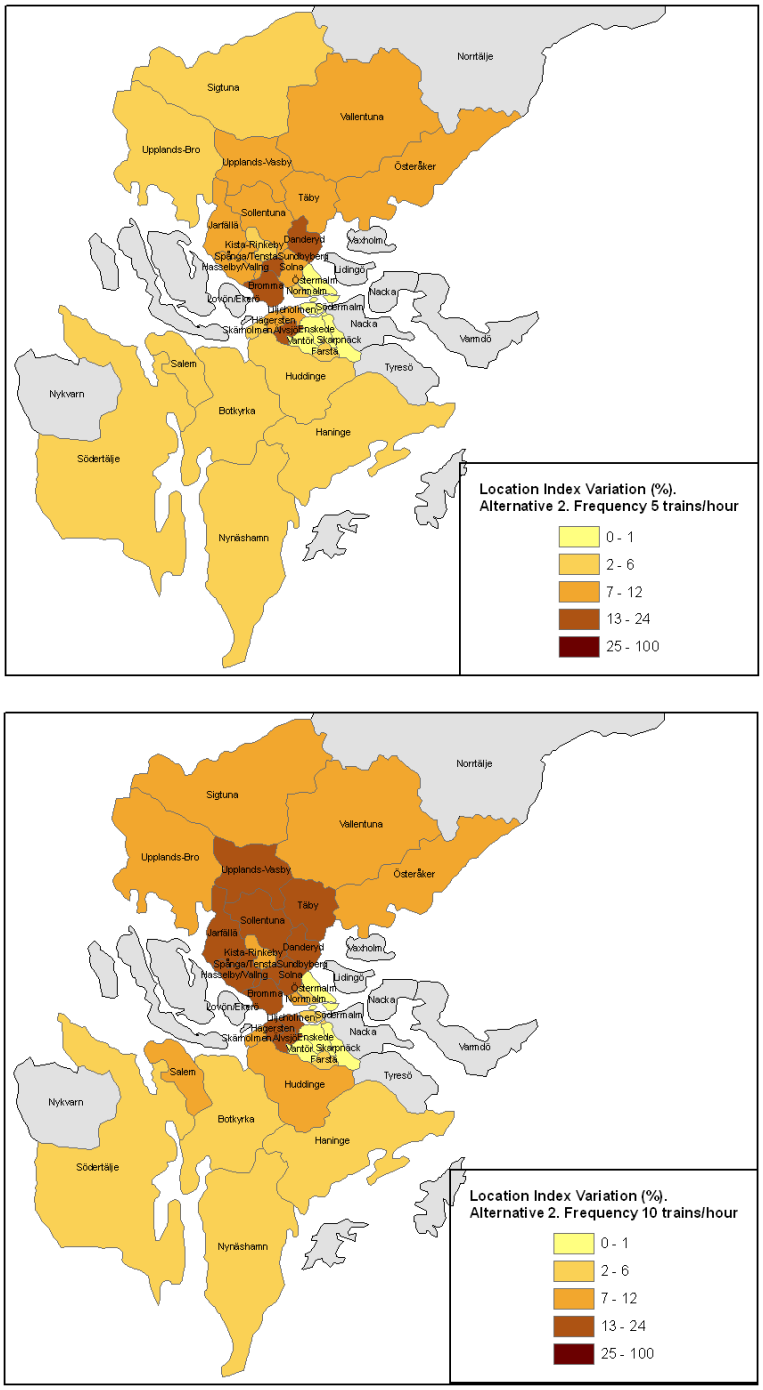


Figure 4.10 and 4.11. Alternative 2. Variation of Location Index in Stockholm area.

As was done for the first alternative, we are going to exclude the central areas in order to conveniently assess the flows between the north and the south.

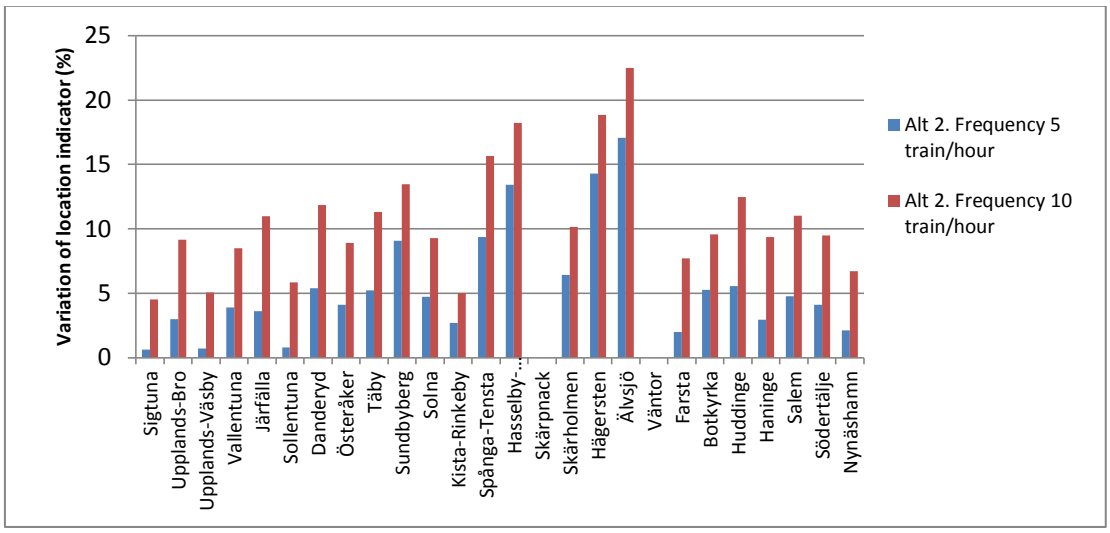


Figure 4.12. Alternative 2. Variation of Location Indicator between north and southern suburbs (%).

The improvement in accessibility is important in most of the studied areas; The majority of the peripheral suburbs improve their indexes around 10% in the high frequency scenario. Moreover, these increases are more uniform than in the first alternative.

In addition, the values for southern suburbs are higher than in the first alternative if we consider the high frequency scenario. It means that the second alternative allows for improving the accessibility in the north-south flows more than the first alternative.

Some facts can be analyzed comparing general analysis (figure 4.9) and north-south analysis (figure 4.12). Älvsjö is in the last case the most favored district; however, it was not part of the general analysis. The interpretation is that Älvsjö improves its accessibility mostly due to its connections with the northern suburbs.

Moreover, northern suburbs like Upplands – Väsby or Täby, improve their accessibility mostly due to the new connections with the northern and north-western suburbs.

The general conclusion is that the second alternative considerably upgrades the accessibility in all studied areas, but these improvements are not due to the same reasons in all the areas. Particularly:

- Northern suburbs reduce their travel times a lot, but mostly between themselves. However, they improve the accessibility to southern suburbs as well.

- Southern suburbs upgrade the time access to northern suburbs, but they almost do not vary the travel times between themselves.

This behavior is owing to the fact that the second alternative has only two stations in the southern part of Stockholm (Älvsjö and Telefonplan). In addition, these stations are located quite close to the city centre, and thus the by-pass does not have noticeable effects on distant suburbs such as Nynäshamn or Haninge.

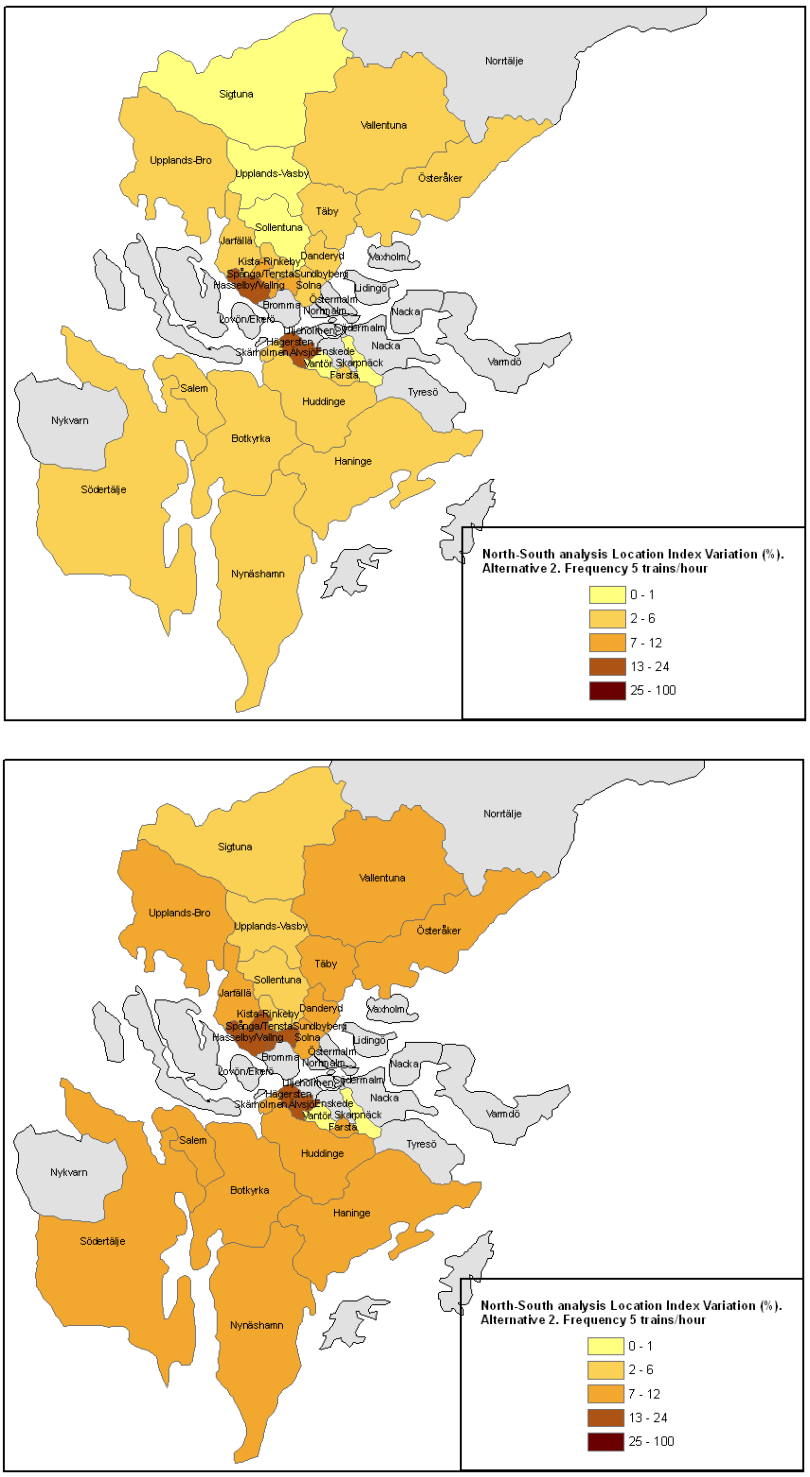


Figure 4.13 and 4.14. Alt 2. Variation of Location Indicator. North-South flows analysis.

-Daily accessibility index

Regarding the Daily accessibility index, the maps and the graphs show as expected, that the peripheral suburbs undergo an increase in their accessibility. However, these improvements are almost imperceptible in the low frequency scenario (5 trains/hour/direction).

Moreover, the variations in the index are smaller than in the first alternative. It should be remembered that it was the contrary in the location indicator. Therefore, it is important to have different indexes in order to compare and contrast them.

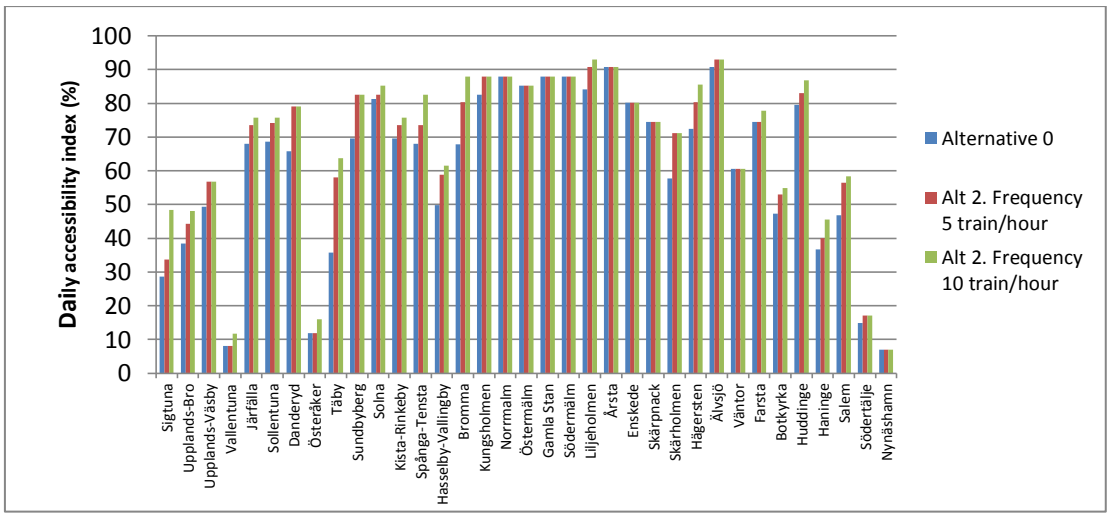


Figure 4.15. Alternative 2. Daily Accessibility Index (%).

Figure 4.16 shows the variation between scenarios. It is easier to see that central areas like Norrmalm or Gamla Stan do not upgrade the percentage of population attended.

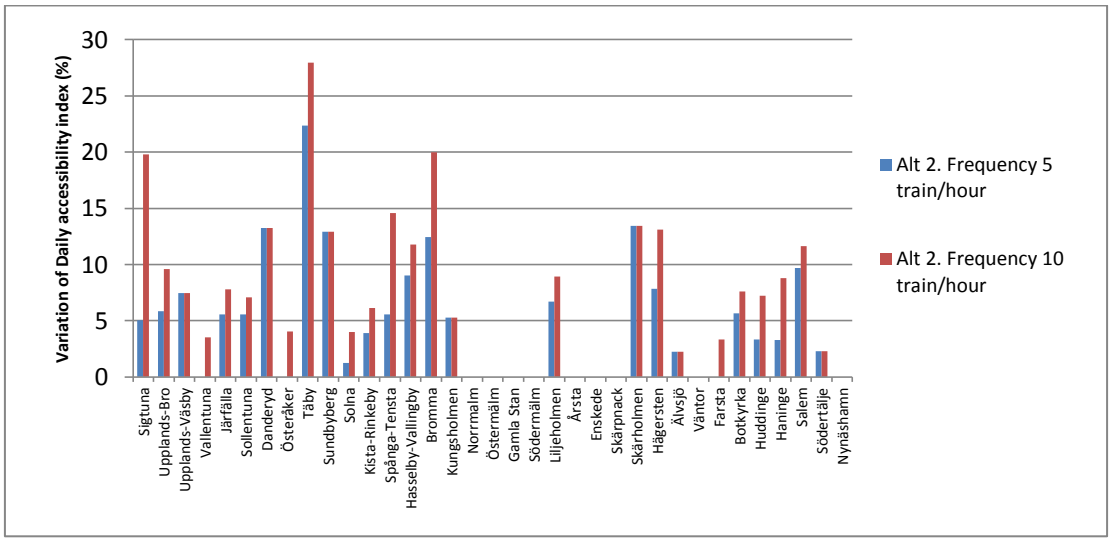


Figure 4.16. Alternative 2. Daily Accessibility Index Variation (%).

The most astonishing fact is that Sigtuna and Upplands–Bro upgrade their Daily Accessibility notably. It means that they had several destinations in the limit of 45 minutes which are sufficiently accessible with high frequency.

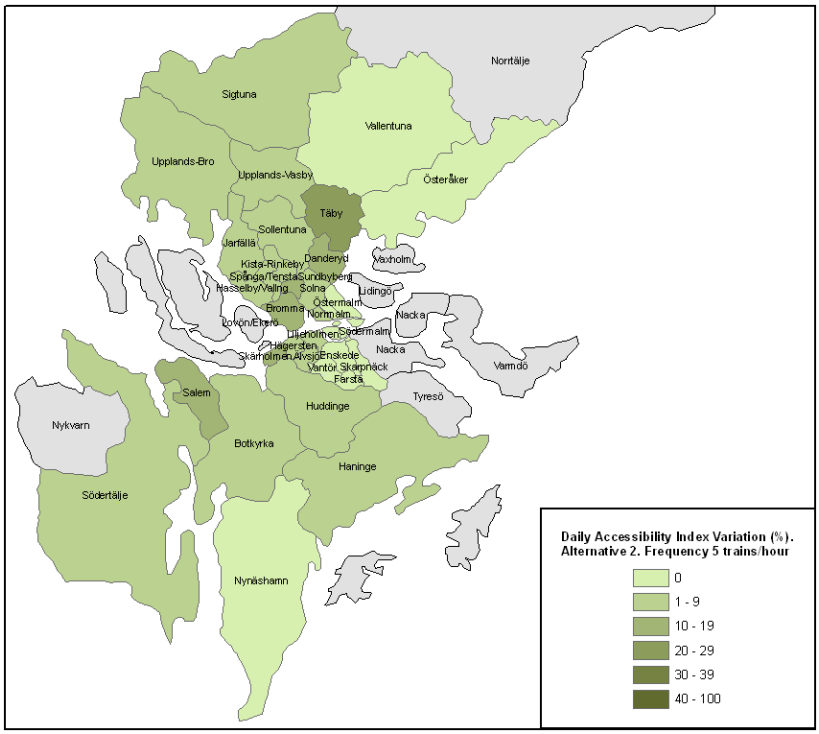


Figure 4.17. Alternative 2. Daily Accessibility Index Variation. Frequency 5 trains/hour.

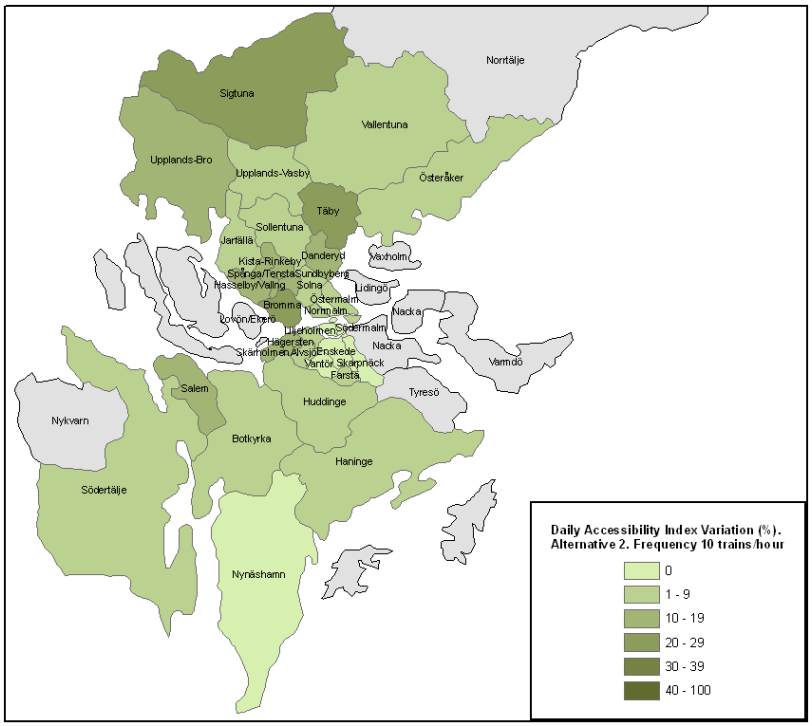


Figure 4.18. Alternative 2. Daily Accessibility Index Variation. Frequency 10 trains/hour.

4.3.4.- Alternative 3

This alternative involves 4 new commuter stations situated in Årstaberg, Liljeholmen, Fridhemsplan and Solna. All of them are located quite close to the city centre.

The travel times between the new stations have been obtained as explained above. They can be examined in table 4.5.

-Location Indicator:

If we compare the graph below with the rest of the alternatives (see figures 4.2 and 4.9), it is obvious that the reduction in the location index is much lower than in the other cases. However, several central areas, like Liljeholmen or Kungsholmen undergo notable improvements due to the presence of new stations there.

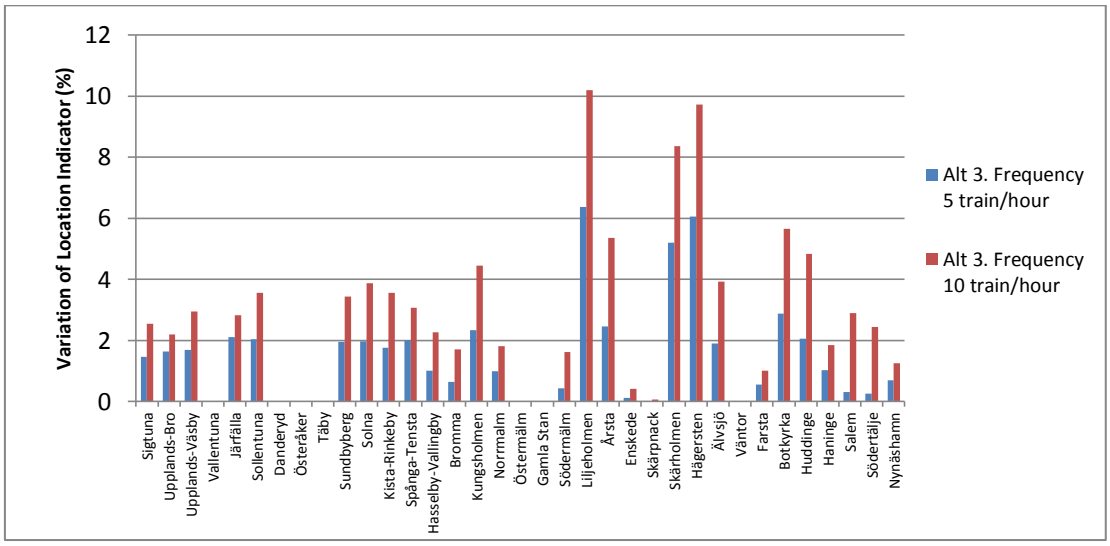


Figure 4.19. Alternative 3 graph. Variation of Location Indicator (%).

All the peripheral suburbs improve their indexes less than 5%. Therefore, as we expected, it is important to say that the third alternative is not the most proper option from the point of view of territorial cohesion, since the By-pass would upgrade the accessibility in central areas more than in the peripheral ones.

In the high frequency scenario (10 trains/hour/direction), several areas present variations higher than 10%, but it is a local effect and the rest of the suburbs do not improve so much their results.

The maps allow to see the low magnitude of the third alternative´s effects on the accessibility.

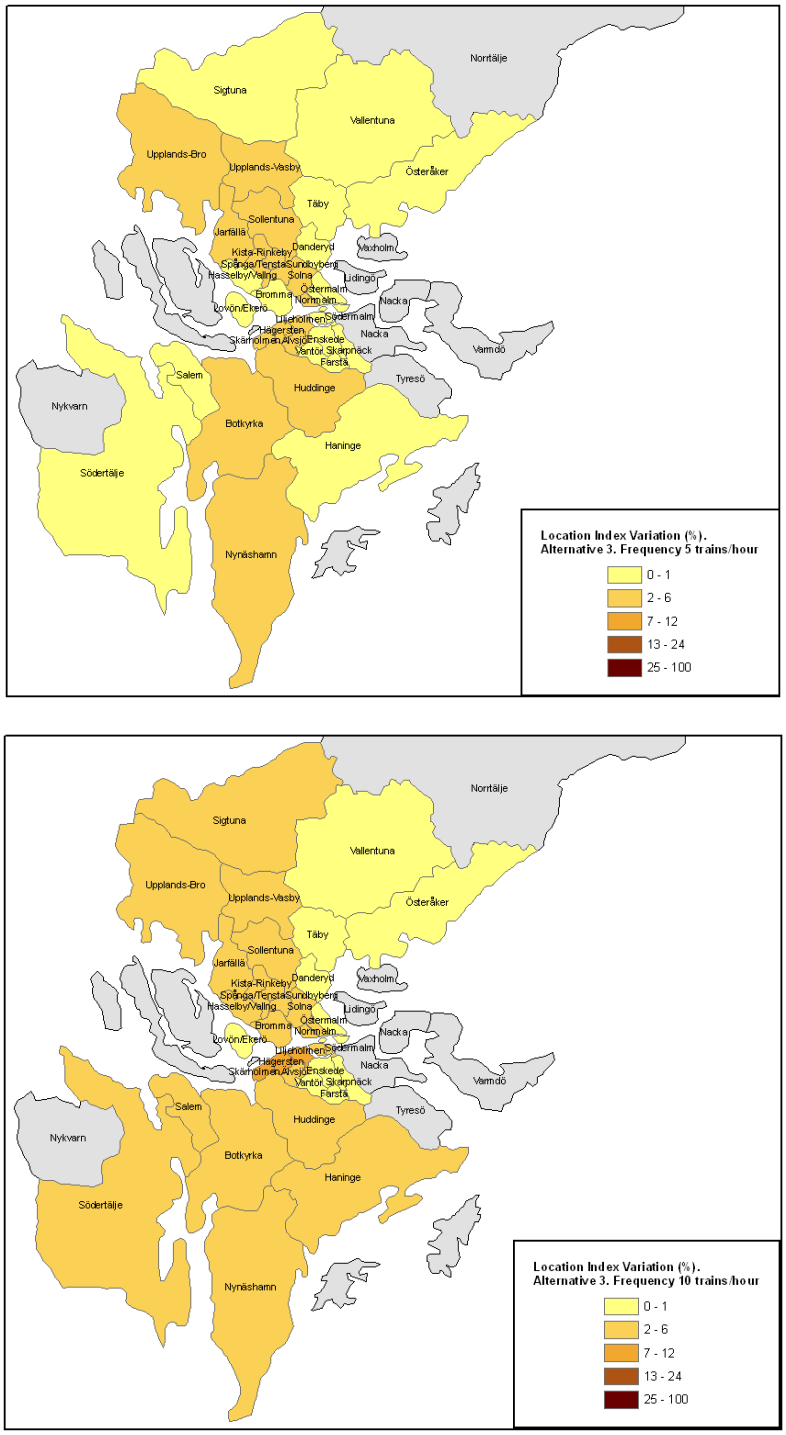


Figure 4.20 and 4.21. Alternative 3. Variation of Location Index in Stockholm area.

Despite the fact that the increase in the general location index is not important, if we analyze the flow north – south (figures 4.22, 4.23 and 4.24), it is possible to appreciate the improvement in several areas. Therefore, we can say that the third alternative presents modest results, but most of the improvements are produced in north - south flows.

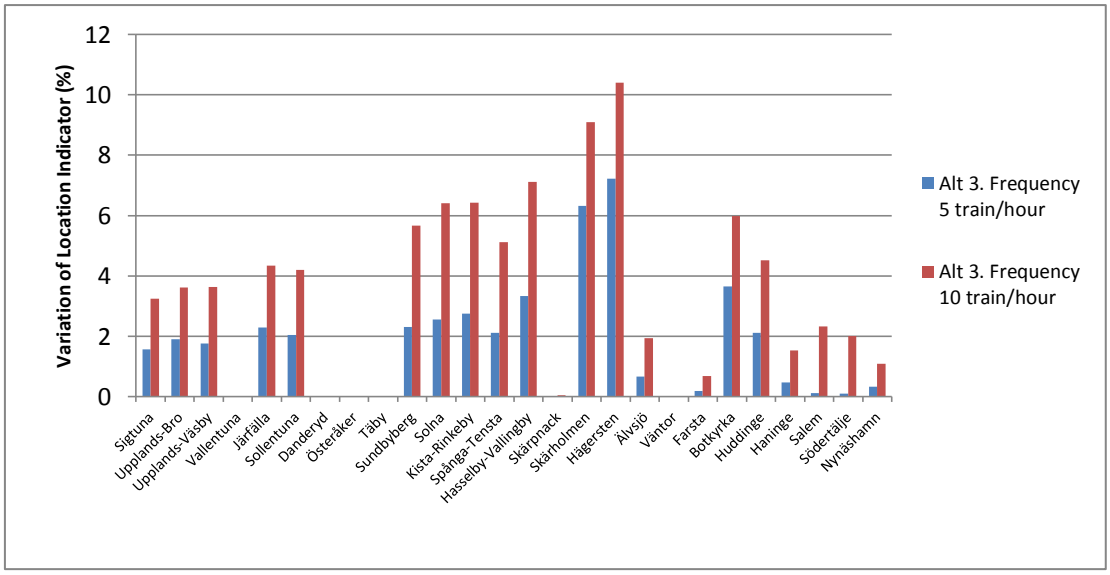


Figure 4.22. Alternative 3. Variation of Location Indicator between north and southern suburbs (%).

It is important to say that northern suburbs like Täby, Danderyd or Vallentuna, do not vary their indexes because they are connected to the railway network by Roslagbanan, and in this alternative, Roslags line do not have a direct link with the By-pass.

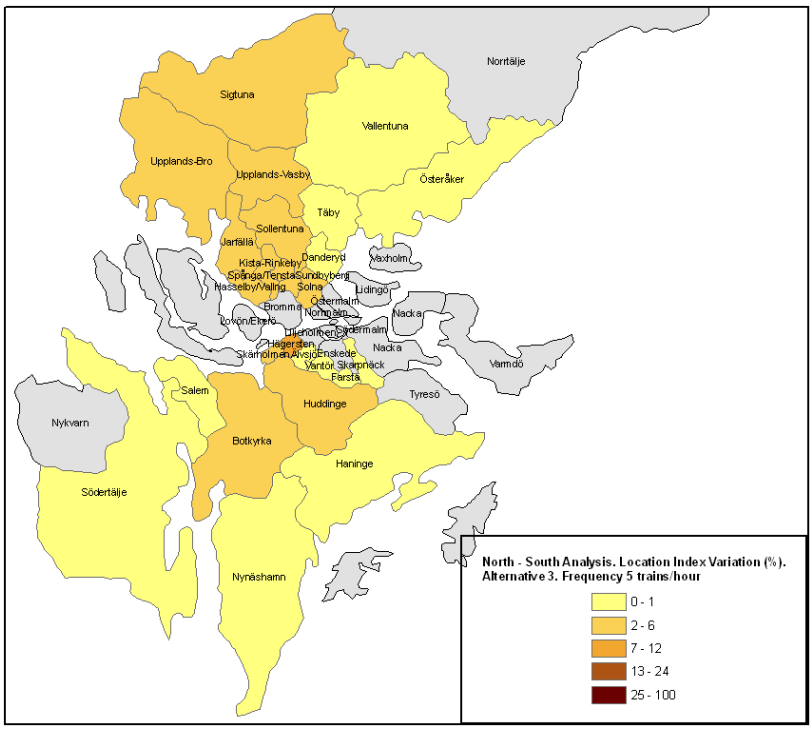


Figure 4.23. Alt 3. Variation of Location Indicator. North-South flows analysis. Freq 5 trains/hour.

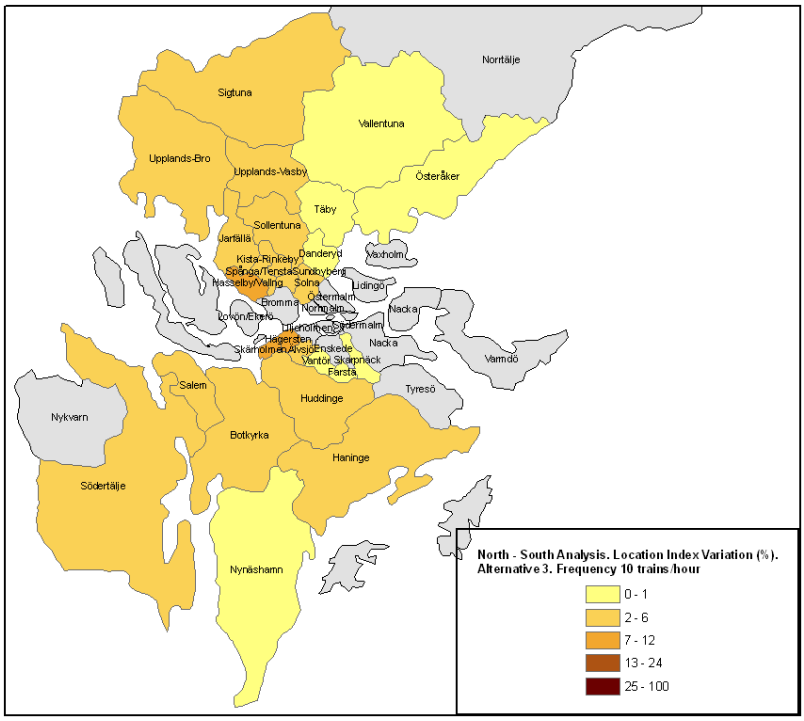


Figure 4.24. Alt 3. Variation of Location Indicator. North-South flows analysis. Freq 10 trains/hour.

-Daily accessibility index.

The third alternative does not have a remarkable effect on the daily accessibility index. Obviously, it is due to the fact that the stations are located in the centre of the city, and the longest travel times (more than 45 minutes) are produced between peripheral areas.

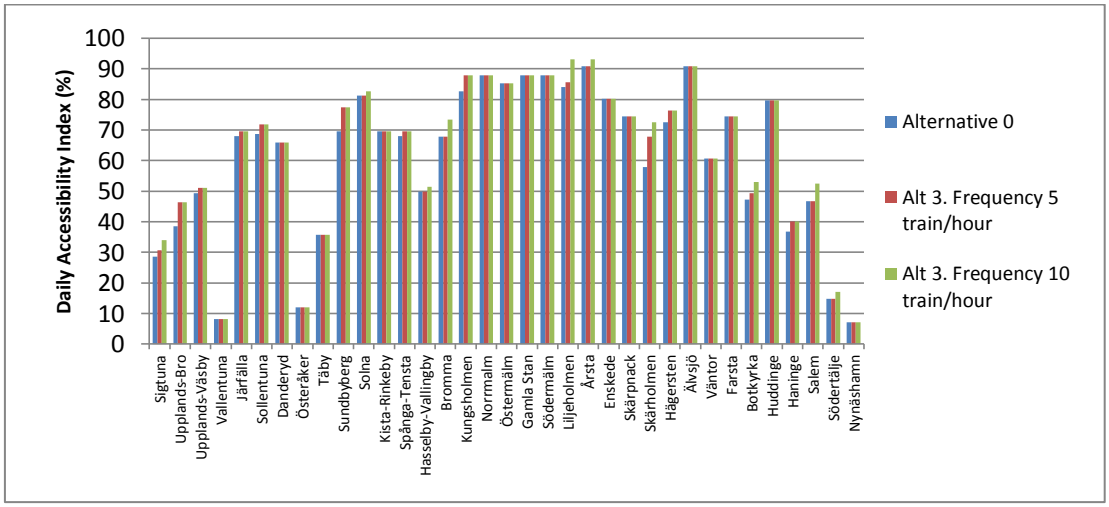


Figure 4.25. Alternative 3. Daily Accessibility Index (%).

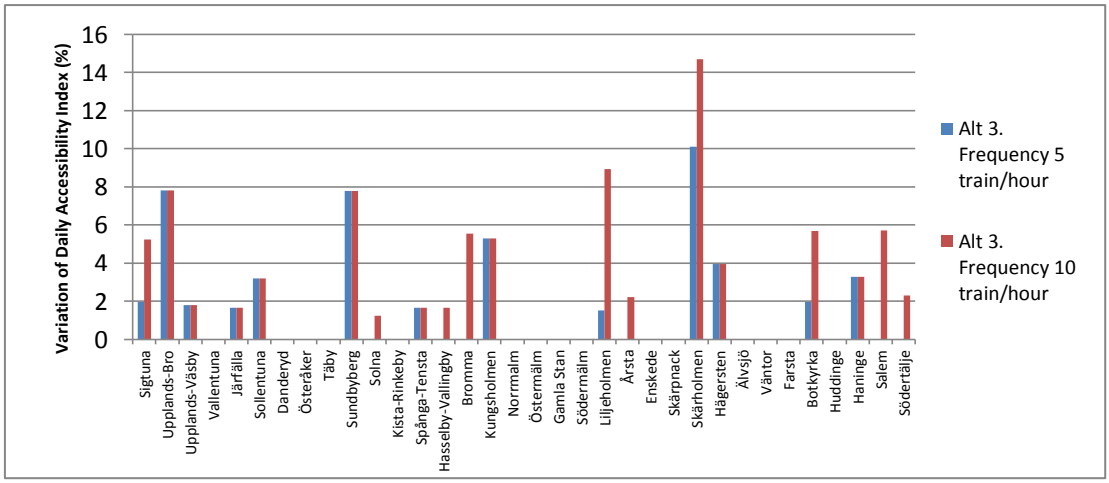


Figure 4.26. Alternative3. Daily Accessibility Index Variation (%).

In figure 4.26, we can appreciate the changes in the index. Skärholmen has a high value due to its being connected with Liljeholmen (new station) by metro red line. Therefore, Skärholmen (and Hägersten as well) improve their accessibility to north – west suburbs, since they do not have to go via T–Centralen to change trains.

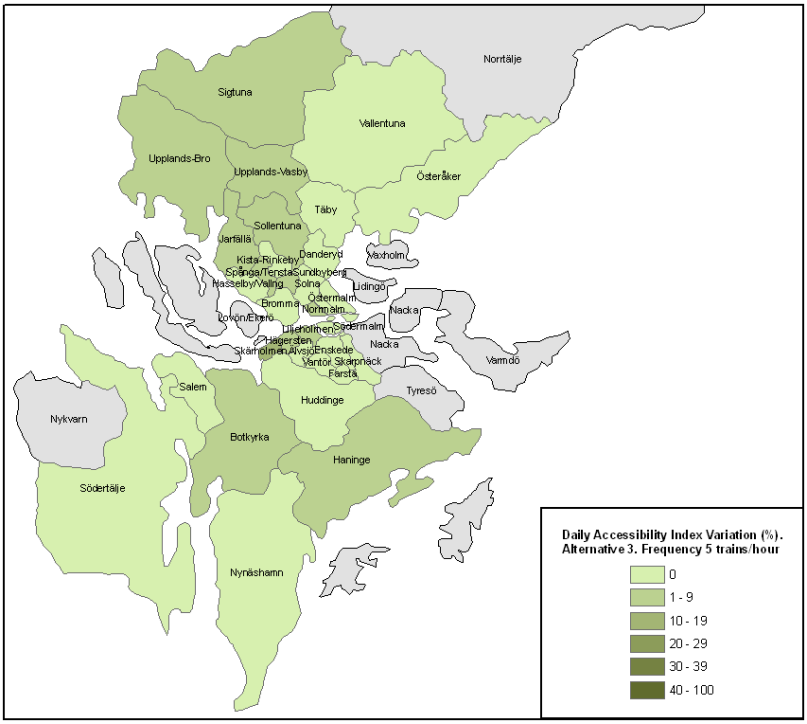


Figure 4.27. Alternative 3. Daily Accessibility Index Variation. Frequency 5 trains/hour.

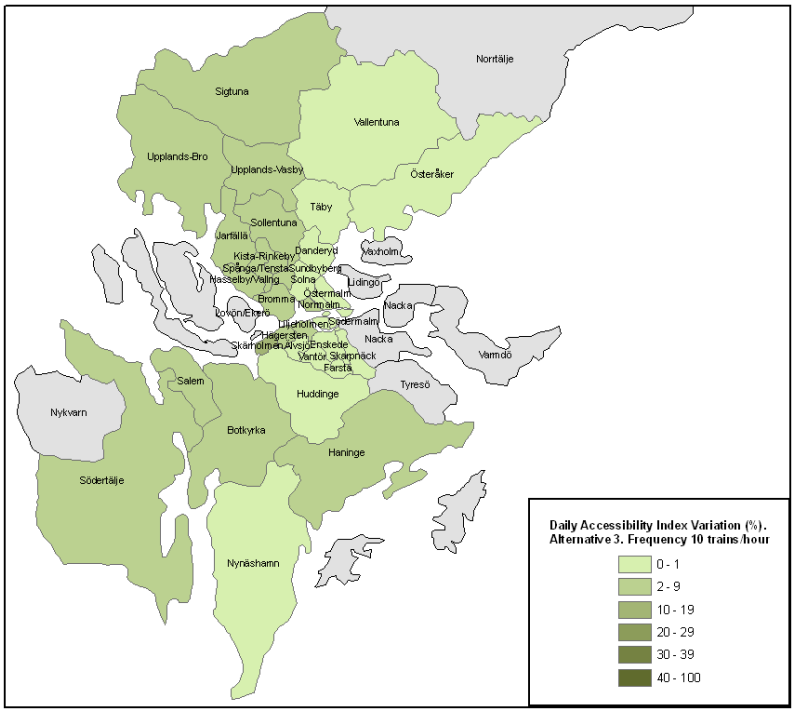


Figure 4.28. Alternative 3. Daily Accessibility Index Variation. Frequency 10 trains/hour.

4.4.- Summary

The assessments made have provided a lot of interesting data from where it is possible to draw some conclusions from the point of view of the local/commuter transport. Below, there is a summary of the results obtained.

Regarding the location indicator, the second alternative presents uniform values in most of the territorial units. Especially, the best improvements are produced in the north – west suburbs and in the area around Solna – Sundbyberg, whereas the first alternative produces its best results in the northern suburbs. As far as southern suburbs are concerned, the second alternative presents the best values, but quite close to the first one.

The third alternative is always worse than the rest of options. If a weighted average of the indicators is made, Alternative 2 is the best regarding location indicator (see figure 4.29).

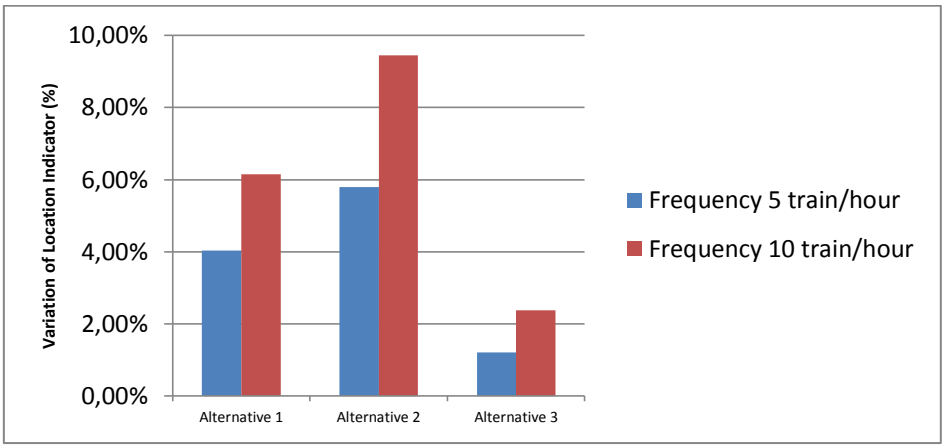


Figure 4.29. Location indicator variation. Alternatives summary.

The analysis made without the central parts show more or less the same results. However, in this case the first alternative is closer to the second one. In the low frequency scenario (5 trains/hour/direction), the first alternative improves the accessibility more than the second one. It is due to the longest alternative (Alt. 1) having its effects concentrated in the flows north – south, and it does not have so much effect on the central areas.

The third alternative is much worse than the others from the point of view of this indicator.

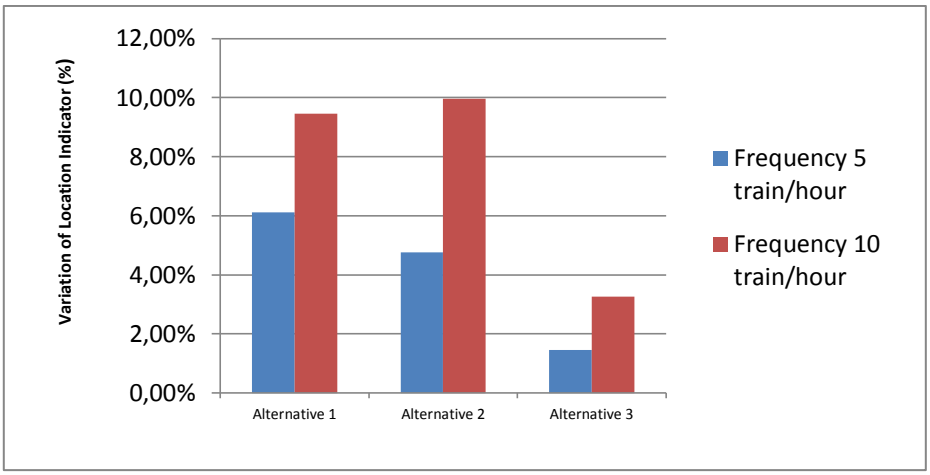


Figure 4.30. Location indicator variation.North-South flows. Alternatives summary.

The percentage of population that can reach their destination in less than 45 minutes is increased much more with the first alternative. It is probably due to most of the distant suburbs, which have the highest travel times, are directly affected for Alternative 1 route.

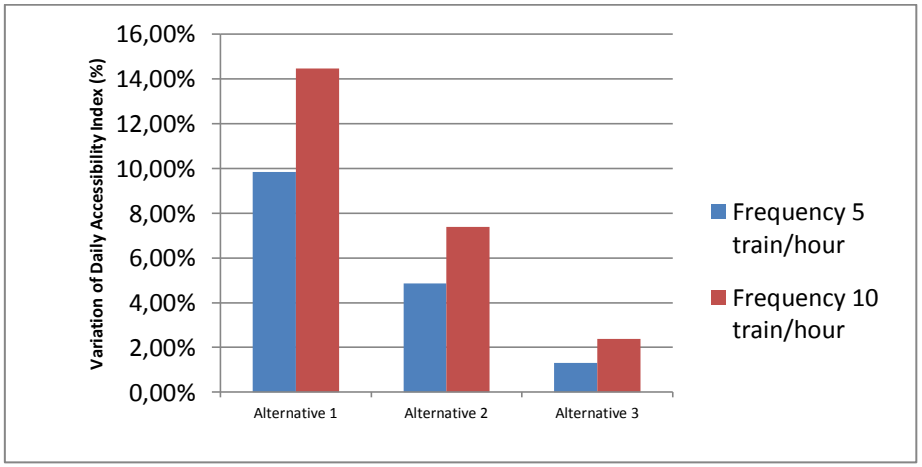


Figure 4.31. Daily Accessibility Index variation. North-South flows. Alternatives summary.

Therefore, from the results obtained both Alternatives 1 and 2 have great possitive effects on the local railway system. By attending at all the before explained, it is important to remark that accessibility is not the only factor when choosing the best route alternative, there are many other factors.

	Location Indicator	Daily accessibility Index	OVERALL
Alternative 0			
Alternative 1			
Alternative 2			
Alternative 3			

Figure 4.32. Characteristics of alternatives from local/commuter traffic point of view.

5 Analysis of effects on the Regional Traffic

5.1.- Introduction

Regional traffic is undergoing an important growth mainly due to the reduction of travel times in transport systems. It results in people establishing their residence farther away from their workplaces.

In Stockholm, the regional railway services are quite centralized in Stockholm C station. All trains which make regional routes stop at this station. Since the number of these trains is quite large and combined with other services like long distance or freight trains, Stockholm Central will reach its capacity limit in 30 years (Nelldal, Lindfeldt, Fröidh, 2010).

However, the centrality of the system, i.e. all the trains stop in the centre of the city, produces the effect that most of the customers reach their workplace easily from the station. However, despite of the fact that a large number of workplaces are situated in the centre of the city, it is important to take into account that a lot of them are located in the suburbs.

Another problem of a centralized system is that travels which have to cross through Stockholm, have to spend a lot of time running through the centre of the city.

Several important cities have organized their regional train systems in order to avoid that trains cross the congested areas in the centre of the cities. This model consists of local regional stations in the periphery of the city from where the trains depart.

Therefore, if a By-pass alternative is built, the possibilities of change in the Stockholm´s regional train system are evident. Thus, in this chapter, some issues related with all the facts exposed above will be assessed. Particularly, the topics evaluated are:

- The changes in the system running if regional stations are located in the periphery to the detriment of Stockholm Central.

- The changes in the travel times between main lines (example Mälarbanan – The South/West Main Line) if the By-pass alternatives are built.

To assess the first point, a comparison between access travel times from the different main lines to the different zones in Stockholm´s metropolitan area will be made. In this way it is possible to evaluate the effects that the new stations would have in the system.

5.2.-Regional Stations in Stockholm area. New models proposed.

5.2.1.-Alternative 0

Today, as is explained in chapter 2, Stockholm has three regional stations close to the centre. They are Flemingsberg which is situated on the The South/West Main Line; Sundbyberg, located on Mälarbanan; and Stockholm C, where all the regional trains stop. In addition, there is a regional station in Södertälje, but it is excluded in this study because of the fact that it is far away from Stockholm. It is remarkable that the The East Coast Line does not have a regional station in the periphery of Stockholm, since the closest regional station is situated in Arlanda Airport.

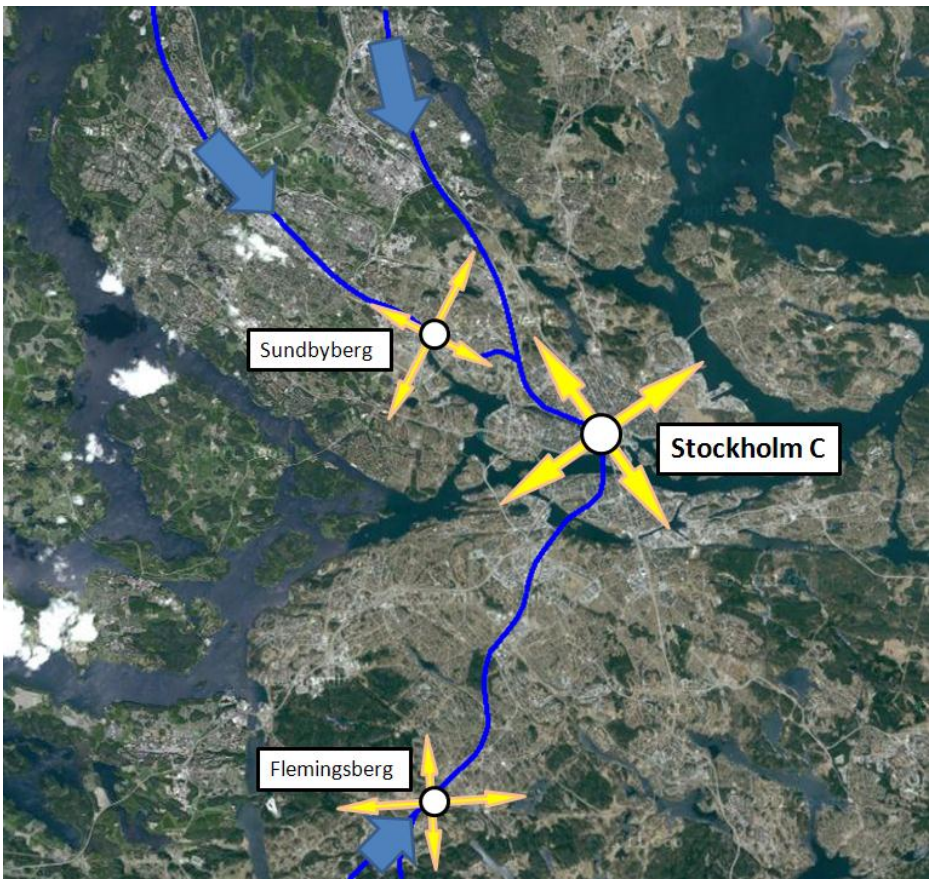


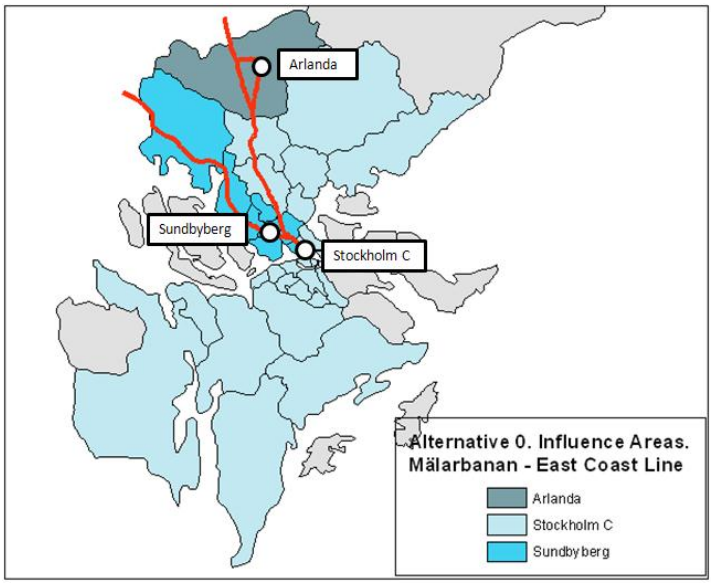
Figure 5.1. Today regional stations system in Stockholm´s area.

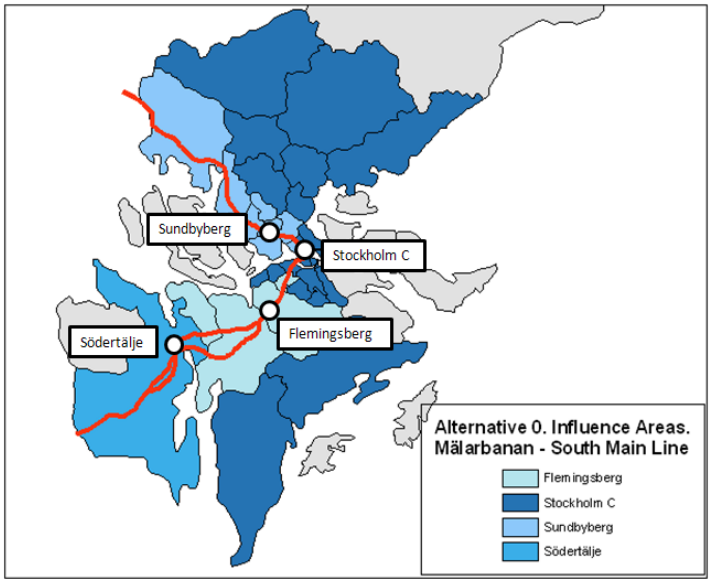
Figure 5.1 shows a sketch of the regional stations in the Stockholm area. From Stockholm Central the customers have to take local public transport to reach their destination. Moreover, Flemingsberg and Sundbyberg work as regional stations as well, but the population in its influence area is smaller.

It is important to remark that stations utilized will be different depending on the origin and destination. For example, trains from south to The East Coast Line cannot stop at Sundbyberg. Therefore the analyses are made separately for each flow (N-S, W-S and W-N). Figure 5.2 shows the influence area for each regional station. The influence areas have been calculated attending the travel times in the local public transport, which were obtained in chapter 4. Each district has been attached to the closest station.

In the table 5.1, there is information about the influence areas. Particularly, the table shows the workplaces covered and the average access time to each station.

The access times have been obtained by weighted average of travel times (local transport; Chapter 4). The indicator used to weight the times has been the number of workplaces in each area, since a large part of regional travels is motivated by work issues.





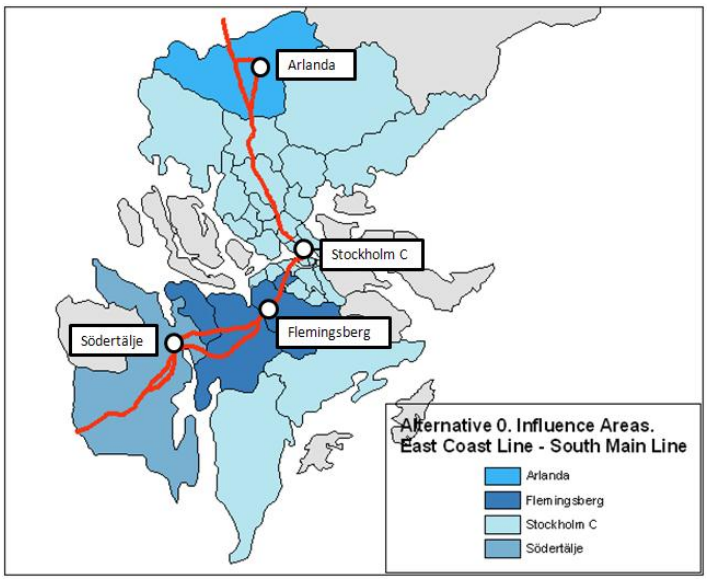


Figure 5.2.Influence area for each regional station depending on the flow. Alternative 0.

Alternative 0

Mälarbanan / The East Coast Line

Station	Workplaces	% Workplaces	Access time; weighted average (min)
Sundbyberg	266412	26.2%	13.8 minutes
Stockholm C	725537	71.3%	22.7 minutes
Arlanda	25152	2.5%	12 minutes
TOTAL	1017101	100%	19.8 minutes

Mälarbanan - The South/West Main Line

Station	Workplaces	% Workplaces	Access time; weighted average (min)
Sundbyberg	266412	26.2%	13.8 minutes
Stockholm C	630960	62%	21.4 minutes
Flemingsberg	75045	7.4%	22.3 minutes
Södertälje	44684	4.4%	8 minutes
TOTAL	1017101	100%	18.9 minutes

The East Coast Line - The South/West Main Line

Station	Workplaces	% Workplaces	Access time; weighted average (min)
Södertälje	44684	4.4%	8 minutes
Flemingsberg	75045	7.4%	22.3 minutes
Stockholm C	872220	85.8%	20.4 minutes
Arlanda	25152	2.5%	12 minutes
TOTAL	1017101	100%	19.8 minutes

Table 5.1. Features of influence areas.

Despite the fact that Stockholm C has in its influence area the central zones, which have a large part of the workplaces, its access time is quite high (20-22 minutes) in all the flows. It is due to farthest suburbs (like Nynäshamn or Vallentuna) which utilize Stockholm Central as their regional station.

The fact that the inhabitants of Nynäshamn or Vallentuna have to travel to Stockholm to take a regional train is evidence of the centrality of the system, or in other words the lack of transverse infrastructure.

5.2.2- Alternative 1

Figure 5.3 shows the proposed model for railway regional traffic if the first alternative is built. It is remarkable that Stockholm C has been eliminated as regional station. It would allow to have enough capacity in Stockholm Central to absorb the demand increase in other railway services like long distance.

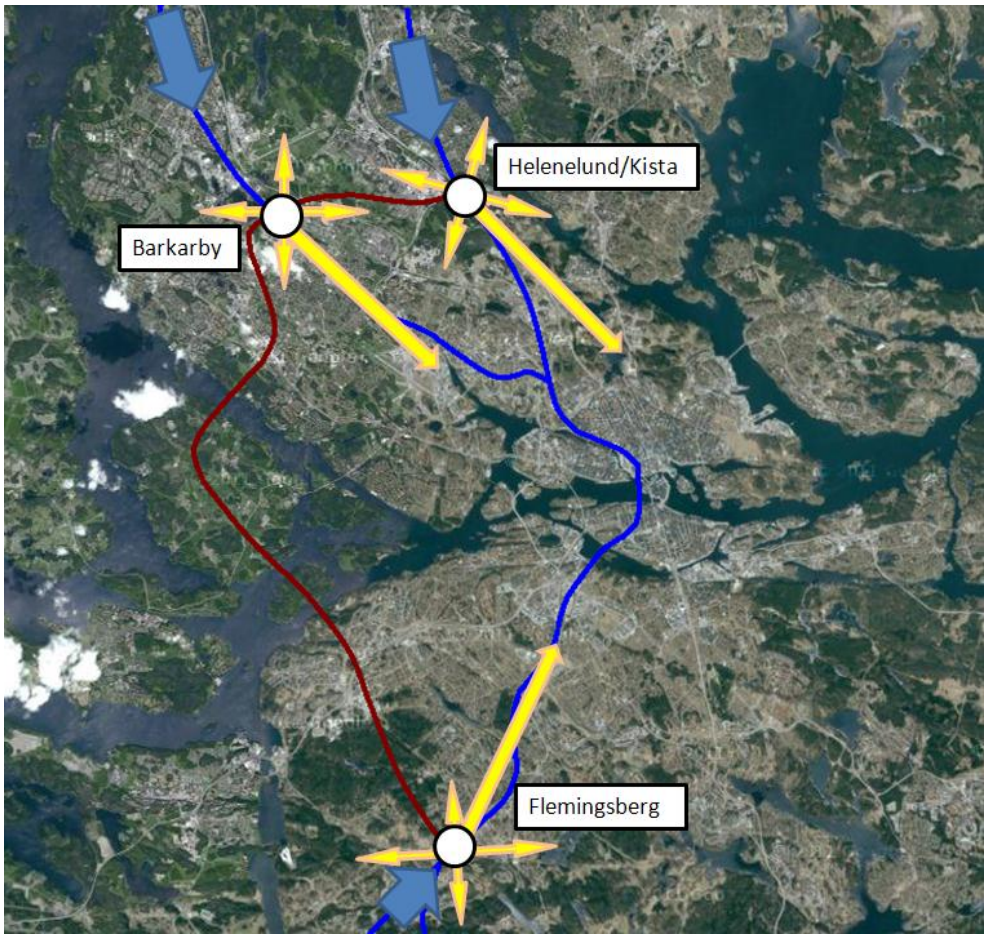


Figure 5.3. Alternative 1. Regional stations model proposed.

The stations are situated between 10 and 15 kilometers to the centre. The feeder traffic would be made by local public transport.

In figure 5.4 the influence areas for each flow are drawn. In this case, the importance of each station is more uniform than in Alternative 0. It is due to the stations are located uniformly along the territory, and thus they can cover a similar area

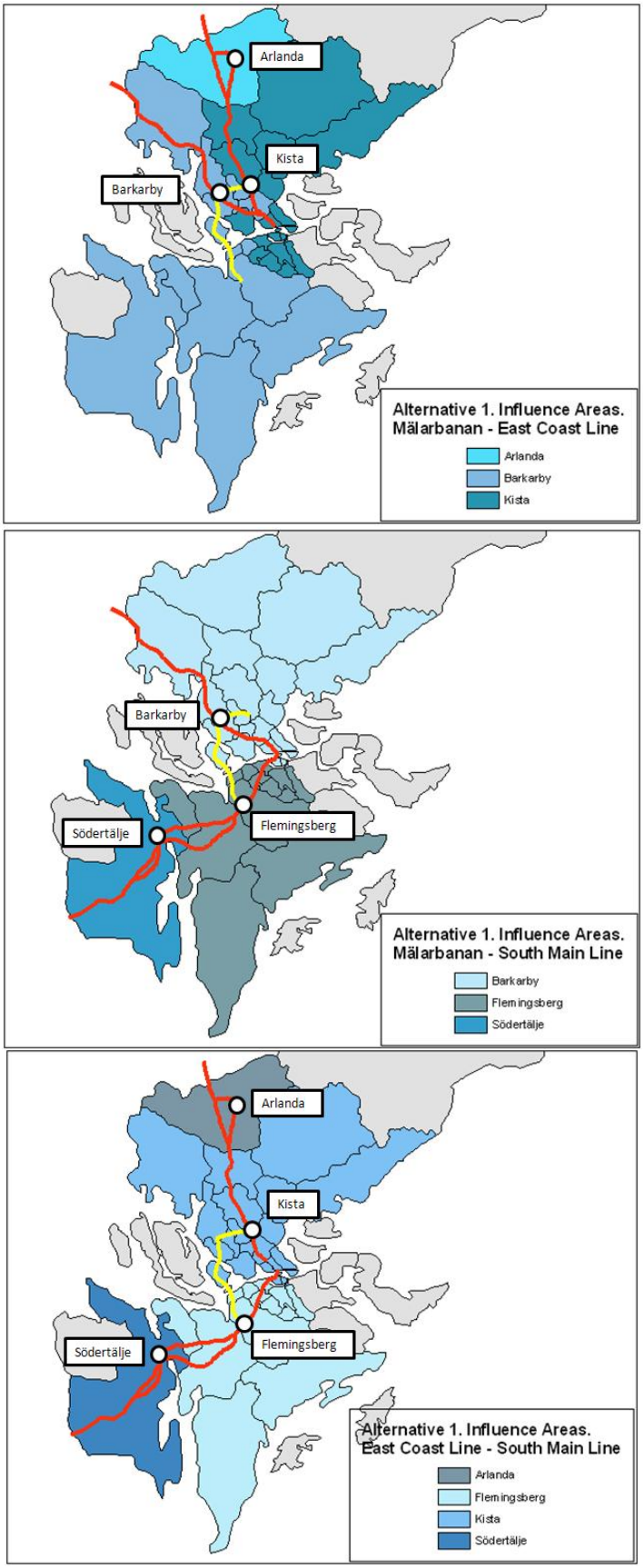


Figure 5.4. Alternative 1. Influence areas for each regional station depending on the line.

Alternative 1

Mälarbanan / The East Coast Line

Station	Workplaces	% Workplaces	Access time; weighted average
Arlanda	25152	2.5%	12 minutes
Kista	624925	61.4%	19.7 minutes
Barkarby	367024	36.1%	24.4 minutes
TOTAL	1017101	100%	21.2 minutes

Mälarbanan - The South/West Main Line

Station	Workplaces	% Workplaces	Access time; weighted average
Södertälje	44684	4.4%	8 minutes
Barkarby	765151	75.2%	20.7 minutes
Flemingsberg	207266	20.4%	20.1 minutes
TOTAL	1017101	100%	20.1 minutes

The East Coast Line - The South/West Main

Station	Workplaces	% Workplaces	Access time; weighted average
Södertälje	44684	4.4%	8 minutes
Kista	739999	72.8%	18.8 minutes
Arlanda	25152	2.5%	12 minutes
Flemingsberg	207266	20.4%	20.1 minutes
TOTAL	1017101	100%	18.5 minutes

Table 5.2. Alternative 1. Features of influence areas.

The results are quite interesting. Despite the regional stations are situated far to the city centre (where a large part of the workplaces are located), the access time is similar to Alternative 0. In the flows to/from The South Main Line, Flemingsberg would reduce its access times despite it receives a larger number customers. It is due to the new infrastructure which improves travel times between southern suburbs.

The north suburbs, which are served mostly by Kista and Barkarby, reduce remarkably their access time to the regional station. It is due to the link between Täby and Kista.

The data obtained shows the important role that transverse infrastructure has in overall accessibility.

5.2.3.- Alternative 2

The proposed model for this alternative is quite similar to the previous one. There are 3 main regional stations in the Stockholm´s area which are situated in each main line. In this case, the regional stations are located closer to the centre than in the first alternative. In figure 5.5, a sketch of the model is presented:

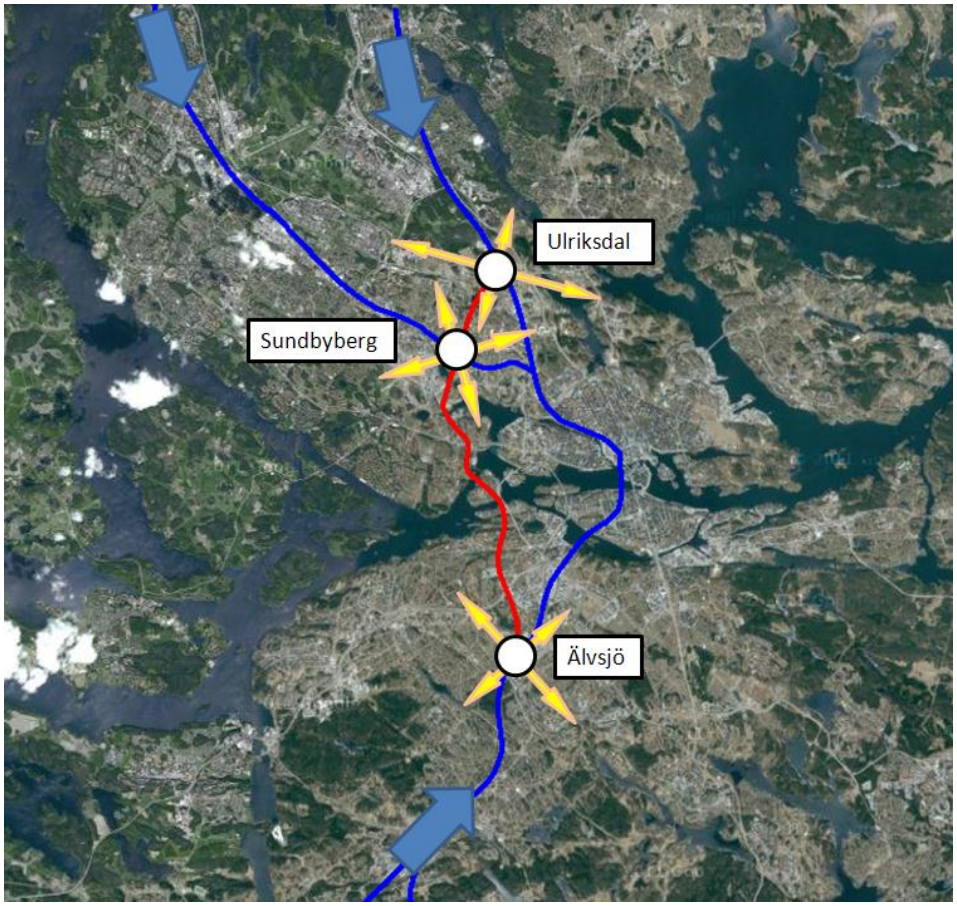


Figure 5.5. Alternative 2. Regional model proposed.

The influence areas in this case are similar to the previous case. It is remarkable that central Stockholm districts are divided into the different regional stations. It is due to the stations are located in the centre´s periphery, and it could be an important decision factor thus a lot of administrative and institutional services are located in the centre of Stockholm.

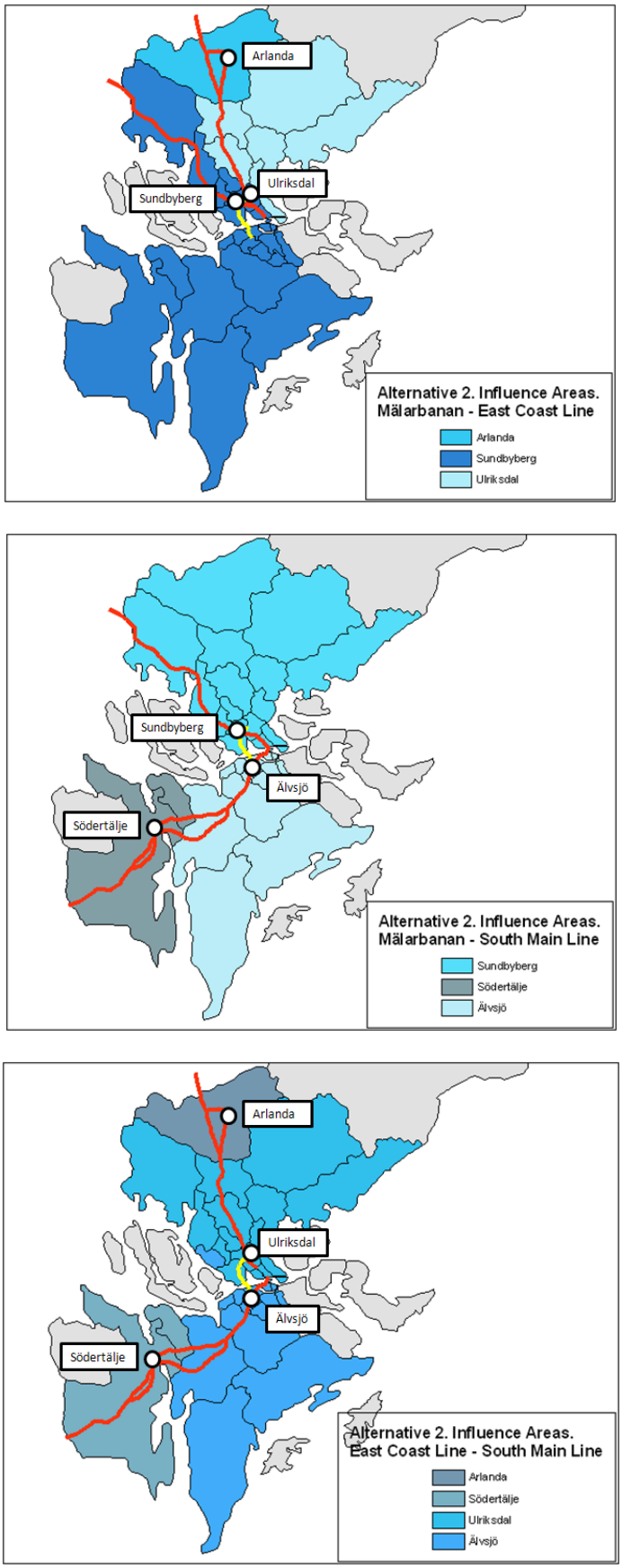


Figure 5.6. Alternative 2. Influence areas of regional stations.

Alternative 2

Mälarbanan / The East Coast Line

Station	Workplaces	% Workplaces	Access time; weighted average (min)
Arlanda	25152	2.5%	12 minutes
Ulriksdal	269623	26.5%	15.4 minutes
Sundbyberg	722326	71%	18.2 minutes
TOTAL	1017101	100%	17.3 minutes

Mälarbanan - The South/West Main Line

Station	Workplaces	% Workplaces	Access time; weighted average (min)
Sundbyberg	688371	67.7%	14.7 minutes
Älvsjö	281208	27.6%	17.7 minutes
Södertälje	47522	4.7%	8 minutes
TOTAL	1017101	100%	15.2 minutes

The East Coast Line - The South/West Main Line

Station	Workplaces	% Workplaces	Access time; weighted average (min)
Arlanda	25152	2.5%	12 minutes
Södertälje	47522	4.7%	8 minutes
Ulriksdal	649209	63.8%	14 minutes
Älvsjö	295218	29%	18.1 minutes
TOTAL	1017101	100 %	14.9 minutes

Table 5.3. Alternative 2. Features of influence areas.

If the table 5.3 is compared with tables 5.1 and 5.2, the results for Alternative 2 are quite better. The access times are reduced substantially in all flows. It is due to the second alternative have its regional stations in an equilibrium point, i.e. close to the city centre and accessible for distant suburbs.

The results show that Sundbyberg would be the most crowded station in west flows. Moreover, Ulriksdal would be the main station in flows between The East Coast Line and The South Main Line. It is mainly due to a large part of workplaces are located in northern suburbs.

5.2.4.- Alternative 3

This alternative presents some similarities with the existing or alternative 0. The regional stations proposed are situated quite close to Stockholm Central, and the differences in the values assessed are not going to be big.

There are three regional stations situated in Solna (The East Coast Line), Sundbyberg (Mälarbanan) and Årstaberg (The South/West Main Line). All of them are located around important areas in Stockholm region.

It is important to remark that trains coming from north only can visit one of northern stations. In the same way, trains coming from the south will have two possibilities: go through Mälarbanan or through The East Coast Line.

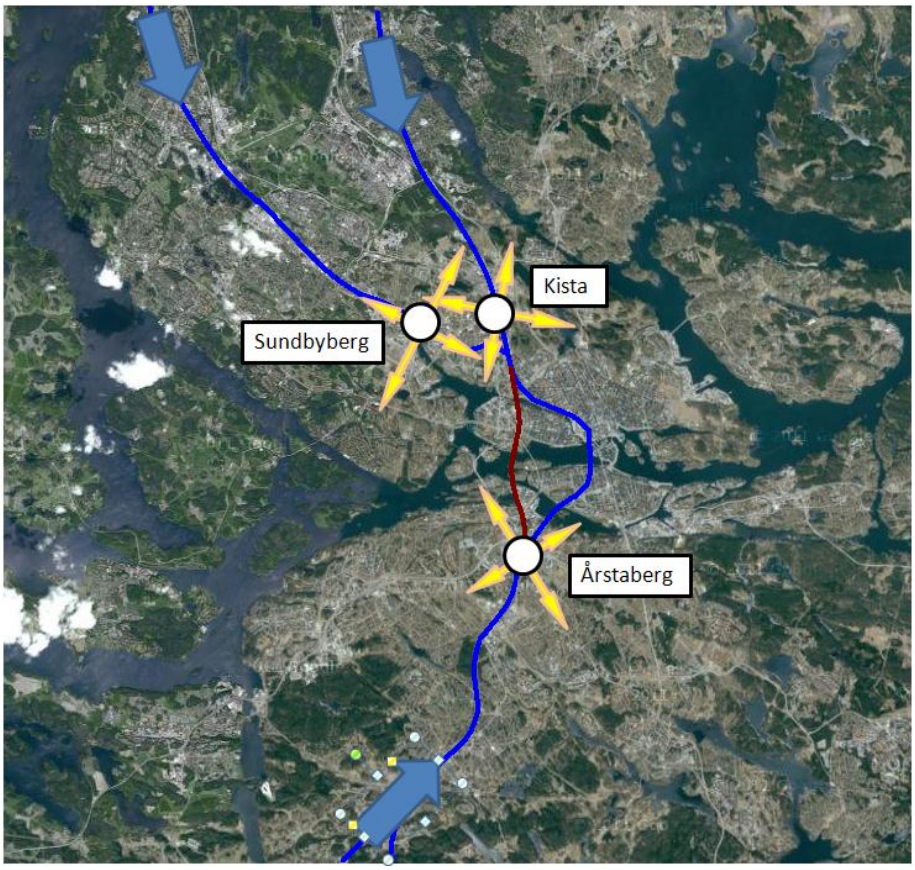


Figure 5.7. Alternative 3. Regional model proposed.

Figure 5.8 shows the influence areas. The most remarkable fact is that city centre is divided into involved stations. In addition, it is important to remark that despite Åarstaberg is situated in the south, it covers Roslags demand in flows Mälarbanan / The South Main Line. It is due to Årstaberg has good connections with north of the city.

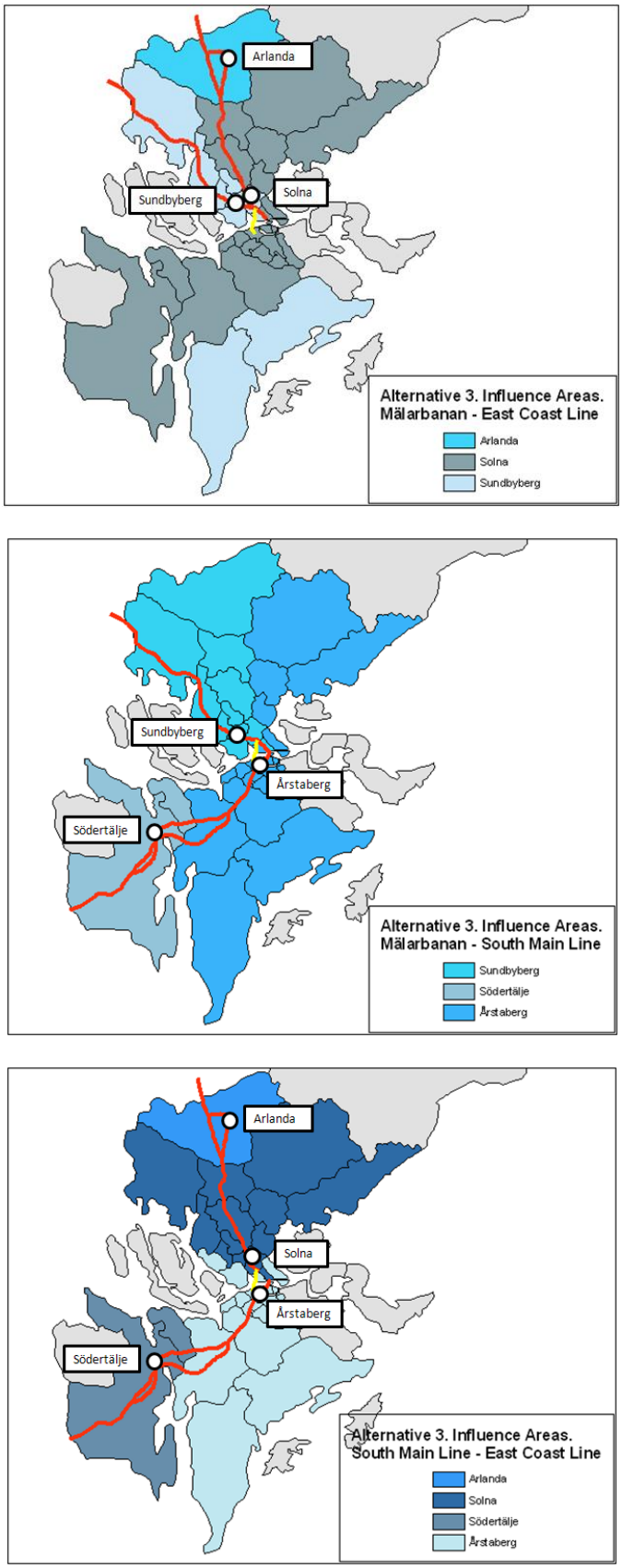


Figure 5.8. Alternative 3. Influence areas of regional stations.

Alternative 3

Mälarbanan - The East Coast Line

Station	Workplaces	% Workplaces	Access time; weighted average (min)
Arlanda	25152	2.5%	12
Solna	694550	68.3%	23.8
Sundbyberg	297399	29.2%	17.3
TOTAL	1017101	100%	21.7

Mälarbanan - The South/West Main Line

Station	Workpla	% Workplaces	Access time; weighted average (min)
Sundbyberg	376497	37%	15
Årstaberg	593082	58.3%	20.7
Södertälje	47522	4.7%	8
TOTAL	1017101	100 %	18

The East Coast Line - The South/West Main Line

Station	Workpla	% Workplaces	Access time; weighted average (min)
Södertälje	47522	4.7%	8
Solna	488726	48%	21.8
Årstaberg	480853	47.3%	16.8
TOTAL	1017101	100%	18.5

Table 5.4. Alternative 3. Features of influence areas.

The access times are better than in the Alternative 0 in flows to/from The South Main Line. However, the results are worse in the flow Mälarbanan / The East Coast Line. It is important to remark that Alternative 3 does not have a new link between Solna and Sundbyberg stations.

Despite the results are not much better than in the Alternative 0, if regional main stations are located in Solna, Sundbyberg and Årstaberg, the traffic in Stockholm Central decreases substantially, and the capacity problem is avoided.

5.2.4.- Comparison of alternatives.

In figure 5.9, are represented the weighted average access times for each alternative.

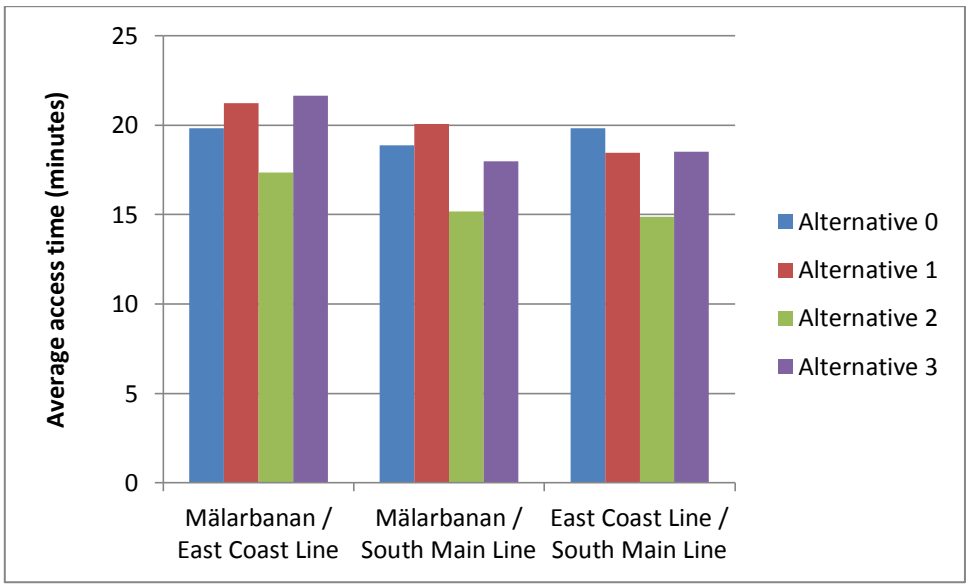


Figure 5.9. Comparison of access times to the regional stations.

As it is explained above, the second alternative is the best from regional stations perspective. It allows to reduce access time in all the flows. Alternatives 1 and 3 reduce travel times in some cases, and in addition, they would enable to derivate part of Stockholm Central traffic.

Therefore, the by-pass is a good idea from regional stations perspective thus the results indicate that peripheral stations are better than a main central station.

5.3.- Time travels between main lines.

If the By-pass is built, it exist the possibility to connect the main lines in order to establish regional services which link important cities in the vicinity of Stockholm.

In some cases, like the travels between Uppsala and Västerås, it is necessary to change the train at Stockholm Central. In a future network with the By-pass, junctions between main lines will allow to plan services that will link directly these cities. In addition, these new services would enable to cover Stockholm´s demand.

In order to assess the changes in the travel times, a small network has been modeled. It includes the three main lines which converge in Stockholm (i.e. The East Coast Line, Mälarbanan and The South/West Main Line) and the different By-pass alternatives. Since in this thesis, only the changes produced by alternatives are assessed, it is only necessary to model the parts of the lines affected by the Alternatives.

Therefore, the network modeled is:

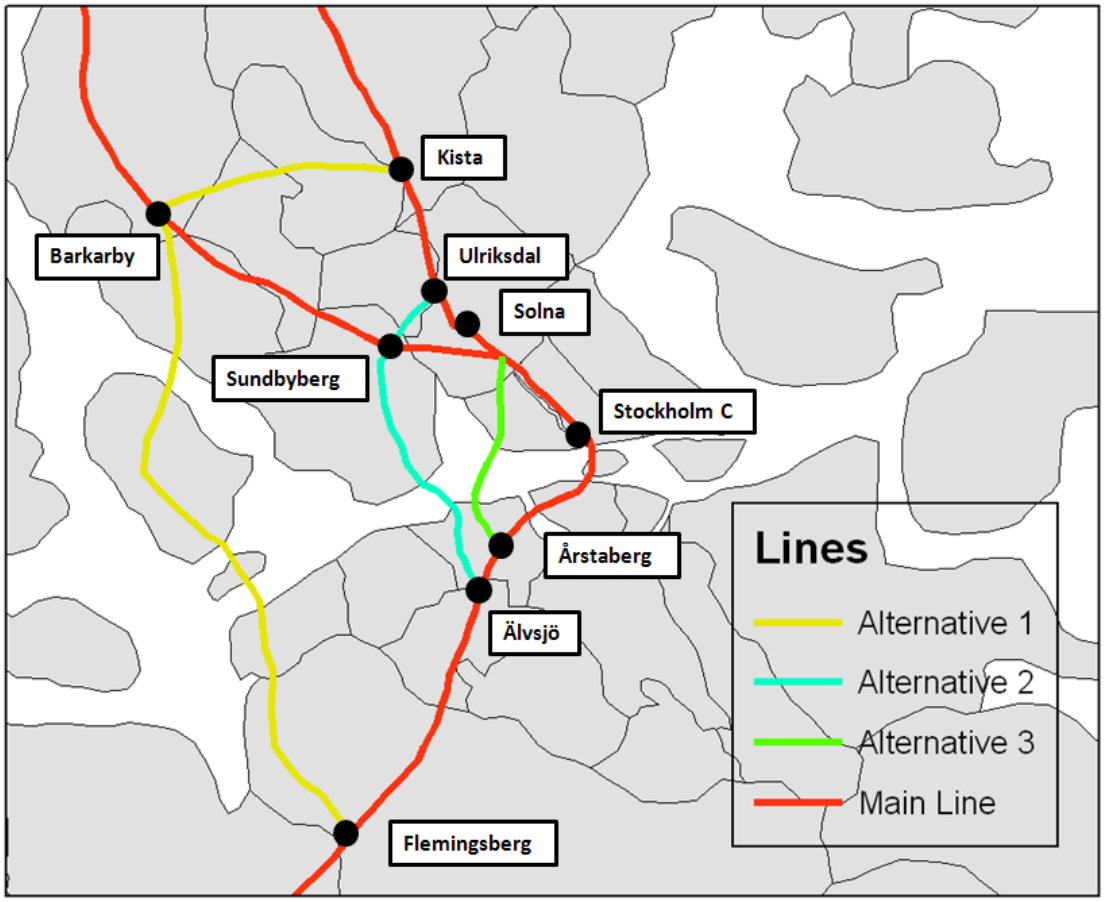


Figure 5.9. Sketch of network modeled in order to evaluate the changes in travel times.

The data about the travel times in the existing lines have been obtained from different sources. Some of them can be looked up in the Mälarbanan project

document (Banverket, 2008). The rest of them have been estimated from today travel times.

Regarding the new stretches, the methodology used is to compare them with similar length existing stretches. In the Appendix 4, the stretches utilized in the comparison can be consulted. Thus, we can establish the new travel times.

In the study, three control points have been established. They are Flemingsberg, Barkarby, and Kista, since they are the most distant nodes. The objective is to obtain the travel times between these points with regional services, in order to assess the changes produced by different alternatives.

Below, figure 5.10 shows the travel times utilized in each Alternative:

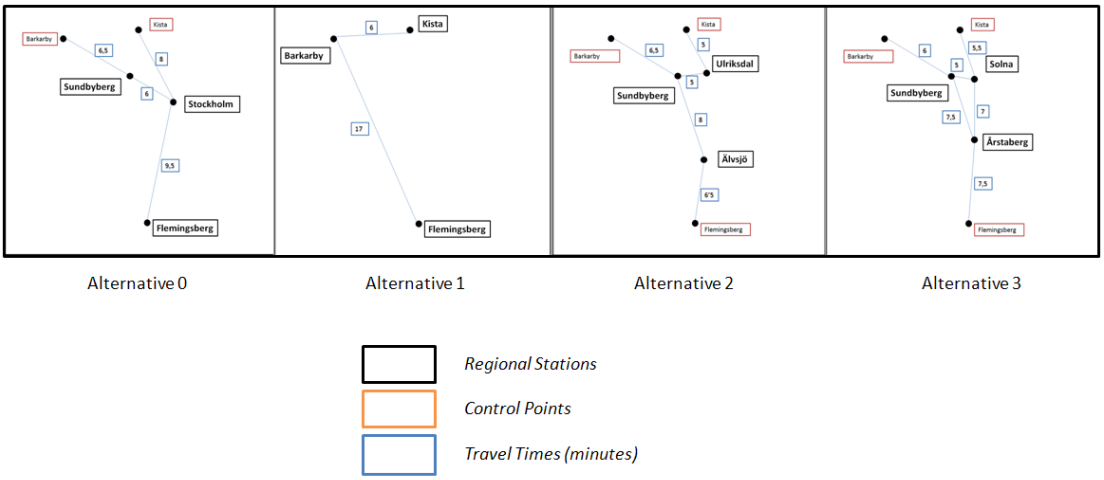


Figure 5.10. Modeled network for each alternative.

Today (Alternative 0) it is only possible to go from one main line to another one, waiting a determined amount of time in Stockholm C. Only a few OD pairs do not need a train interchange in Stockholm C, and thus most of the travels which need to go through two main lines have to change trains.

The waiting times depend on the cities involved, but in the majority of the cases it is more than 15 minutes. However, in this thesis, the assumption made is that services between main lines will exist in all directions, i.e. it will be possible to go from all the cities in the north to all the cities in the south without change of trains.

Moreover, it is necessary to fix the stop times in each station. In Alternative 0, the stops in Stockholm C are 7 minutes for all the travel possibilities, whereas in Flemingsberg and Sundbyberg the stop time is 60 seconds.

In the By-pass alternatives, the stop time is 3 minutes in the main regional stations. These times are lower than in Stockholm Central due to the fact that in the new stations there will be less customers waiting for the train.

At this point, the data available is enough to evaluate the travel times between main lines.

The figures below show the times required to travel between the different control points. The results for the By-pass alternatives improve notably Alternative 0 in some cases. For example, Alternatives 1, 2 and 3 are much better in the travels between The East Coast Line and Mälarbanan than Alternative 0. However, trips between The East Coast Line and The South/West Main Line are penalized with by-pass alternatives

Travels between Mälarbanan and The South/West Main Line are shorter with the by-pass. Particularly, travel time between these lines is largely reduced in Alternative 1.

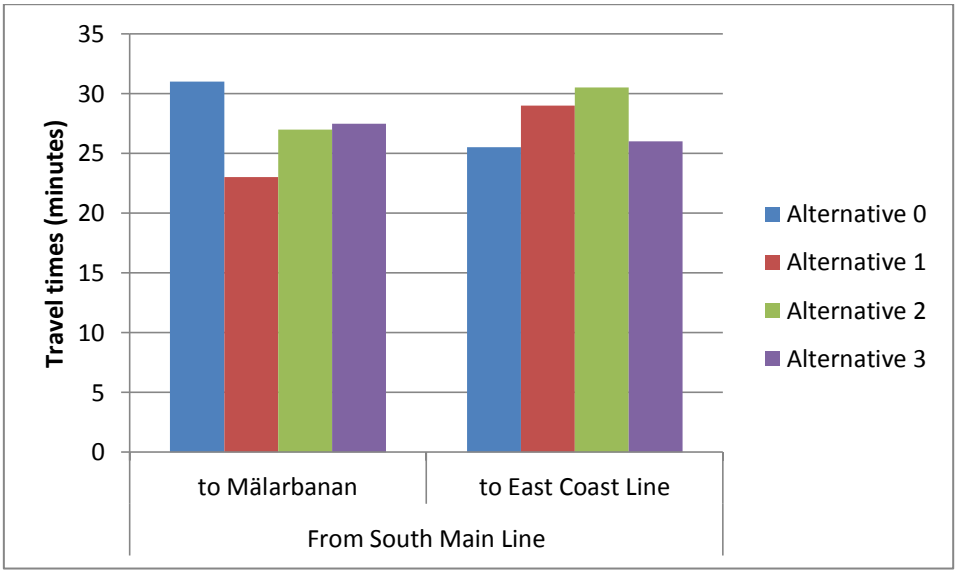


Figure 5.11. Travel times (minutes) to/from South/West Main Line.

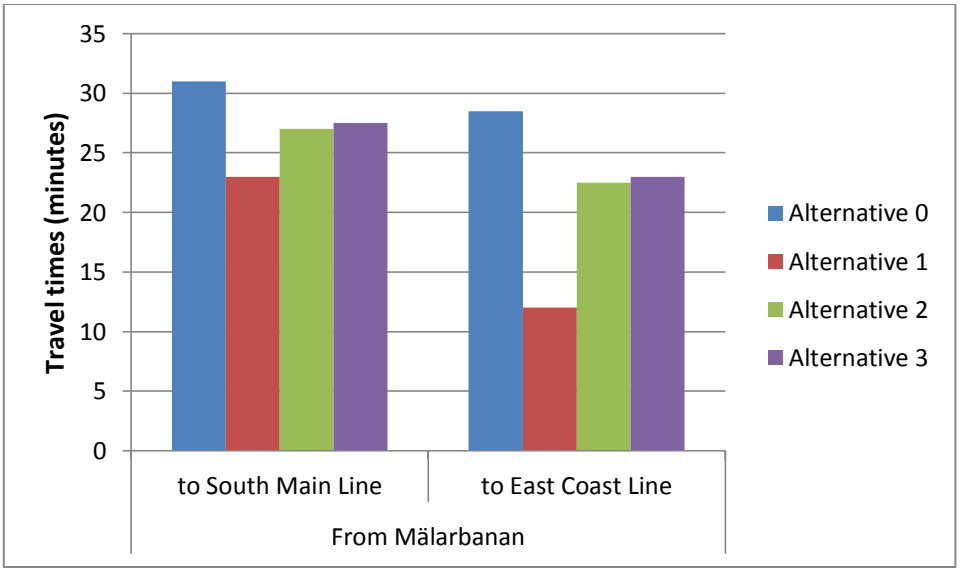


Figure 5.12. Travel times (minutes) to/from Mälarbanan.

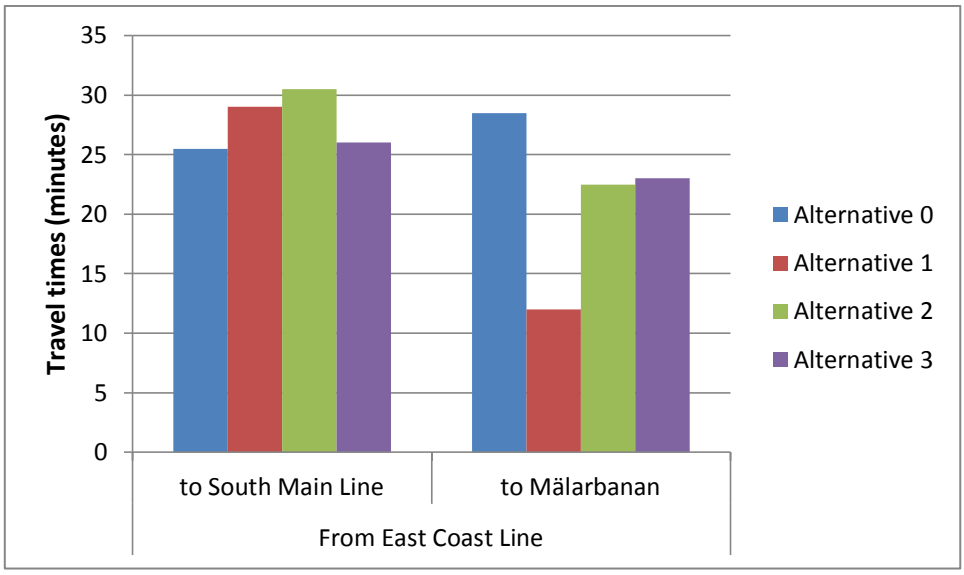


Figure 5.13. Travel times (minutes) to/from East Coast Line.

Since the results differ depending on the flows analyzed, it is important to have some information about the traffic between main lines in order to arrange flows in order of importance.

The table 5.5 shows demand data extracted from a forecast for 2030. These data refer to public transport, and they could be a good indicator of railway traffic between studied lines. Different flows are represented by different colors.

	Uppsala län	Södermanlands län	Östergötlands län	Örebro län	Västmanlands län	Gävleborgs län
Uppsala län		367	77	56	1264	647
Södermanlands län	553		983	553	1241	24
Östergötlands län	77	578		115	74	3
Örebro län	66	500	233		651	8
Västmanlands län	1482	1277	91	739		55
Gävleborgs län	438	14	3	6	33	

		TRAFFIC FLOW
	The South/West Main Line and The East Coast Line	1118
	The South/West Main Line and Mälarbanan	2683
	Mälarbanan and The East Coast Line	2970

Table 5.5. Traffic demand of public transport in Mälardalen valley.

In view of traffic data, largest flows will be produced between Mälarbanan and The East Coast Line but the travels between The South Main Line and Mälarbanan are important as well. These flows get benefit in terms of travel time with the by-pass.

On the other hand, flows between The South/West Main Line and The East Coast Line are not as relevant as the others. It is important to remember that by-pass alternatives penalize travel time between these lines.

5.4.- Summary

Regarding **influence areas**, the comparison between the different by-pass options and Alternative 0, shows that transverse infrastructure (by-pass) and regional stations in the periphery could improve the regional rail system in the Stockholm area. The access times to the regional stations, which we can interpret as an accessibility measure, are improved with by-pass.

Moreover, with the by-pass, Stockholm Central would get available capacity to be able to support a demand of an increase in other railway services, such as long-distance or high-speed-trains.

The results make it clear that Stockholm´s railway system is too much concentrated in one point (Stockholm central) and it needs a new non-radial infrastructure to get both:

- Improvement of the accessibility in the Stockholm area
- A solution to avoid a capacity problem in Stockholm Central station.

If a comparison is made between the different by-pass options, i.e. Alternatives 1, 2 and 3, certain conclusions can be drawn.

The second alternative (Älvsjö-Mörby) presents the best results in access times. These times are much better than the times in Alternative 1 and 3.

It means that Alternative 2 route is located in a point of equilibrium between the city centre and peripheral suburbs, or in other words, close enough to the city centre and quite accessible to the periphery.

Therefore, when considering the studied aspects up until now, Alternative 2 is the most proper choice in the point of view of the location of regional stations. However, other aspects have to be studied in order to take a decision.

Regarding, **travel times between main lines**, By-pass alternatives improve in most of cases Alternative 0 times. It could be due to the assumptions made, where it has been supposed direct services between all main lines passing Stockholm C with seven minutes stops.

In addition, the improvements in travel times are produced in the stretches with the heaviest traffic, i.e. Mälarbanan-The South Main Line and Mälarbanan-The East Coast Line.

Alternative 1 is the best option in this case. In some routes, like Barkarby-Kista, travel time is reduced to 20 minutes. It means that, for example, travels between Uppsala and Västerås would come out as much more attractive for passengers.

Moreover, in this chapter, just the extreme cases have been studied, i.e., peripheral stations or Stockholm C. It is important to remark that it is possible to have a mixed model where some lines stop in suburb stations and others in Stockholm C. In this way, it would be possible to exploit the advantages of each of them.

In conclusion, the table 5.6 shows the results for the alternatives from a regional traffic point of view.

	Influence areas	Travel Times	OVERALL
Alternative 0			
Alternative 1			
Alternative 2			
Alternative 3			

Negative
Positive aspects
Very Positive

Table 5.6. Characteristics of alternatives from regional traffic point of view.

6 Analysis of effects on long-distance traffic.

6.1.-Introduction

Long-distance services in Sweden have undergone high improvements during recent years due to the introduction of X2000 trains. These trains are able to run over 200 km/h on conventional tracks. Nowadays, there are X2000 services running towards Gävle and Sundsvall through the The East Coast Line, and towards Gothenburg, Malmö and Copenhagen through The South Main Line. However there are no direct lines between north and south, i.e. it is not possible to travel from Gävle to Malmö without change of trains at Stockholm Central.

In the last years a lot of investigations have been carried out in order to assess the possibility of building a HS network that would allow trains to run over 300 km/h. The corridors analyzed are Stockholm-Malmö/Copenhagen and Stockholm-Gothenburg. The intention is to build a separate network, since HS trains require different track characteristics.

In this thesis it is supposed that in 2030 there will be high-speed services between all main lines, i.e:

- Travels to/from Mälarbanan to/from The East Coast Line.
- Travels to/from Mälarbanan to/from The South/West Main Line.
- Travels to/from The South/West Main Line to/from The East Coast Line.

Regarding Stockholm area, as was the case with regional trains, and departures and arrivals are concentrated to Stockholm Central, and thus it contributes to the congestion in the city centre. Despite the situation being quite similar to that of the regional traffic, it is not possible to make the same assessments due to the differences between systems. For example, the travel motivations in long-distance travels do not require daily periodicity. The main motivations are leisure or work issues. Therefore, these trips often have their destination close to the centre of the city.

When a new high speed line is being planned, two principles can be applied regarding the location of the stations in the cities:

- Traditional principle: The stations are situated in the city centre from where the accessibility to the rest of the districts used to be quite good. However, it often entails sharing the tracks with other services through the city. This fact produces both an increase in the travel times due to the congestion in urban areas and capacity conflicts due to the heterogeneous traffic.
  Today´s Stockholm high speed services are organized following this principle. However, it is important to remark that the Swedish high speed trains (X2000) run on conventional tracks.
- Motorway principle: The stations are located in the periphery of the cities along a by-pass. Despite the fact that the access time to the city centre is larger than in the traditional principle, this model presents other advantages. If the stations are located in the periphery, the trains do not have to cross the city and do not have to share the tracks with other trains. It allows to reduce travel times and to increase the capacity in the city tracks. Obviously, this principle is built from the assumption that the by-pass is just for high-speed services.
  The application of this principle would be possible in Stockholm if a railway by-pass is built.

There is not one principle better than the other; it depends on the features of the city. Therefore, in this chapter a comparison between the two principles is made.

From the high speed perspective, new tracks can be built with conventional characteristics (all kind of passenger trains are able to run through the line) or with high-speed characteristics (just high-speed trains can run through the line).

If the by-pass is built following high speed requirements, it would not be possible for other trains to run through the line. For example, a freight train running through a high speed line produces both a fall in the capacity and a fast deterioration of the infrastructure. In addition, the complexity of the building project is quite high due to the fact that alternatives are located in densely urbanized areas. Therefore, if the by-pass is built exclusively for high-speed trains, most of the route would have to run by tunnel.

If the by-pass is built according to conventional characteristics, the radius and banked curves are much less demanding. It allows to reduce notably the building costs. In addition, several kinds of trains could run through the new line. However, high-speed trains have to reduce their speeds and, in consequence, the positive by-pass effects are reduced.

Regarding the above considerations, the main advantage of building the by-pass just for high-speed trains is to reduce travel times. Therefore, it is important to evaluate the changes in travel times in order to define track characteristics.

6.2. - Travel times.

It is important to evaluate the time spent when crossing the city. The control points utilized are the same as in the chapter on regional traffic (chapter 5), i.e. Flemingsberg, Barkarby and Kista.

Since it is not possible to forecast whether the 300 km/h network will be built or not, in the studies below two **scenarios** are defined:

1. High-speed trains running through conventional network. The trains will be Gröna Tåget which is going to replace X2000.
2. High-speed trains running through separate tracks. The trains will run over 300 km/h and the by-pass has to be just for high-speed services.

Figure 6.1 shows the long-distance stations for each alternative. Travel times for the stretches have been established for both scenarios: 250 km/h and 300 km/h.

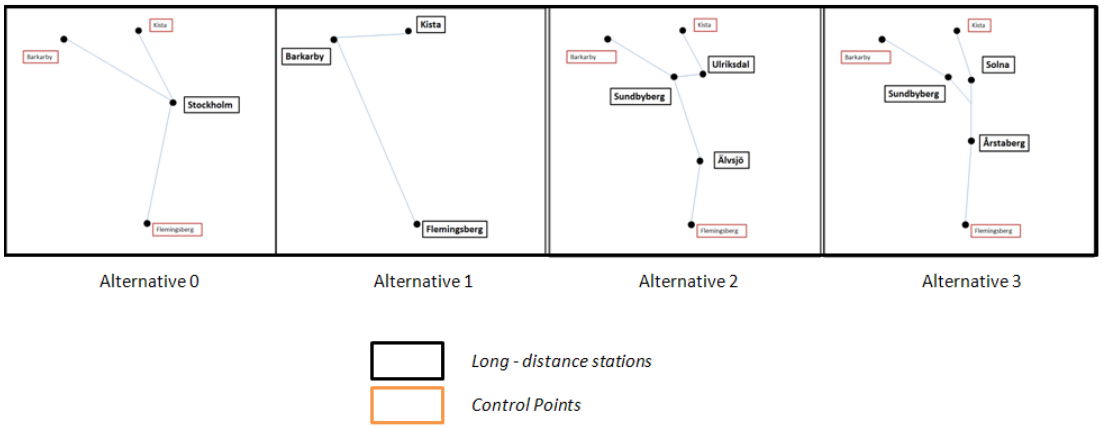


Figure 6.1. Long-distance stations in Stockholm area

In Alternative 0 the travel times are almost the same as in the regional chapter. It is due to the congestion of the central tracks and the features of the tracks.

In the first scenario (250 km/h), travel times for the new stretches are quite similar to regional trains. It is due to the fact that high-speed trains are unable to run at maximum speed through conventional tracks. In addition, most of the stretches do not have enough length to enable reaching the maximum speed.

If the tracks are built to allow trains running over 300 km/h, the travel times in the new stretches are reduced. This reduction is quite big in Alternative 1, where the length of the new links allows for reaching high speeds.

In Alternative 0 the stop time has been fixed to 7 minutes. For the rest of the alternatives the stop time for each station is 3 minutes.

The time needed to travel between the control points has been calculated. Figures 6.2, 6.3 and 6.4 show the differences between the scenarios for each alternative.

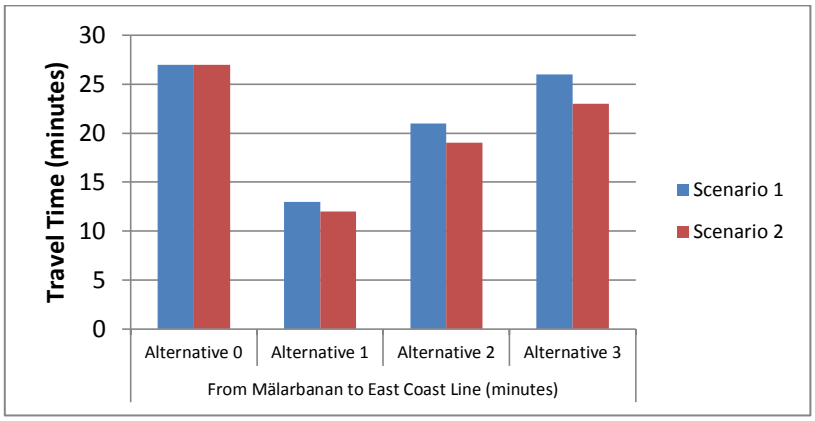


Figure 6.2. Travel times between Mälarbanan and The East Coast Line.

The flows between Mälarbanan and the The East Coast Line are largely favored (figure 6.2). Alternative 1 improves the travel times more than 50%. Nowadays, there are no high-speed services for Mälarbanan, but this line is to be upgraded. In the future, travels between Gothenburg and Stockholm could be made through Mälarbanan.

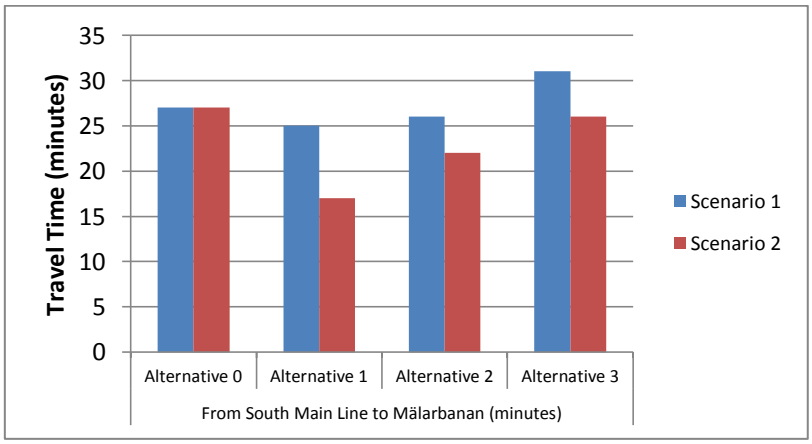


Figure 6.3. Travel times between Mälarbanan and The South Main Line.

Regarding the link between the The South/West Main Line and Mälarbanan, just scenario 2 (by-pass built for 300 km/h) presents notable improvements. Alternative 1 is the best alternative again. This is attributable to the fact that the stretches between stations are longer and then trains can reach higher speeds.

Travels between the The South/West Main Line and the The East Coast Line are not favored by the by-pass (figure 6.4). It is important to remark that the largest northern and southern cities are situated on these lines, and thus, the largest flows will be produced between these lines.

In conclusion, by-pass alternatives do not improve the travel times remarkably in most of the cases. In addition, differences between scenarios are not notable. It is important to remember that the main advantage of building the second scenario is to reduce travel times. Since the effects are not important, **second scenario is rejected** in posterior analyses.

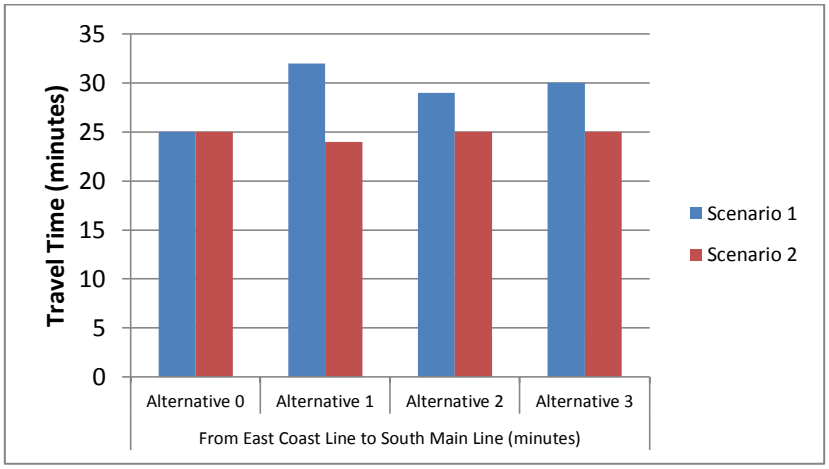


Figure 6.4. Travel times between The East Coast Line and The South Main Line.

6.3 Accessibility.

First, it is important to fix a proper indicator to establish the relative importance of the areas, since a weighted average of access times will be carried out at this section.

The main motivations for long-distance travels are work issues and leisure. Most of the customers spend more than one day in the destination city, and thus the proximity to the hotels is essential. The assumption made in this section is that long-distance travelers are more interested than regional travelers in reaching the city centre. Therefore, the access times are calculated following the principle below:

- 80% of customers have as their destination the centre of the city.
- The rest of the travelers are divided into the different districts depending on the number of workplaces.

Influence areas and access times are calculated for each flow between main lines.

6.3.1 Alternative 0

In Alternative 0, there is only one station located in Stockholm C. Obviously this station has to cover all the demands in the Stockholm area and thus access time is the same for all flows. The average access time, following the assumptions made above, is 14.5 minutes. This value is lower than is the case in regional assessment due to the fact that, in this case, the demand is more concentrated to the city centre.

Alternative 0

Station	Workplaces	% Workplaces	Access time; weighted average (min)
Stockholm C	1017101	100%	14.5
TOTAL	1017101	100%	14.5

Table 6.1. Alternative 0. Influence area for long-distance services.

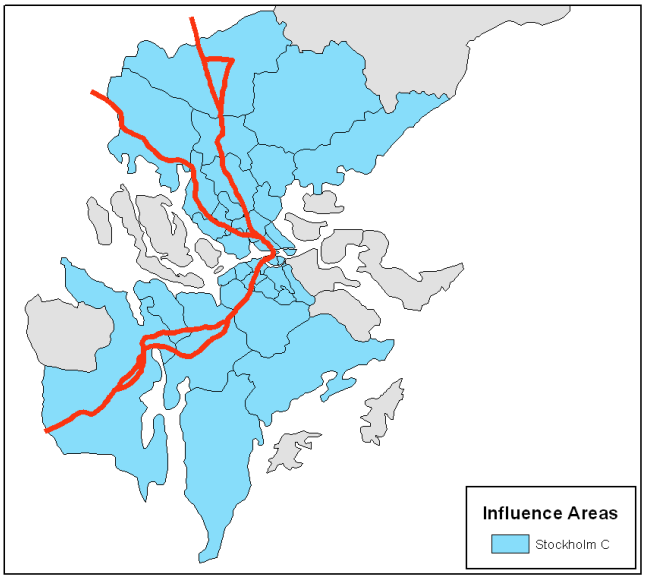


Figure 6.5. Alternative 0. Influence area of long-distance stations.

6.3.2.- Alternative 1.

In this alternative, as explained above, there are three long-distance stations which are located in Flemingsberg, Barkarby and Kista. The stations utilized depend on the flow studied.

- Travels between Mälarbanan and the The East Coast Line: Barkarby and Kista.

- Travels between Mälarbanan and the The South/West Main Line: Barkarby and Flemingsberg

- Travels between the The East Coast Line and the The South/West Main Line: Kista and Flemingsberg.

As expected, the access times are higher than in Alternative 0. It is because stations are situated in the periphery and the demand is concentrated to the city centre.

Alternative 1

Mälarbanan / The East Coast Line

Station	Workplaces	% Workplaces	Access time; weighted average (min)
Kista	650077	63.9%	18.8
Barkarby	367024	36.1%	24.4
TOTAL	1017101	100%	20.8

Mälarbanan-The South/West Main Line

Station	Workpl	% Workplaces	Access time; weighted average (min)
Barkarby	765151	75.2%	21.3
Flemingsberg	251950	24.8%	20.2
TOTAL	101710	100%	21

The East Coast Line-The South/West

Station	Workpl	% Workplaces	Access time; weighted average (min)
Kista	774036	76.1%	18.7
Flemingsberg	243065	23.9%	19.8
TOTAL	101710	100%	18.9

Table 6.2. Alternative 1. Influence area and access time to long-distance stations.

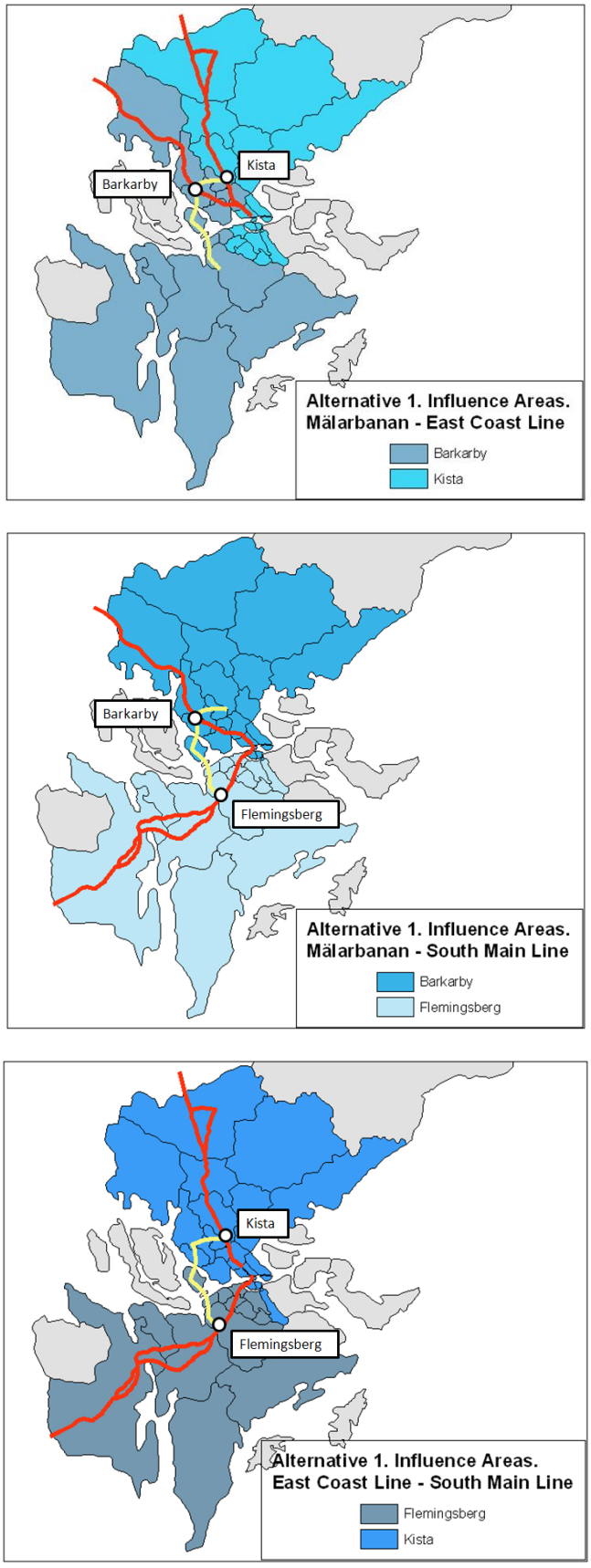


Figure 6.6. Alternative 1. Influence area of long-distance stations.

6.3.3.- Alternative 2.

The second alternative has its long-distance stations situated in Älvsjö, Sundbyberg and Ulriksdal. As in the first alternative, stations utilized depend on the flow:

- Travels between Mälarbanan and The East Coast Line: Sundbyberg and Ulriksdal.

- Travels between Mälarbanan and The South/West Main Line: Sundbyberg and Älvsjö

- Travels between The East Coast Line and The South/West Main Line: Ulriksdal and Älvsjö.

Despite there are three long-distance stations, the results are worse than in Alternative 0. It is due to the importance of the city centre as a generator of long-distance demand.

Alternative 2

Mälarbanan - The East Coast Line

Station	Workplaces	% Workplaces	Access time; weighted average (min)
Ulriksdal	294775	29%	17.5
Sundbyberg	722326	71%	14.4
TOTAL	1017101	100%	15.3

Mälarbanan-The South/West Main Line

Station	Workplaces	% Workplaces	Access time; weighted average (min)
Sundbyberg	688371	67.7%	13.5
Älvsjö	328730	32.3%	16.9
TOTAL	1017101	100%	14.6

The East Coast Line-The South/West Main

Station	Workplaces	% Workplaces	Access time; weighted average (min)
Ulriksdal	674361	66.3%	14.2
Älvsjö	342740	33.7%	17
TOTAL	1017101	100%	15.2

Table 6.3. Alternative 2. Influence area and access time to long-distance stations.

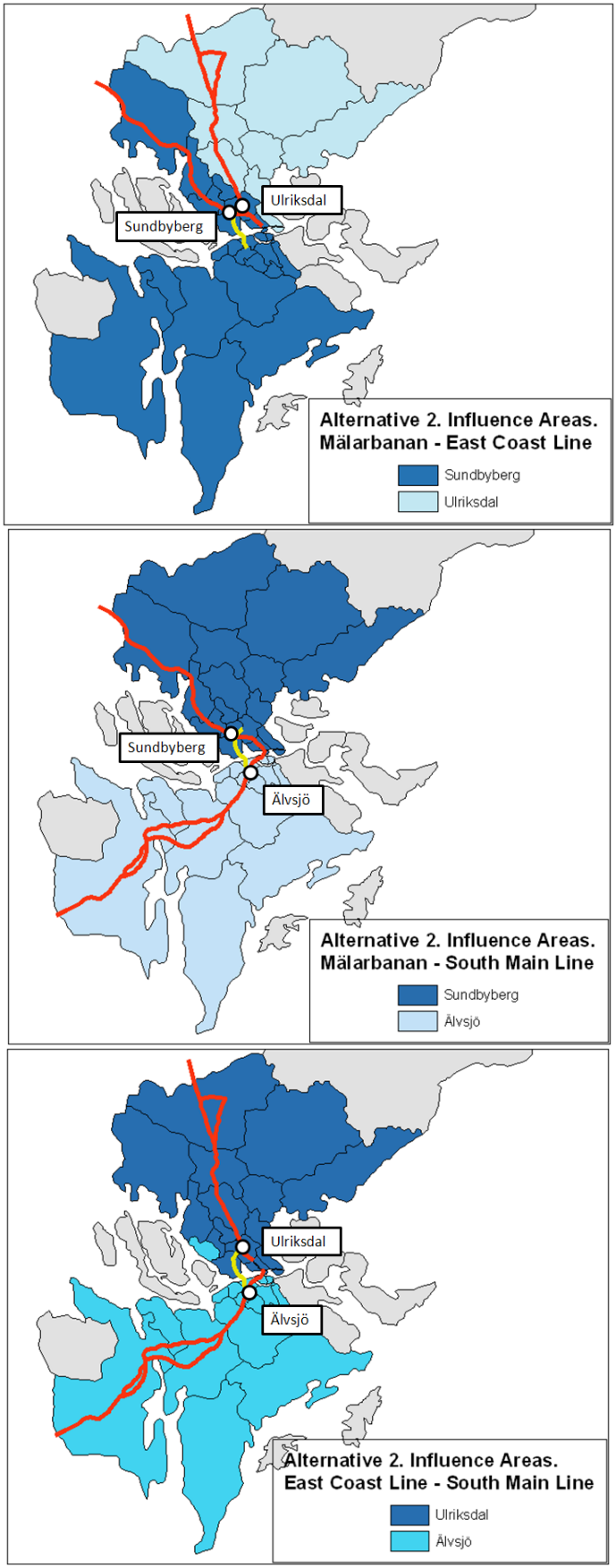


Figure 6.7. Alternative 2. Influence area of long-distance stations.

6.3.4.- Alternative 3

In this case, long-distance stations are located quite close to the city centre. These stations are Årstaberg, Sundbyberg and Solna. Trains stop at the following stations:

- Travels between Mälarbanan and The East Coast Line: Sundbyberg and Solna.

- Travels between Mälarbanan and The South/West Main Line: Sundbyberg and Årstaberg.

- Travels between The East Coast Line and The South/West Main Line: Solna and Årstaberg.

Access times are better than in Alternative 0 in flows to/from The South/West Main Line. However, an increase in access time is produced in the flow between Mälarbanan and The East Coast Line

Alternative 3

Mälarbanan - The East Coast Line

Station	Workplaces	% Workplaces	Access time; weighted average (min)
Solna	719702	70.8%	16.1
Sundbyberg	297399	29.2%	14.9
TOTAL	1017101	100%	15.8

Mälarbanan - The South/West Main Line

Station	Workplaces	% Workplaces	Access time; weighted average (min)
Sundbyberg	376497	37%	11.3
Årstaberg	640604	63%	15.7
TOTAL	1017101	100%	14

The East Coast Line - The South/West Main

Station	Workplaces	% Workplaces	Access time; weighted average (min)
Solna	565033	55.6%	14.9
Årstaberg	452068	44.5%	13.47
TOTAL	1017101	100%	14.3

Table 6.4. Alternative 3. Influence area and access times to long-distance stations.

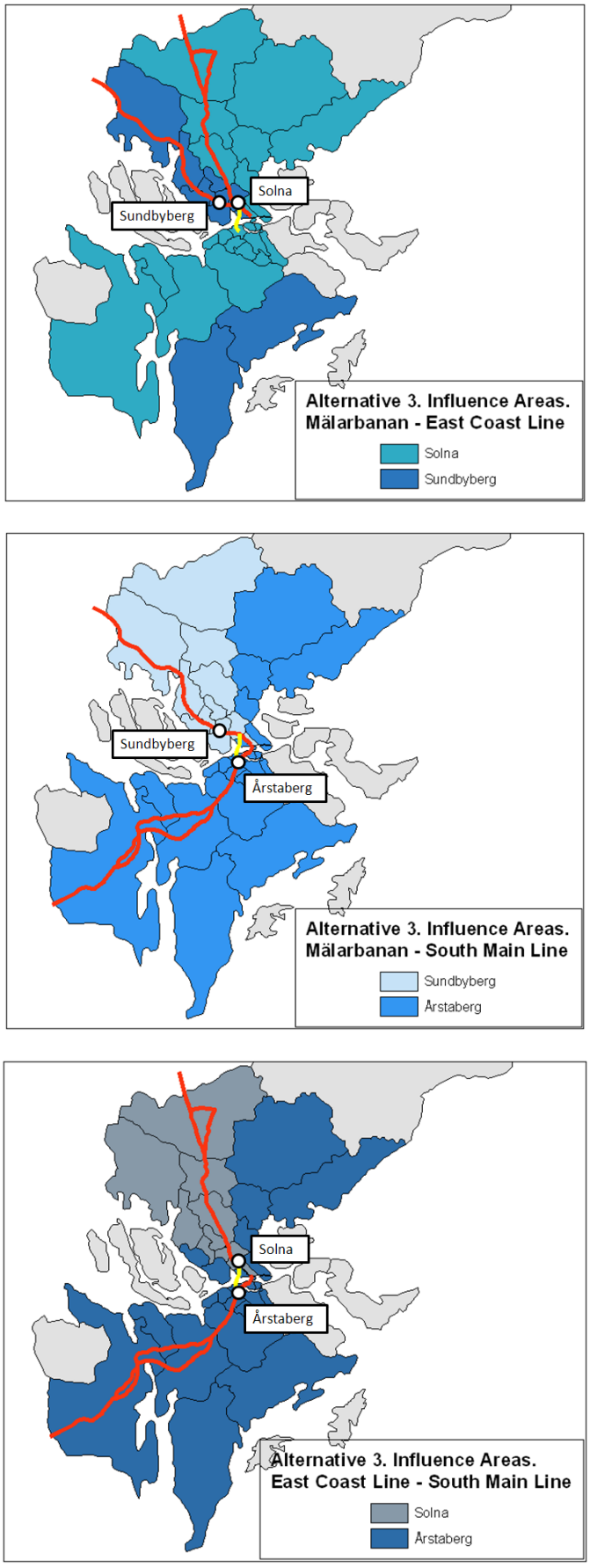


Figure 6.8. Alternative 3. Influence area of long-distance stations.

6.3.5.- Comparison of Alternatives.

In order to compare properly the alternatives, in figure 6.9 are represented the average access times for each flow. Since in the by-pass alternatives there are more than one long-distance station, the influence areas depend on the flow studied. Therefore, it is necessary to calculate the average access time.

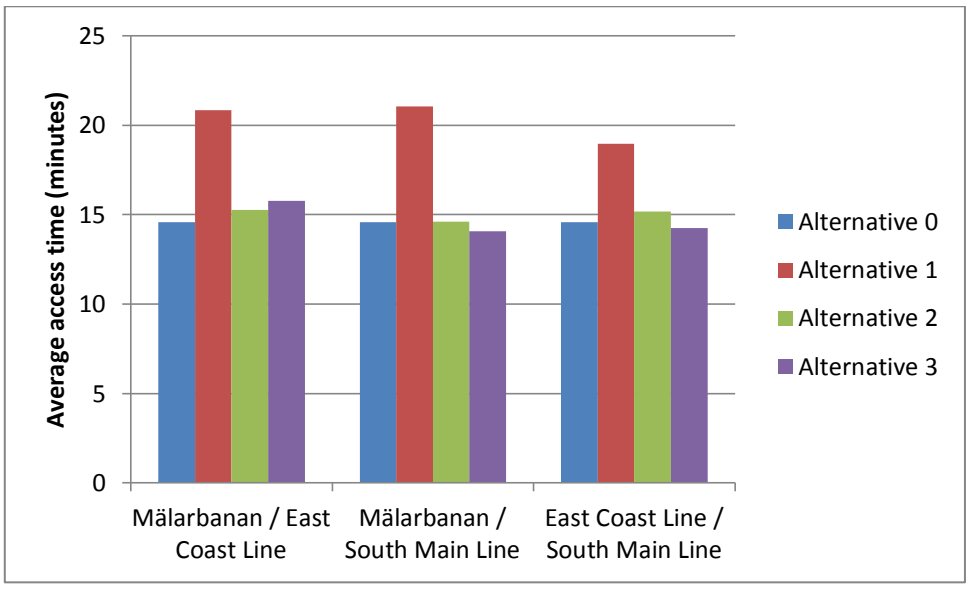


Figure 6.9. Comparison of Alternatives. Access times to long-distance stations.

Alternative 1 is to the disadvantage to access times so much in all flows. Moreover, Alternative 2 and Alternative 3 present values similar to Alternative 0 despite their having three long-distance stations close to the city centre.

Therefore, the most proper option from the perspective of access times is to maintain today´s model (one station in Stockholm C), since by-pass options do not improve this indicator.

6.4.- Summary

The option to build a by-pass with high-speed tracks has been rejected. The main advantage of building by-pass just for high-speed trains is to reduce travel times; however, the time differences between the scenarios are not remarkable and thus the most proper option is to build conventional tracks.

Regarding travel times, by-pass alternatives improve today´s situation in the flows to/from Mälarbanan. However, Alternative 0 is the best for flows between The South Main Line and The East Coast Line. It is important to remark that main cities in Sweden are reached from Stockholm through The South Main Line and Mälarbanan, and thus flows between these lines have a major importance. In conclusion, only Alternative 1 presents better overall results than Alternative 0 from a travel time perspective.

Accessibility has been evaluated by comparing access times to long-distance stations. In this case, demand is more concentrated to the city centre than to regional services.

The results show that Alternative 1 increases access times more than 25% in all flows. This is because the demand is quite concentrated to the centre of the city and long-distance stations are located in the periphery.

Alternatives 2 and 3 have access times similar to Alternative 0, even if they have three long-distance stations. Therefore, the building costs are not justifiable from the point of view of accessibility improvements.

Moreover, the by-pass possibilities would allow for diverting the traffic from the city centre and thereafter avoid capacity problems in Stockholm Central. However, effects on other kinds of traffic are higher than in long-distance, and thus diverting these services is not the best option.

In conclusion, the table 6.5 shows the results for the alternatives from a long-distance traffic perspective:

	Travel Times	Accessibility	**OVERALL**
Alternative 0			
Alternative 1			
Alternative 2			
Alternative 3			

Negative
Positive aspects
Very Positive

Table 6.5. Characteristics of alternatives from long-distance traffic perspective.

7 Analysis of Effects on Freight Traffic.

7.1 Introduction

As is explained in chapter 2, in 2030, the Stockholm area will have four main nodes from a freight transport point of view. They are two ports (Kapellskär in the north and Norvik in the south) and two main freight terminals (Rosersberg in the north and Årsta in the south).

All freight trains have to run through Stockholm Central nowadays. Even though the number of trains is quite low, it is reasonable to think that the number of trains will rise in the future.

Several European institutions want to give a major boost to railway freight transport in order to promote freight intermodality. If the railway freight transport is upgraded, the demand for this kind of transport is going to increase in the future.

Regarding the Stockholm area, in the future, there will be freight traffic flows between the north and south main terminals. Therefore, if the freight traffic is increased a lot, trains will not be able to cross Stockholm Central, since they would interfere with important passenger services.

In addition, the trains are crossing through the city and it is not good from an esthetic point of view. For example, freight trains cross the bridge between Norrmalm and Gamla Stan which is located in a place with an interesting landscape.

Moreover, dangerous freight must not be transported through populated areas, since there is always a danger that a disaster occurs.

In order to avoid this situation, the by-pass could be a good alternative for diverting freight traffic to the periphery.

7.2. Analysis

It is important to make some remarks on the track requirements for freight traffic. Since freight trains have to transport a lot of tons, they are able to run through tracks with low gradients. In tracks built by tunnel it is often necessary to reach the gradient limit for passenger trains which is always higher than the freight gradient.

If the by-pass alternatives are analyzed, it is obvious that most of the second and the third alternative routes have to be built by tunnel.

In addition, the impact of a disaster related with dangerous freight is much higher when it happens in a tunnel.

Therefore, it is unnecessary to study these alternatives (2 and 3) as freight line options, since their features are not proper for this kind of services.

A major part of the first alternative route is running on ground level, and thus it would be possible to schedule freight trains. Therefore, it is the unique feasible option from point of view of freight traffic.

On the other hand, Alternative 1 crosses several urban areas as well. Thus, it is mandatory to study deeply whether the requirements of freight traffic involved are proper or not. Therefore, it would be necessary to have information about the real needs of traffic in 2030 and its features.

In addition, these date are interesting in order to evaluate whether the increase of the building costs (the gradients are lower than in passenger traffic) are worth it or not.

	Freight Traffic
Alternative 0	
Alternative 1	
Alternative 2	
Alternative 3	

	Negative
	Positive aspects
	Very Positive

Table 7.1. Characteristics of alternatives from freight traffic perspective.

8 Conclusions

8.1 Final Analysis

In this thesis several analyses have been carried out in order to assess the feasibility of building a railway by-pass through the west of Stockholm. As was explained in the first chapter, this new line is to reduce the traffic congestion at Stockholm Central. In addition, another goal is to improve the accessibility between the northern and southern suburbs.

The analyses have been made separately for different railway services and the conclusions extracted are different respectively.

8.1.1 Local/Commuter Traffic

Regarding local and commuter traffic, the assessments made show that by-pass alternatives could notably increase the accessibility in the Stockholm Region.

The first alternative (Handen – Täby) has an important cohesive role, since it improves the overall accessibility of peripheral suburbs. In addition, flows between north and south are largely favored with this alternative.

In view of the results, Alternative 2 (Älvsjö – Mörby) is the best option from a local/commuter traffic perspective, since it presents the highest improvements in accessibility. However, the route runs parallel to the new tram from Alvik to Sundbyberg and it would be necessary to study the interaction between them.

Alternative 3 does not upgrade the accessibility from the local/commuter point of view. The stations are situated close to the city centre and therefore this alternative is not appropriate to vertebrate the territory. The reason is that the effects are concentrated to the central part of the system.

In conclusion, Alternatives 1 and 2 are the proper alternatives for diverting part of the commuter traffic from Stockholm C, and in addition implementing them would enable an improvement of the accessibility between the northern and southern suburbs. Moreover, it is necessary to carry out a demand study in order to evaluate the flows of traffic on the new line.

8.1.2 Regional Traffic

With respect to regional traffic, the analyses have been focused on accessibility and travel times. A new regional railway system has been proposed for each alternative. In the studied cases, Stockholm Central has been excluded.

Alternative 1 does not improve the accessibility to regional stations; however, travel times between main lines are largely favored. For example, travel time between Mälarbanan and The East Coast Line is reduced more than 20 minutes. It means that travel time between Västerås and Uppsala would be reduced to more than 15%.

The second alternative presupposes an important upgrade in the accessibility to regional stations. Therefore, customers would spend less time on reaching their destinations. On the other hand, the reduction in travel times is not as high as in Alternative 1.

Even though the third alternative has three regional stations in the centre of the city, the accessibility from the Stockholm Region does not vary remarkably. Moreover, travel times between main lines are not improved substantially.

8.1.3 Long-Distance Traffic

Regarding long-distance traffic, in this thesis, the effects of establishing peripheral long-distance stations has been evaluated. In addition, travel times between main lines have been calculated in order to quantify by-pass impacts.

First, the possibility of building the by-pass only for high-speed trains has been rejected because changes in travel times were not important. Actually, the main reason to build the by-pass exclusively for high-speed trains is to reduce travel times between adjacent cities. These travel times are reduced in flow Mälarbanan - The East Coast Line, but in flow The South/West Main Line – The East Coast Line the times are increased. It is important to consider the fact that main cities in Sweden are situated towards the south and the north, and thus they are linked by The South/West Main Line and The East Coast Line. Therefore, it is more appropriate to build the by-pass with conventional characteristics in order to enable other kinds of trains to run through the line.

Alternative 1 improves the travel time between Mälarbanan and The East Coast Line more than 20 minutes, but on the other hand, it increases travel time between The South/West Main Line and The East Coast Line. In addition, this alternative notably hinders the access time to the stations since most of the long-distance customers have their destination in the centre of the city.

Alternatives 2 and 3 do not modify substantially Alternative 0. Therefore, they could be used in order to divert long-distance traffic from Stockholm C since travel times and accessibility would not vary much.

8.1.4 Freight Traffic

The possibilities of enabling diversion of freight traffic from Stockholm Central to the By-pass have been reduced to Alternative 1. It is attributable to the circumstance that Alternatives 2 and 3 routes run by tunnel, and the gradients are too high for freight trains. In addition, these alternatives (2 and 3) do not reduce the risk of accidents related with dangerous freight.

Therefore, only Alternative 1 is a proper option from a freight traffic perspective.

8.1.5. Dynamic effects

Despite these effects has not been deeply studied in this report, it is important to remark that rail By-Pass could generate important dynamic effects.

These effects involve the location of new activities and services in peripheral areas where the By-pass largely improves the accessibility. Moreover the suburbs affected increase their attractiveness from the residential perspective. All these effects could change the patterns of mobility in a metropolitan area..

Regarding the alternatives studied in this thesis it is remarkable to say that Alternative 1 (Handen-Täby) connects several peripheral areas where the development potential is quite high.

Alternatives 2 and 3, run through important areas where a lot of economical activities are located.

Therefore, the first alternative has the highest growth potential and it would generate important dynamic effects. Thus, this factor has to be taken into account in the final decision. However, these effects have to be deeply evaluated in further studies.

8.2 Recommendations

In conclusion, the table below (table 8.1) shows the results for each alternative. Colors show how much proper each alternative is for each kind of traffic.

It is important to remark that evaluation focuses on accessibility and travel times. Therefore, it cannot be considered a definitive decision, since other factors have to be taken into account in order to decide the most proper alternative. Some of those factors are:

- Demand Study.
- Environmental Issues.
- Economical Assessment

	Local/Commuter Traffic	Regional Traffic	Long-Distance traffic	Freight Traffic
Alternative 0				
Alternative 1				
Alternative 2				
Alternative 3				

Negative
Positive aspects
Very Positive

Table 8.1. Characteristics of alternatives for each kind of traffic.

In view of the results, some recommendations can be made:

- By-pass alternatives are proper for diverting local/commuter and regional traffic from the perspective of accessibility. Moreover, Alternatives 1 and 2 have a high positive impact on accessibility in the Stockholm area.

- Alternative 3 can be utilized to divert traffic from Stockholm Central, but its effects on accessibility and travel times are quite low.

- By-pass alternatives do not have remarkable impacts on long-distance traffic, and in several cases Alternative 0 is better from an accessibility point of view.

- Alternative 1 is adequate to receive freight traffic, but alternatives 2 and 3 cannot cover this kind of services.

Regarding these conclusions there are several proper configurations.

CONFIGURATION 1

Alternative 2 presents the best results for local/commuter and regional traffic. However, freight trains cannot run through this route. In addition, Stockholm Central (Alternative 0) presents advantages from long-distances services point of view. Therefore, the first recommended configuration is:

- Long-Distance and freight trains running through existing lines, i.e. tracks through the city centre.
- Regional trains stopping at three peripheral stations: Älvsjö, Sundbyberg and Ulriksdal. Its purpose is to eliminate regional trains in Stockholm Central.
- Part of commuter trains running through Alternative 2 route from Älvsjö to Mörby. In this way, capacity problem in Stockholm City (future commuter station) may be avoided.

The figure below (figure 8.1) shows a sketch of the overall railway system.

CONFIGURATION 2

If freight traffic increases its relevance in the future, it can be a problem in railway operation. In addition, it would be necessary to derivate this kind of traffic. Since just **Alternative 1** is proper for freight traffic, the recommended configuration is:

- Long-distance trains running through the centre of the city. It means just one long-distance station: Stockholm Central.
- Regional trains operating along Alternative 1 route from Handen to Kista. The regional stations would be located at Kista, Barkarby and Flemingsberg.
- Commuter network includes the stations of Alternative 1. New commuter stations are situated in Skärholmen, Lövon/Ekerö, Vällingby and Täby. In addition the new line uses Handen, Flemingsberg, Barkarby and Kista/Helenelund as stations.
- Freight trains running between Kista and Handen along Alternative 1 route.

Figure 8.2 shows a sketch of this configuration.

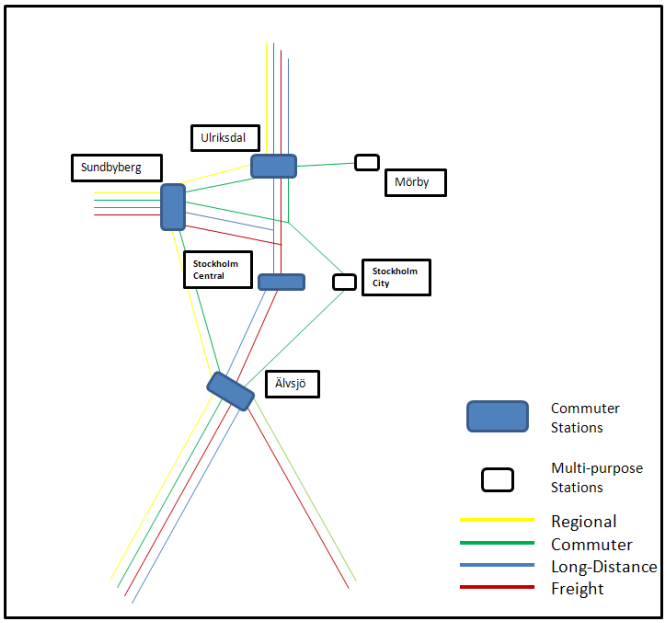


Figure 8.1. Configuration 1 proposed. Alternative 2.

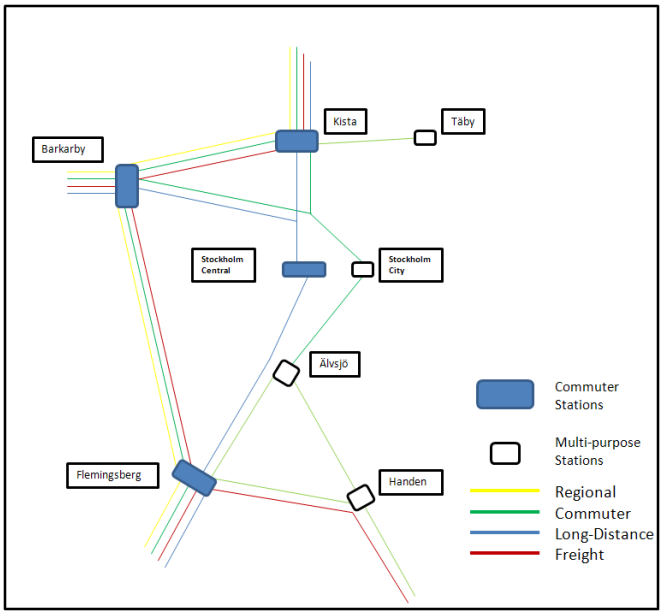


Figure 8.2. Configuration 2 proposed. Alternative 1.

8.3 Further Studies

Below, there is a list with further studies that could be interesting in order to complete the conclusions extracted from this thesis:

- Study of dynamic effects: It could produce differentiating factors between the alternatives.
- Demand study: It is a crucial factor from traffic and economy point of view.
- Economical Assessment: Obviously, it is necessary to develop a cost-benefit analysis in order to evaluate the feasibility of the project.
- Comparison between tram projects (which have been planned in Stockholm) and the alternatives proposed in this thesis. They could be compared from different perspectives like accessibility, dynamic factors, demand, etc.

9 Literature

- Fröidh, O.: *Introduction of regional high speed trains. A study of the effects of the Svealand line on the travel market, travel behavior and accessibility*, 2003

- Facchinetti, M: *Efectos espaciales de las estaciones del TGV inplantadas en la periferia de las ciudades pequeñas*. Ingeniería y Territorio nº70.

- Nelldal, Lindfeldt and Fröidh: *Stockholm Central 2050*. KTH, 2010.

- Litman, T*: Evaluating Accessibility for Transportation Planning. Measuring People's Ability To Reach Desired Goods and Activities.* 2011.

- Poole, A.: *Measuring public transport accessibility.* 2003.

- Geurs, Van Wee: *Accessibility evaluation of land-use and transport strategies: review and research directions*. 2003.

- Franklin, Waddell and Britting: *Sensitivity Analysis Approach for an Integrated Land Development & Travel Demand Modeling System*. 2002.

- Martín, Gutiérrez and Román: *Data Envelopment Analysis (DEA) Index to Measure the Accessibility Impacts of New Infrastructure Investments: The Case of the High-speed Train Corridor Madrid–Barcelona–French Border.* 2003.

- Moreno, L.: *Evaluation of Route Alternatives for a new railway line to Norrtälje/Kapellskär from a passenger traffic perspective*. 2008.

- SJ, www.sj.se

- SL, www.sl.se

- SCB (Statiska Centralbyran), www.scb.se

- Trafikverket, www.trafikverket.se

- Banverket, www.banverket.se

-

Appendices

Contents

Appendix 1. Floyd-Warshall algorithm. MATLAB code.

In this thesis, Floyd-Warshall algorithm has been used in order to calculate the travel times on the local railway network. This algorithm (sometimes known as the **Roy-Floyd algorithm** or **Warshall's algorithm**) is for solving the all-pairs shortest path problem on weighted, directed graphs in cubic time.

The Floyd–Warshall algorithm takes as input an adjacency matrix (connections matrix) representation of a weighted, directed graph (V, E). The weight of a path between two vertices is the sum of the weights of the edges along that path. The edges E of the graph may have negative weights, but the graph must not have any negative weight cycles. The algorithm computes, for each pair of vertices, the minimum weight among all paths between the two vertices. The running time complexity is $\Theta(|V|^3)$.

The algorithm is based on the following observation:

- Assuming the vertices of a directed graph G are $V=$, consider a subset .
- For any pair of vertices i, j in V, consider all paths from i to j whose intermediate vertices are all taken from, and p is a minimum weight path from among them.
- The algorithm exploits a relationship between path p and shortest paths from i to j with all intermediate vertices in the set.
- The relationship depends on whether or not k is an intermediate vertex of path p.

Source: http://www.algorithmist.com/

Below, the code implemented on MATLAB is attached.

```
function D = FastFloyd(D)

        n = size(D, 1);

        for k=1:n

                i2k = repmat(D(:,k), 1, n);
                k2j = repmat(D(k,:), n, 1);

                D = min(D, i2k+k2j);

        end

end
```

Appendix 2. Travel Times on Local Traffic.

In the following pages the tables show the travel times used in the local transport model.

The railway lines included are:

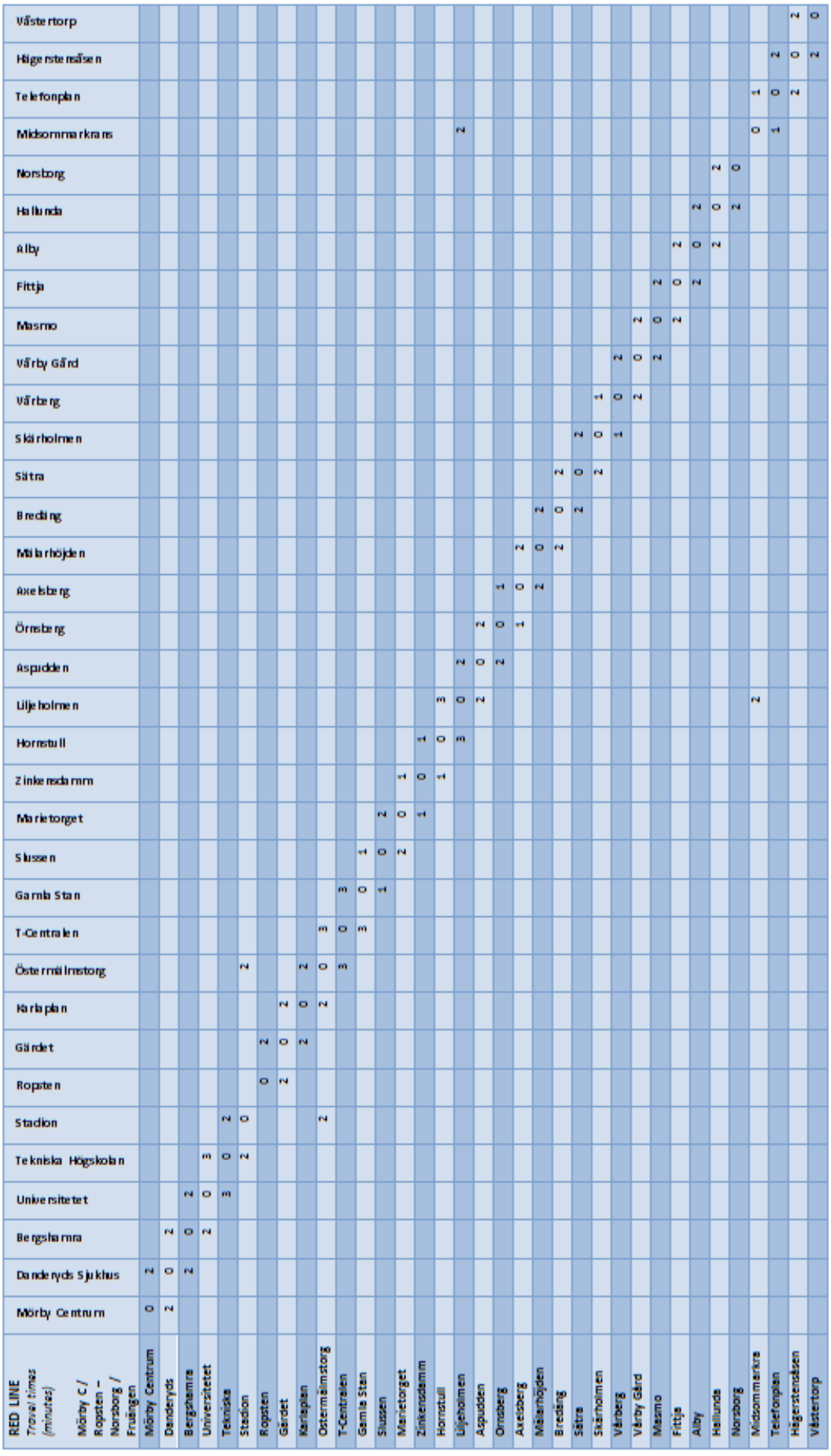
- Metro Lines
- Pendeltåg Lines
- Tvärbanan
- Nockebybanan
- Roslagsbanan

In addition, the frequencies assumed in these lines are attached in the last page.

BLUE LINE Hjulsta / Akalla - Kungsträdgården	Hjulsta	Tensta	Rinkeby	Rissne	Duvdo	Sundbybergs Centrum	Vreten	Huvudsta	Akalla	Husby	Kista	Hallonbergen	Näckrosen	Solna Centrum	Västra Skogen	Stadshagen	Fridhemsplan	Rådhuset	T-Centralen	Kungsträdgården
Hjulsta	0	2																		
Tensta	2	0	2																	
Rinkeby		2	0	3																
Rissne			3	0	2															
Duvdo				2	0	1														
Sundbybergs C.					1	0	2													
Vreten						2	0	2												
Huvudsta							2	0							2					
Akalla									0	2										
Husby									2	0	2									
Kista										2	0	4								
Hallonbergen											4	0	2							
Näckrosen												2	0	2						
Solna Centrum													2	0	2					
Västra Skogen								2						2	0	2				
Stadshagen															2	0	2			
Fridhemsplan																2	0	2		
Rådhuset																	2	0	2	
T-Centralen																		2	0	2
Kungsträdgården																			2	0

GREEN LINE Hässelby – T-Centralen	Hässelby Strand	Hässelby Gård	Johannelund	Vällingby	Råcksta	Blackeberg	Islandstorget	Ångbyplan	Åkeshov	Brommaplan	Abrahamsberg	Stora Mossen	Alvik	Kristineberg	Thoridsplan	Fridhemsplan	St Eriksplan	Odenplan	Rådmansgatan	Hötorget	T-Centralen
Hässelby Strand	0	1																			
Hässelby Gård	1	0	2																		
Johannelund		2	0	2																	
Vällingby			2	0	2																
Råcksta				2	0	1															
Blackeberg					1	0	2														
Islandstorget						2	0	1													
Ångbyplan							1	0	2												
Åkeshov								2	0	2											
Brommaplan									2	0	2										
Abrahamsberg										2	0	2									
Stora Mossen											2	0	2								
Alvik												2	0	3							
Kristineberg													3	0	1						
Thoridsplan														1	0	2					
Fridhemsplan															2	0	1				
St Eriksplan																1	0	2			
Odenplan																	2	0	1		
Rådmansgatan																		1	0	2	
Hötorget																			2	0	2
T-Centralen																				2	0

GREEN LINE *Travel times (minutes)* T-Centralen – Hagsätra / Farsta Strand / Skarpnäck	T-Centralen	Gamla Stan	Slussen	Medborgarplatsen	Skanstull	Gullmarsplan	Globen	Enskede Gård	Sockenplan	Svedmyra	Stureby	Bandhagen	Högsdalen	Rågsved	Hagsätra	Skärmarbrink	Blåsut	Sandsborg	Skogskirkogården	Tallkrogen	Gubbängen	Hökarängen	Farsta	Farsta Strand	Hammarbyhöjden	Björkhagen	Kärrtorp	Bagarmossen	Skarpnäck
T-Centralen	0	3																											
Gamla Stan	3	0	1																										
Slussen		1	0	1																									
Medborgarplatsen			1	0	2																								
Skanstull				2	0	2																							
Gullmarsplan					2	0	2									2													
Globen						2	0	2																					
Enskede Gård							2	0	1																				
Sockenplan								1	0	2																			
Svedmyra									2	0	1																		
Stureby										1	0	2																	
Bandhagen											2	0	1																
Högsdalen												1	0	2															
Rågsved													2	0	2														
Hagsätra														2	0														
Skärmarbrink						2										0	1								1				
Blåsut																1	0	2											
Sandsborg																	2	0	1										
Skogskirkogården																		1	0	2									
Tallkrogen																			2	0	2								
Gubbängen																				2	0	1							
Hökarängen																					1	0	2						
Farsta																						2	0	2					
Farsta Strand																							2	0					
Hammarbyhöjden																1									0	2			
Björkhagen																									2	0	1		
Kärrtorp																										1	0	3	
Bagarmossen																											3	0	2
Skarpnäck																												2	0


RED LINE
Travel times (minutes)
Mörby C / Ropsten – Norsborg / Fruängen
Mörby Centrum
Danderyds
Bergshamra
Universitetet
Tekniska
Stadion
Ropsten
Gärdet
Karlaplan
Östermälmstorg
T-Centralen
Gamla Stan
Slussen
Marietorget
Zinkensdamm
Hornstull
Liljeholmen
Aspudden
Örnsberg
Axelsberg
Midsommarkrans
Telefonplan
Högerstensåsen
Västertorp

PENDELTÅG *Travel times (minutes)* J35; Bålsta - Nynäshamn	Bålsta	Bro	Kungsängen	Kallhäll	Jakobsberg	Barkarby	Spånga	Sundbyberg	Karlberg	Stckhlm C	Stckhlm S	Årstaberg	Älvsjö	Farsta Strand	Trångsund	Skogås	Handen	Jordbro	Västerhaninge	Krigslida	Tungelsta	Hemfosa	Segersäng	Ösmo	Nynäsgård	Gröndalsviken	Nynäshamn
Bålsta	0	6																									
Bro	6	0	5,5																								
Kungsängen		5,5	0	4																							
Kallhäll			4	0	3,5																						
Jakobsberg				3,5	0	3,5																					
Barkarby					3,5	0	3																				
Spånga						3	0	4																			
Sundbyberg							4	0	4,5																		
Karlberg								4,5	0	4,5																	
Stckhlm C									4,5	0	4,5																
Stckhlm S										4,5	0	3															
Årstaberg											3	0	3														
Älvsjö												3	0	6													
Farsta Strand													6	0	2,5												
Trångsund														2,5	0	2,5											
Skogås															2,5	0	4										
Handen																4	0	3									
Jordbro																	3	0	6								
Västerhaninge																		6	0	5							
Krigslida																			5	0	3						
Tungelsta																				3	0	5					
Hemfosa																					5	0	4,5				
Segersäng																						4,5	0	4,5			
Ösmo																							4,5	0	5,5		
Nynäsgård																								5,5	0	2,5	
Gröndalsviken																									2,5	0	2,5
Nynäshamn																										2,5	0

PENDELTÅG *Travel times (minutes)* J36; Märsta – Södertälje C	Märsta	Rosersberg	Upplands-Väsby	Rotebro	Norrviken	Häggvik	Sollentuna	Helenesund	Ulriksdal	Solna	Tomteboda	Karlberg	Stockholm C	Stckhlm södra	Årstaberg	Älvsjö	Stuvsta	Huddinge	Flemingsberg	Tullinge	Tumba	Rönninge	Östertälje	Södertälje hamn	Södertälje centrum
Märsta	0	4																							
Rosersberg	4	0	5																						
Upplands-Väsby		5	0	4																					
Rotebro			4	0	2,5																				
Norrviken				2,5	0	3																			
Häggvik					3	0	2																		
Sollentuna						2	0	3																	
Helenesund							3	0	3																
Ulriksdal								3	0	2															
Solna									2	0		4													
Tomteboda											0														
Karlberg										4		0	3,5												
Stockholm C												3,5	0	5,5											
Stckhlm södra													5,5	0	3										
Årstaberg														3	0	3									
Alvsjö															3	0	3								
Stuvsta																3	0	3							
Huddinge																	3	0	3						
Flemingsberg																		3	0	3					
Tullinge																			3	0	4				
Tumba																				4	0	4,5			
Rönninge																					4,5	0	5		
Ostertälje																						5	0	3	
Södertälje hamn																							3	0	6,5
Södertälje centrum																								6,5	0

NOCKEBYBANAN *Travel times (minutes)*	Nockeby	Nockeby torg	Olovslund	Höglandstorget	Ålstens gård	Ålstensgatan	Smedslätten	Klövervägen	Alléparken	Alvik
Nockeby	0	3								
Nockeby torg	3	0	1							
Olovslund		1	0	2						
Höglandstorget			2	0	1					
Ålstens gård				1	0	1				
Ålstensgatan					1	0	1			
Smedslätten						1	0	2		
Klövervägen							2	0	2	
Alléparken								2	0	1
Alvik									1	0

TVÄRBANAN *Travel times (minutes)*	Sickla udde	Sickla kaj	Luma	Mårtensdal	Gullmarsplan	Globen	Linde	Valla torg	Årstafältet	Årstaberg	Årstadal	Liljeholmen	Trekanten	Gröndal	Stora Essingen	Alviks strand	Alvik	Johannesfred	Norra Ulvsunda	Karlsbodavägen	Bällsta Bro	Sundbybergs Centrum	Solna Bussiness Park	Solna Centrum	Solna Stadium
Sickla udde	0	1																							
Sickla kaj	1	0	2																						
Luma		2	0	2																					
Mårtensdal			2	0	3																				
Gullmarsplan				3	0	1																			
Globen					1	0	2																		
Linde						2	0	1																	
Valla torg							1	0	2																
Årstafältet								2	0	1															
Årstaberg									1	0	2														
Årstadal										2	0	3													
Liljeholmen											3	0	1												
Trekanten												1	0	2											
Gröndal													2	0	3										
Stora Essingen														3	0	2									
Alviks strand															2	0	3								
Alvik																3	0	2							
Johannesfred																	2	0	2						
Norra Ulvsunda																		2	0	1					
Karlsbodavägen																			1	0	2				
Bällsta Bro																				2	0	1			
Sundbybergs Centrum																					1	0	2		
Solna Bussiness Park																						2	0	3	
Solna Centrum																							3	0	2
Solna Stadium																								2	0

ROSLAGSBANAN *Travel times (minutes)* Kårsta – Stockholm Östra	Kårsta	Ekskogen	Frösunda	Lindholmen	Molnby	Ormsta	Vallentuna	Bällsta	Kragstalund	Täby kyrkby	Visinge	Ensta	Tibble	Roslags Näsby	Djursholms Ösby	Mörby	Universitetet	Stockholms östra
Kårsta	0	3																
Ekskogen	3	0	4															
Frösunda		4	0	7														
Lindholmen			7	0	2													
Molnby				2	0	3												
Ormsta					3	0	3											
Vallentuna						3	0	2										
Bällsta							2	0	3									
Kragstalund								3	0	3								
Täby kyrkby									3	0	4							
Visinge										4	0	2						
Ensta											2	0	1					
Tibble												1	0	3				
Roslags Näsby													3	0	4			
Djursholms Ösby														4	0	2		
Mörby															2	0	4	
Universitetet																4	0	3
Stockholms östra																	3	0

ROSLAGSBANAN *Travel times (minutes)* Österskär – Stockholm Östra	Österskär	Tunagård	Åkersberga	Åkers Runö	Täljö	Rydbo	Hägernäs	Viggbyholm	Galoppfältet	Täby centrum	Roslags Näsby	Enebyberg	Djursholms Ekeby	Bråvallavägen	Djursholms Ösby	Mörby	Stocksund	Universitetet	Stockholms östra
Österskär	0	1																	
Tunagård	1	0	3																
Åkersberga		3	0	2															
Åkers Runö			2	0	2														
Täljö				2	0	6													
Rydbo					6	0	4												
Hägernäs						4	0	3											
Viggbyholm							3	0	2										
Galoppfältet								2	0	1									
Täby centrum									1	0	3								
Roslags Näsby										3	0	1							
Enebyberg											1	0	2						
Djursholms Ekeby												2	0	1					
Bråvallavägen													1	0	3				
Djursholms Ösby														3	0	2			
Mörby															2	0	2		
Stocksund																2	0	3	
Universitetet																	3	0	3
Stockholms östra																		3	0

ROSLAGSBANAN *Travel times (minutes)* Näsbypark – Stockholm Östra	Näsbypark	Näsby allé	Lahäll	Altorp	Östberga	Vendevägen	Djursholms Ösby	Mörby	Stocksund	Universitetet	Stockholms östra
Näsbypark	0	1									
Näsby allé	1	0	2								
Lahäll		2	0	2							
Altorp			2	0	1						
Östberga				1	0	2					
Vendevägen					2	0	2				
Djursholms Ösby						2	0	2			
Mörby							2	0	2		
Stocksund								2	0	3	
Universitetet									3	0	3
Stockholms östra										3	0

-Frequencies assumed

LINE	FREQUENCY	WAITING TIME
	minutes	*minutes*
Metro lines	4	2
Tvärbanan	10	5
Nockebybanan	10	5
Roslagsbanan		
Kärsta - Vallentuna	15	7,5
Österskär - Åkersberga	15	7,5
Näsbypark - Djursholm Ösby	15	7,5
Åkersberga - Stockholm Södra	10	5
Vallentuna - Stockholm Södra	10	5
Pendeltåg J35		
Bålsta - Barkarby	10	5
Nynäshamn - Västerhaninge	10	5
Barkarby - Västerhaninge	7 -8	3,25
Pendeltåg J36		
Märsta - Häggvik	10	5
Södertälje - Tumba	10	5
Häggvik - Tumba	7 -8	3,25

Appendix 3. Travel times in the new stretches. Commuter Traffic.

-Alternative 1

Täby-Kista

	Length (km)	Service Speed (km/h)	
Rosersberg-Uppland V.	7,4	98,67	
Älvsjö-Farsta Strand	7,6	76,00	
Skögas-Handen	6,1	91,50	Travel Time (minutes)
Täby-Kista	7	88,72	4,73

Kista-Bärkarby

	Length (km)	Service Speed (km/h)	
Röninge-Östertälje	5,9	78,67	
Skögas-Handen	6,1	91,50	
Tungelsta-Hemfosa	5,5	66,00	Travel Time (minutes)
Kista-Bärkarby	6	78,72	4,57

Bärkarby-Vällingby

	Length (km)	Service Speed (km/h)	
Tumba-Röninge	4,9	72,59	
Källhal-Jakovsberg	3,7	63,43	
Sundyberg-Spånga	4,9	73,50	
Spånga-Karlberg	4,3	57,33	Travel Time (minutes)
Bärkarby-Vällingby	4,6	70,00	3,94

Vällingby-Lovön

	Length (km)	Service Speed (km/h)	
Rosersberg-Uppland V.	7,4	98,67	
Älvsjö-Farsta Strand	7,6	76,00	
Skögas-Handen	6,1	91,50	Travel Time (minutes)
Vällingby-Lovön	7	88,72	4,73

Lovön-Skärholmen

	Length (km)	Service Speed (km/h)	
Helenesund-Ulriksdal	3,8	84,44	
Tullinge-Tumba	3,8	63,33	
Tumba-Röninge	4,9	72,59	
Källhal-Jakovsberg	3,7	63,43	
Sundyberg-Spånga	4,9	73,50	
Spånga-Karlberg	4,3	57,33	Travel Time (minutes)
Lovön-Skärholmen	4,2	69,11	3,65

Skarholmen-Flemingsberg

	Length (km)	Service Speed (km/h)	
Rosersberg-Uppland V.	7,4	98,67	
Älvsjö-Farsta Strand	7,6	76,00	
Skögas-Handen	6,1	91,50	Travel Time (minutes)
Skarholmen-Flemingsberg	7	88,72	4,73

Flemingsberg-Handen

	Length (km)	Service Speed (km/h)	
Bälsta-Bro	9,1	91,00	
Bro-Kungshangen	10	109,09	Travel Time (minutes)
Flemingsberg-Handen	13	100,05	7,80

-Alternative 2

Mörby-Ulriksdal

	Length (km)	Service Speed (km/h)	
Helenesund-Ulriksdal	3,8	84,44	
Tullinge-Tumba	3,8	63,33	
Källhal-Jakovsberg	3,7	64,75	
Häggvik-Norrviken	2,3	46,00	
Älvsjö-Årstaberg	3,4	68,00	
Stuvsta-Älvsjö	3,1	62,00	
Trångsund-Farsta Strand	2,1	42,00	
Helenesund-Sollentuna	2,3	46,00	Travel Time (minutes)
Mörby-Ulriksdal	3	59,57	3,02

Ulriksdal-Sundbyberg

	Length (km)	Service Speed (km/h)	
Helenesund-Ulriksdal	3,8	84,44	
Tullinge-Tumba	3,8	63,33	
Källhal-Jakovsberg	3,7	64,75	
Häggvik-Norrviken	2,3	46,00	
Älvsjö-Årstaberg	3,4	68,00	
Stuvsta-Älvsjö	3,1	62,00	
Trångsund-Farsta Strand	2,1	42,00	
Helenesund-Sollentuna	2,3	46,00	Travel Time (minutes)
Ulriksdal-Sundbyberg	3	59,57	3,02

Sundbyberg-Alvik

	Length (km)	Service Speed (km/h)	
Helenesund-Ulriksdal	3,8	84,44	
Tullinge-Tumba	3,8	63,33	
Källhal-Jakovsberg	3,7	63,43	
Sundyberg-Spånga	4,9	73,50	
Spånga-Karlberg	4,3	57,33	Travel Time (minutes)
Tumba-Röninge	4,9	72,59	
Sundbyberg-Alvik	4,2	69,11	3,65

Alvik-Telefonplan

	Length (km)	Service Speed (km/h)	
Helenesund-Ulriksdal	3,8	84,44	
Tullinge-Tumba	3,8	63,33	
Tumba-Röninge	4,9	72,59	
Källhal-Jakovsberg	3,7	63,43	
Sundyberg-Spånga	4,9	73,50	
Spånga-Karlberg	4,3	57,33	Travel Time (minutes)
Alvik-Telefonplan	4	69,11	3,47

Telefonplan-Älvsjö

	Length (km)	Service Speed (km/h)	
Helenesund-Sollentuna	2,3	46,00	
Tullinge-Tumba	3,8	63,33	
Stuvsta-Älvsjö	3,1	62,00	
Källhal-Jakovsberg	3,7	63,43	
Trångsund-Farsta Strand	2,1	42,00	
Häggvik-Norrviken	2,3	46,00	Travel Time (minutes)
Telefonplan-Älvsjö	2,8	53,79	3,12

-Alternative 3

Årstaberg-Liljeholmen

	Length (km)	Service Speed (km/h)	
Helenesund-Sollentuna	2,3	46,00	
Nynäsgard-Gröndalsviken	1,7	34,00	
Gröndalsviken-Nynäshamn	1,6	48,00	
Stuvsta-Huddinge	2,1	42,00	
Trångsund-Farsta Strand	2,1	42,00	
Häggvik-Norrviken	2,3	46,00	Travel Time (minutes)
Årstaberg-Liljeholmen	2	43,00	2,79

Liljeholmen-Fridhemsplan

	Length (km)	Service Speed (km/h)	
Helenesund-Ulriksdal	3,8	84,44	
Tullinge-Tumba	3,8	63,33	
Källhal-Jakovsberg	3,7	63,43	
Stuvsta-Älvsjö	3,1	62,00	
Spånga-Karlberg	4,3	57,33	
Häggvik-Norrviken	2,3	46,00	Travel Time (minutes)
Årstaberg-Liljeholmen	3,5	62,76	3,35

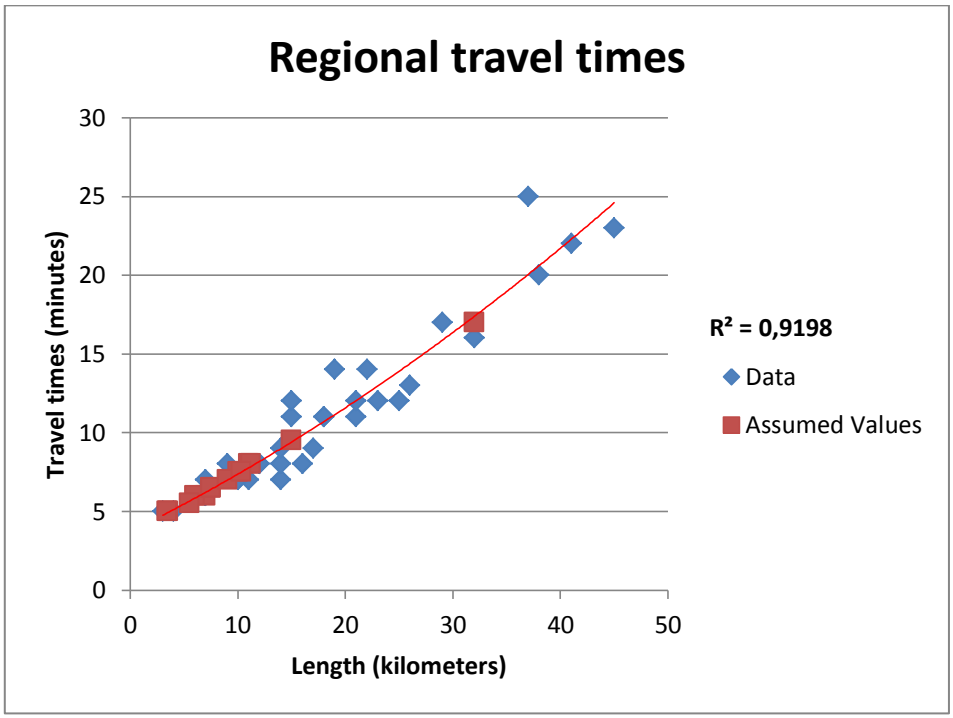
Fridhemsplan-Solna

	Length (km)	Service Speed (km/h)	
Helenesund-Ulriksdal	3,8	84,44	
Tullinge-Tumba	3,8	63,33	
Källhal-Jakovsberg	3,7	63,43	
Stuvsta-Älvsjö	3,1	62,00	
Spånga-Karlberg	4,3	57,33	
Häggvik-Norrviken	2,3	46,00	Travel Time (minutes)
Fridhemsplan-Solna	3,5	62,76	3,35

Appendix 4. Travel times in the new stretches. Regional Traffic.

Below, the table shows all the stretches used in order to establish the travel times for the new links. In addition there is a scatter plot where the pairs length-travel times are displayed. The assumed values for the new links are based in a regression analysis.

The trend line obtained is polynomial; however, it is quite similar to the linear analysis. It is important to remark that there is a lack of data to shortest stretches (less than 5 kilometers). The analysis would fit more to the reality with these data.



	Length	Travel time	Source
Sundbyberg - Stockholm	7	7	Mälarbanan project
Sundbyberg - Bålsta	38	20	Mälarbanan project
Flemingsberg - Södertälje	21	11	www.sj.se
Stockholm - Flemingsberg	15	11	www.sj.se
Stockholm - Märsta	37	25	www.sj.se
Märsta - Knvista	12	8	www.sj.se
Knvista - Uppsala	12	8	www.sj.se
Göteborg - Mölnlycke	15	12	www.sj.se
Alvesta - Växjö	18	11	www.sj.se
Hovmantorp - Lessebo	9	8	www.sj.se
Jönköping - Bankeryd	11	7	www.sj.se
Skövde C - Stenstorp	16	8	www.sj.se
Stenstorp - Falköping	14	7	www.sj.se
Jonköping - Huksvarna	6	6	www.sj.se
Huksvarna - Tenhult	10	7	www.sj.se
Flen - Katrineholm	23	12	www.sj.se
Katrineholm - Vingåker	21	12	www.sj.se
Vingåker - Hallsberg	45	23	www.sj.se
Södertälje - Nykvarn	14	8	www.sj.se
Nykvarn - Läggesta	17	9	www.sj.se
Eskilstuna - Strängäs	32	16	www.sj.se
Eskilstuna - Kungsör	26	13	www.sj.se
Kungsör - Arboga	18	11	www.sj.se
Herrljunga - Vårgårda	14	9	www.sj.se
Vårgårda - Alinsås	25	12	www.sj.se
Göteborg - Liseberg	3	5	www.sj.se
Karlstad C - Kil	19	14	www.sj.se
Kil - Grums	22	14	www.sj.se
Grums - Säffle	29	17	www.sj.se
Mellerud - Öxnered	41	22	www.sj.se
Öxnered - Trollhätan C	10	7	www.sj.se
Hindås - Rävlanda	7	6	www.sj.se
Rävlanda - Bollebygd	4	5	www.sj.se
Göteborg - Mölndal	7	7	www.sj.se