17/08/2006
1N1152

KTH Architecture and the Built Environment

Department of Transport and Economics
Division of Transport and Location Analysis

THE ROSLAGSBANAN CITY EXTENSION

A rough analysis of different alternatives by means of weighted trip time comparison

Project work in transport and location analysis

By Florian Wieland

Supervisor: Lars-Göran Mattsson

Abstract

This study wishes to propose an extension of Roslagsbanan in order to dispose of changing at the present terminal at Östra station that lies two kilometres north east of Stockholm's city centre. It surveys the need of such a link, as well as different alternatives by assessing them, and finally recommends actions, based on the study.

Initially, a survey has been conducted to receive knowledge about the destinations of the travellers. Based on this, important destinations have been identified, and the weighted trip time has been calculated. Those have been compared, to find the gain of time, based on the present trip time. The difference in weighted trip time was the input for elasticity calculations, where the number of expected additional passengers has been calculated. Finally, the total gain of time for old and new passengers was expressed in a monetary unit, to compare it with the expenses.

Based on these calculations, an extension as tram line has been suggested, since it is able to carry travellers nearer to their destinations, and thus, save travel time. However, before such an action can be taken, the existing net must be adapted to modern standards.

It can be concluded that Roslagsbanan, after having performed the necessary changes, is indeed able to cope with its future challenges. The Östra-tram-link could be an integrated part of a future Stockholm tram net.

Table of Content

1 Introduction

1.1 Purpose of the Study

This study wishes to propose an extension of Roslagsbanan in order to dispose of changing at the present terminal at Östra station that lies two kilometres north east of Stockholm's city centre. It surveys the need of such a link, as well as different alternatives by assessing them, and finally recommends actions, based on the study. However, it must not be seen as an adequate basis for such an action, but as basis for further discussions and studies.

1.2 Public Transport in the Stockholm Area

The local public transport in Stockholm is run by the public company Stockholms Lokaltrafik AB (SL), owned by Stockholm County. Since 1992 SL regularly assigns the operational part to contractors. The backbone of the public transport system is Tunnelbanan (the underground), and Pendeltåget[1] (the rapid transit railway), completed by countless bus lines.

The public transport system is also complemented with some isolated light rail systems:

- Tvärbanan (transverse line) and Nockebybanan, these are modern city railways, which connect the city-near suburbs by building a semicircle around the centre, and offer good possibilities to change to the cross section lines. Tvärbanan has been very successful in attracting passengers and is subject to further extension plans.
- Lidingöbanan is the old tram connection from the island of Lidingö, into the centre, that has been cut at Ropsten, when the tram traffic in Stockholm was closed. Now, travellers have to change to the underground at Ropsten.
- Saltsjöbanan has its terminal at Slussen, a centre-near traffic junction.
- Roslagsbanan – see chapter 1.3

Compared to other European and worldwide cities, Stockholm has a rather large share of public transport travellers. Table 1 shows, that no German city with a comparable size to Stockholm, reaches those values. Only the city of Zurich, Switzerland, shows an equal share.

This extraordinary modal split is mainly a result of the extensive city development policy of the 1950s to 1970s [3]. It was during this time that the underground was built, and also many

[1] The word has not been translated to avoid confusion with the other light rail systems.

of the huge suburbs around Stockholm. Those suburbs, being essential for the growing city, have been constructed in such a way that most of the inhabitants live within the distance of 300 meters from the nearest underground station.

Table 1: Examples of Modal Splits in [%]. Sources: [1][2]

City	Year of Survey	PCM*	Car	Public Transport
Stockholm, City	2004	42	13	45
Stockholm, from/to city	2004	3	31	67
Greater Stockholm	**2004**	**17**	**46**	**37**
Dortmund	1998	27	57	16
Colon	1999	38	42	19
Munich	1996	36	39	24
Stuttgart	2000	32	46	22
Zurich	1992	36	27	37
Sacramento (USA)	2004	6	92	2

* Pedestrians, Cyclists, Motorcyclists

Unlike in Zurich, however, people in Stockholm seem to be rather displeased with their public transport system. According to Sundström [4], the public transport system is no longer reliable, due to reduced infrastructure maintenance during the 90s. A study has been performed showing that vehicle failure occurs ten times more often in Stockholm than in London, and four times more often than in Paris.

Nevertheless the standard of the Stockholm public transport system is very high. It is characterised by a high frequency in service, a large supply of seat places, and low fares.

1.3 The Relevance of Roslagsbanan

Table 2: Population structure – northeast municipalities except from Danderyd (thousands). Source: [1]

Municipality:	Norrtälje	Täby	Vallent.	Vaxholm	Österåker	Greater St.
Inhabitants (increase within 2013)	54 (16%)	60 (6%)	27 (14%)	10 (20%)	37 (22%)	1873 (10%)
Thereof working (from 2003):	25	30	13	5	18	901
Workplaces (from 2003):	19	22	6	3	9	953

The area called Roslagen lies north-east of the city of Stockholm. It belongs partly to greater Stockholm and is the area with the largest expected increase in population, see also Table 2. The six north-eastern municipalities have come to an agreement to strive to rise the

population by 100,000 inhabitants, an increase of about 40 %, in the next 30 years [6]. Such a policy also requires building housing units for 40,000 people, and the creation of 50,000 new jobs.

To gain those ambitious targets, public transport has to play a major roll, thus, these municipalities developed a vision, containing their idea of future transportation in the north east [7]. The backbone of this vision is Roslagspilen, a new branch added to the existing rapid transit railway (Pendeltåget). Roslagspilen would diverge at the station of Solna, and lead to Arninge in the first place, but extensions to Åkersberga and Norrtälje are also being considered. The already existing Roslagsbanan is obviously not thought to be able to cope with the new challenges. On the other hand, as will be described later in this report, with some modifications Roslagsbanan could indeed keep the role of a backbone for the north-west sector.

Figure 1: The network of Roslagsbanan [5]

The currently existing part of Roslagsbana is the only part that remains of a former large network with the village of Rimbo as the centre [5][8]. The line to Stockholm was opened in 1885, and its main goal was the transport of goods, whilst today there is only passenger traffic left. Also, the still existing network of 65 km, see Figure 1, has more than once been subject to a proposed closedown. The last occasion was in connection with the planned extension of the underground from Mörby Centrum to Täby. It was then suggested to build it on the embankment of Roslagsbanan, and to replace the remaining parts by bus. However, it turned out that the public attitude towards the Roslagsbanan was unexpectedly positive, and protest movements prevented it from being closed. A recent study shows that only 12 % of the passengers of Roslagsbanan are dissatisfied with the quality offered; compared to 32 % of the

passengers using the pendeltåg network [10]. See Table 3 for facts about Roslagsbanan.

Table 3: Facts about Roslagsbanan. Sources: [1][5]

Lines:	Stockholm Östra – Kårsta, 41.5 km Stockholm Östra – Österskär, 18.4 km Stockholm Östra – Näsbypark, 5.0 km
Double track:	13.1 km
Stations:	39
Maximum speed:	80 km/h
Power supply:	1500 V =
Signalling:	Remote block, central signal box at Stockholm Östra, ATC since 2003
Gauge:	narrow gauge, 891 mm
Most frequented stations:	Stockholm-Östra, Åkersberga, Täby-Centrum, Roslags-Näsby Vallentuna, Täby-Kyrkby, Mörby
Passengers a workday:	33,700
Thereof to/from St.Östra	20,600

1.4 The Roslagsbanan City Link

As mentioned above, Roslagsbanan could deal with its future challenges, including an increase of the population, and a demand for high quality public transport, by adapting the system to modern standards.

One of the lines most evident shortcomings is the terminal station Stockholm Östra, that is situated two kilometres from the city centre. Therefore, many passengers have to change to the underground to continue to their final destinations. However, it is known that such an interruption of a journey significantly lowers the attractiveness of the mode to the traveller.

To improve the attractiveness of Roslagsbanan it is therefore very natural to consider an extension of the existing line to the city centre. There are different alternatives that could be discussed, such as a fast and direct tunnel, connecting Roslagsbanan to downtown Stockholm, or a tram line being able to carry people even nearer to their destination.

1.5 Presumptions

In this study, the different alternatives will be compared and roughly analysed, to provide an impression of their suitability. Roslagsbanan of today does not at all meet the standards of high quality transport. In addition, it would not be able to cope with more passengers since it,

in some sections, has already reached its capacity limit. Therefore, the following assumptions about its upgrading have been made.

Double track: The lines between Roslags-Näsby and Vallentuna (12 km), as well as between Galoppfältet and Åkersberga (14 km) have to be upgraded to a double track line, to allow a synchronised timetable with departures on the same minutes every hour. To ensure a basic service every 15 minutes, it would be sufficient to build only four new double track sections of 10 km (see [9] for further details). However, eventually the whole line has to be upgraded to double track, to allow express trains (snabbtågen) at peak hours.

Maximum speed: Today the maximum speed is 80 km/h, and an increase to 100 km/h would be reasonable. It decreases the trip time by about 10 % for normal trains, and even more for express trains [9].

Vehicles: One of the pressing problems of Roslagsbanan is the accessibility, which means that vehicle floor and platform are not at level. In addition with an increased maximum speed, the vehicles would be too slow and underpowered. When, in 15 years the present vehicles are amortised, new ones can be bought. SL is considering about buying a version of class A32, the type that is used on Tvärbanan, though, substantial changes have to be made.

Synchronised timetable is standard nowadays at public transport systems. As mentioned above, a basic frequency of 15 minutes on every branch is suggested by SL. If in peak times additional express trains are to be offered, the extension of the full line to double track is necessary.

1.6 Limits of this Study

It has to be taken into account that this study can only provide a rough suggestion of the possible solution. This is due to the limited amount of time available for the study as well as partly insufficient information about various input parameters – see also chapter 4.

2 Methods Used

Initially, a survey was conducted to retrieve knowledge about the destinations of the travellers, as described in chapter 2.1. Based on this, important destinations have been identified, and the weighted travel time has been calculated, as described in chapter 2.2. Those travel times have been compared, to find the gain in time, compared with the present travel time. The differences in weighted travel times were the input for elasticity calculations, defined in chapter 2.3, where the number of expected additional passengers has been calculated. Finally, the total gain in time for old and new passengers was expressed in monetary units, to compare it with the cost of the extension of Roslagsbanan.

2.1 Survey to find the destinations of Roslagsbanan's travellers

To calculate the benefits, a certain alternative offers the travellers, the geographical allocation of destinations must be known. Thus, a survey has been conducted to obtain the data needed.

20,600 passengers per day is the basis of the survey. It has been obtained from the number of passengers per day boarding a train at Stockholm Östra (10,300) published in [1]. The value has been doubled, because the same number is also leaving the trains at Stockholm Östra, if symmetry is assumed.

Table 4: Allocation of Interviews

Time interval	6:00-9:00	9:00-15:00	15:00-18:00	18:00-21:00	Else	Total
Population Öst	5379	6296	5257	2323	1345	20600
Per cent	26	31	26	11	6	100
Reference sample size	26	31	26	11	7	100
Actual sample size	28	32	28	12	0	100
Performed sample size	**19**	**40**	**49**	**27**	**0**	**135**

In accordance with [11], the sample size has been calculated to 96 interviews, to recive a confidence level of 95 %. For a confidence interval of ± 10 %, and a uniformly distributed basis, that is, the destinations are not subject to change over the whole day. Those rather rough assumptions seem nevertheless convenient, considering the limited recourses for this study.

To face a possible inhomogeneity of the basis, the 96 interviews has been spread over four

time periods, what could be identified from [1] as 6 to 9, 9 to 15, 15 to 18, and 18 to 21. The period from 21 to 6 has not been taken into account – see also Table 4.

Stockholm has been divided into 12 areas, whereof the outer areas are defined as infinite. Passengers, changing for pendeltåg, have been allocated to the city area, as the main station lies within that zone, see Figure 3.

The questionnaire has been performed at 23/05/06, and slightly modified at 30/05/06, as the previous experiences have been taken into account. The following questioned were asked (in trains towards Stockholm)*:*

- *Do you continue your travel from Stockholm Östra by underground, bus or as pedestrian?*
- If the answer was 'underground' or 'bus': *Which underground station or buss station is your destination within public transportation?*
- If the Answer was 'as pedestrian': *Please show me on the Stockholm map your destination.*
- *What is the purpose of your journey – business – commuter – education – shopping – leisure?*

2.2 The Weighted Trip Time

To estimate the benefits, achieved by an action, a comparable value is needed. Such a value could be the time needed for the door to door journey. Complemented with additional resistances for changing procedures, the weighted trip time (t_{wtt}) is obtained:

$$t_{wtt} = \sum t_{ivt} + \sum t_{ch} + t_{to} + t_{fr} \qquad \textbf{(2-1)}$$

With:
- t_{ivt} = time for the actual transportation act – in-vehicle time
- t_{ch} = time for the change of trains – weighted changing time
- t_{to} = time from start point to the enter point of public transport
- t_{fr} = time from the last point in the public transport net to the destination

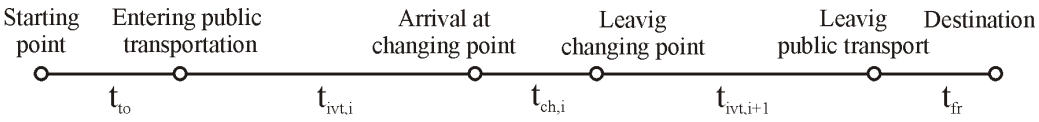

Figure 2: Network graph, trip time

Figure 2 illustrates formula (2-1), and the different time intervals are found as:

$$t_{ch} = t_{k,ch} + 2t_{walk,ch} + 3t_{wait,ch} \qquad \textbf{(2-2)}$$

$$t_{to} = 2t_{walk,to} + 3t_{wait,to} \qquad \textbf{(2-3)}$$

$$t_{fr} = 2t_{walk,fr} \qquad \textbf{(2-4)}$$

$$t_{wait} = t_{freq/2} + \bar{t_d} \qquad \textbf{(2-5)}$$

With:
- $t_{k,ch}$ = constant part of changing resistance
- t_{walk} = walking time
- t_{wait} = waiting time
- $t_{freq/2}$ = half of the headway of a synchronised timetable
- t_d = average train delay

The complex changing time is defined with formula (2-2). It consists of a constant part. Jansson [12] suggests 5 minutes. In this study, however, the constant has been adapted to different situations, 3 minutes if the connection departs from the same platform, 6 minutes otherwise. The flexible part consists of the time needed for the changing process, which, in accordance with Jansson, is weighted with the factor 2.

The time from the start point to the entering point of the public transport system is given in formula (2-3)[2], and consists also of weighted walking and waiting time, whilst the time from

[2] This formula does not appear in this study; only down town destinations have been modelled, and the journeys were assumed to start with the departure of the train.

the public transport net to the final destination as by formula (2-4) only consists of a weighted walking time. The waiting time depends also on the average delay of the line.
See formula (2-5).

2.3 Travel time elasticity as a mean to evaluate time savings

By means of the changes of the weighted trip time, benefits were calculated and have to be evaluated. A tool for rough estimations is the travel time elasticity of demand, which is defined in formula (2-6).

$$\varepsilon = \frac{\frac{n_1 - n_0}{n_0}}{\frac{t_{wtt,1} - t_{wtt,0}}{t_{wtt,0}}} \qquad \textbf{(2-6)}$$

With: ε = elasticity
n_i = number of travellers, i=0 indicates initial state, and i=1 indicates changed state
t_{wtt} = weighted trip time, i=0 indicates initial state, and i=1 indicates changed state

Table 5: Travel time elsaticity [13]

	Journeys < 100 km
Business	-0.60
Private	-0.25

The elasticity of demand expresses the relative change of a dependent value (here: the number of travellers) when the independent value is changed relatively (here: the weighted trip time). In this study elasticity according to Table 5 has been used.

With formula (2-6) rearranged to

$$\Delta n = n_1 - n_0 = \varepsilon \frac{t_{wtt,1} - t_{wtt,0}}{t_{wtt,0}} n_0 \qquad \textbf{(2-7)}$$

the additional expected travellers can be calculated.

3 Results

3.1 The Destinations of the Roslagsbanan travellers

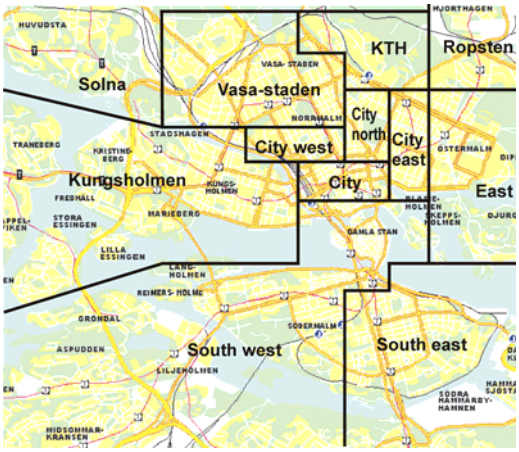

Figure 3: Classification of investigation area

Over a forth of the people interviewed answered that they would travel to the city. Especially interesting for this project is the large share, who continues to the area called city north, as it is presently not reached very well by public transport. That could indicate that a tram-link would be preferable – see Figure 3 and 4

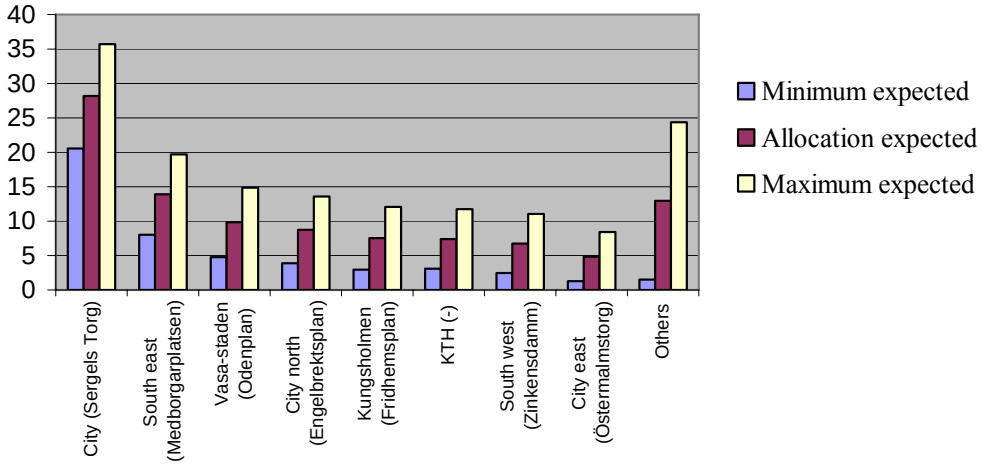

Figure 4: Allocation of destinations at a confidence level of 95 %, in [%]

3.2 The different Alternatives

Five alternatives for a rail-link have been worked out, with the purpose that it should be possible to reach the centre without the need to change at Östra Station; the two basic principles have been tunnel-link, and tram-link. Two alternatives are continuing from Östra station (Östra-tram-link, Östra-tunnel-link), whilst two others are using an existing goods line to reach Odenplan and down town (Vasa-staden-tram-link, City-line-link). The fifth alternative (Main-line-link), is using existing lines only, and continues directly to the central station. Since there is a larger demand for destinations around KTH and City north, as well as higher costs for the links via the goods-line because of system incompatibilities, only the alternatives via Östra station have been studied in detail.

3.2.1 Short Listed Alternatives

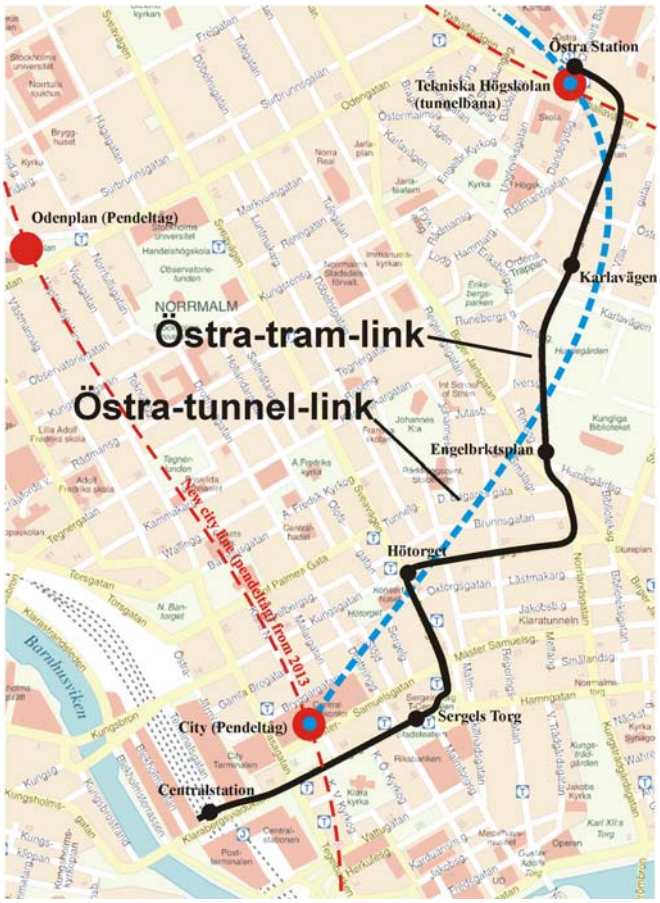

Figure 5: Short listed alternatives (thick-dashed line and full line)

Both of the short listed alternatives tie up at the actual terminal of Roslagsbanan, at Östra station. Figure 5 shows the possible implementation of the alternatives, at which the full line represents the Östra-tram-link, and the thick dashed line the Östra-tunnel-link.

The latter is starts before the terminal, to gather the needed depth for realising a level changing point at the underground station Tekniska Högskolan, and then it continues directly to the future pendeltåg station of City; this offers a rapid connection to downtown Stockholm. The advantages of large capacity, flexibility in vehicle use, and independence from car traffic, stand against the investment costs, as they are expected to be rather high, compared to the tram-line-link.

Kommentar: That ist he name of the Station.

The tram-line-link is going to operate on its old gradient to Engelbrektsplan, whereafter it continues via Kungsgatan to Hötorget, to offer a convenient changing point to the green line of the underground. Along Sveavägen the line reaches Sergels torg for passengers to the city centre, and via Klarabergsgatan and Karabergsviadukten it reaches its destination, in front of Cityterminalen and Central station. The big advantage with the tram-line-link is the possibility to carry passengers nearer to their destinations, since it is possible to have several stops between Östra station and Central station.

3.2.2 The Other Alternatives

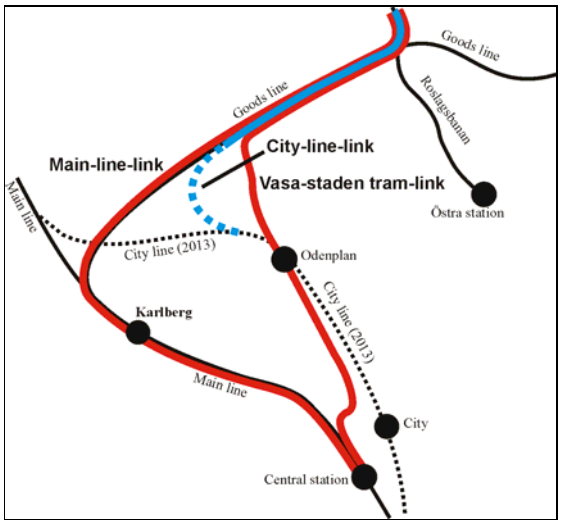

Figure 6: Other alternatives

Figure 6 shows the rejected alternatives, where, amongst others, the Main-line-link, uses the goods-line until it reaches the main-line, where enough capacity is expected to be available, after the opening of the city-line, and the removing of the present pendeltåg-traffic. It continues via Karlberg station to Central station. At first sight the Main-line-link seems fast, cheap, and easy to realise. However, apart from technical difficulties, due to the different systems, only 28 percent of the travellers want to travel directly to the city centre – which is still some meters away from Central station. In addition, no other areas are connected, and link can therefore be expected to be not profitable.

The City-line-link leads Roslagsbanan into a tunnel, near the area of northern station, and connects to the future city-line. This would offer a fast link into the city, with its new pendeltåg stations. Calculations, though, have shown that due to the detour the time saving effects are rather low, not to forget the rather high costs for a tunnel link, as well as the fact that the city-line, will anyhow be rather busy.

To get a cheaper connection to Odenplan, that is the future major changing point in the northern inner Stockholm, also a tram-line alternative, the Vasa-staden-tram-link, has been considered. This link has been ruled out because of the long travel time to the city centre, and the additional costs because of the differences in the systems.

3.3 Time Savings with the Different Alternatives

To compare the weighted trip times for the short listed alternatives, a zero alternative has been created. This equals the present situation with a change of train at Östra station. All alternatives are based on the presumptions from chapter 1.5.

Although there is no station today, Arninge traffic-junction has been chosen as a start point for the model trip to the different destinations in Stockholm since it permits the comparison with Roslagspilen. Arninge traffic-junction is about 16.7 km from Östra station, which is a bit more than the average travel distance at Roslagsbanan of 12.9 km. The comparison has been made with express trains, having three stopovers between Arninge traffic-junction and Östra station.

The results are presented in Figure 7, and they show that the Östra-tunnel-link nearly always provides the least gain of time, compared to Östra-tram-link and Roslagspilen, whilst those

are nearly equal in travel time. The reason could be that Roslagspilen and Östra-tunnel-link offer convenient transport only to a few discrete points, whilst people are carried closer to their destinations by using Östra-tram-link. Roslagspilen can match this tram-link because of its higher top speed, however. The results for the different destinations are discussed in the following paragraphs.

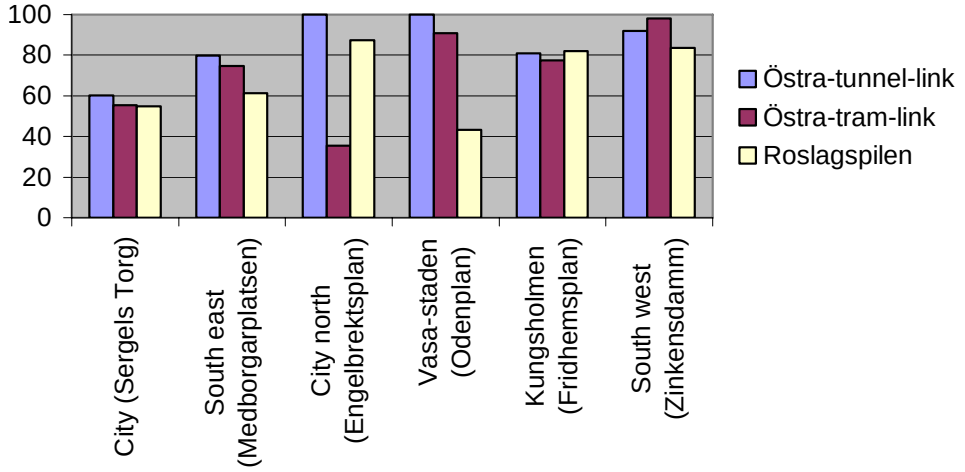

Figure 7: Trip-time change in [%] from Arninge, compared to the zero alternative

All three variants offer 60 % or less weighted trip time for passengers to Sergels torg, since they all are designed for that destination. However, Östra-tram-link is slightly faster, because travellers save the time it takes to reach the ground level from an underground station; also Roslagspilen is in advantage due to its higher top speed.

The differences for the destination of Medborgarplatsen are more distinct, since Roslagspilen is the only variant that continues into the south, to the pendeltåg station Södra. Östra-tram-link benefits from the short walking distances when changing to the green line of the underground at Hötorget.

Östra-tram-link is the only version that offers direct service to Engelbrektsplan, thus, it alone offers a noticeable gain of weighted trip time. The same applies for the destination of Odenplan, as there it is only Roslagspilen that offers direct service.

No difference could be identified for trips to Fridhemsplan, as it is an extension of a trip to Sergels Torg, from which the blue line of the underground is assumed to be used. The fastest connection today is by bus from Östra station.

People who want to travel to Zinkensdamm use the red line of the underground; this can be boarded at Östra station (underground station: Tekniska Högskolan), or at T-centralen, that is the underground station in the city. Östra-tunnel-link performs a shortcut, compared to the red line of the underground. It is likely that on gets an underground-train earlier, if one continues to the city centre by Roslagsbanan.

In addition, connections from Rimbo (rebuild line) and Norrtälje (change from bus to train at Arninge) have been checked, but not included in the cost-benefit-analysis. The zero alternative include the existing buses to Tekniska Högskolan. Figure 8 indicates a considerable shortening of the trip time for Rimbo, from where the trains are assumed to stop at every station until Vallentuna, and then to continue as express train services to Stockholm.

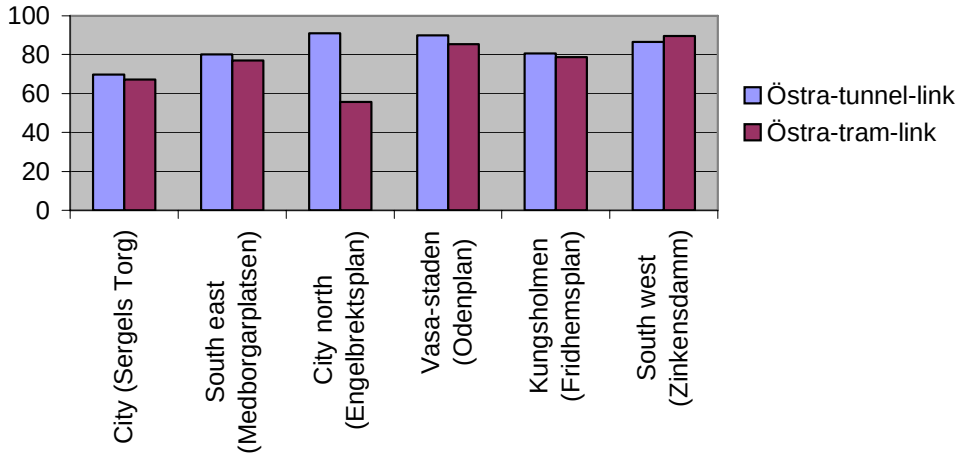

Figure 8: Trip-time change in [%] from Rimbo, compared to the zero alternative

Another situation is shown in Figure 9, where no noticeable differences compared to the zero alternative could be found. The reason for the different results is, that in the case of Rimbo the change at Tekniska Högskolan has been avoided, whilst in case of Norrtälje it has only been moved to Arninge.

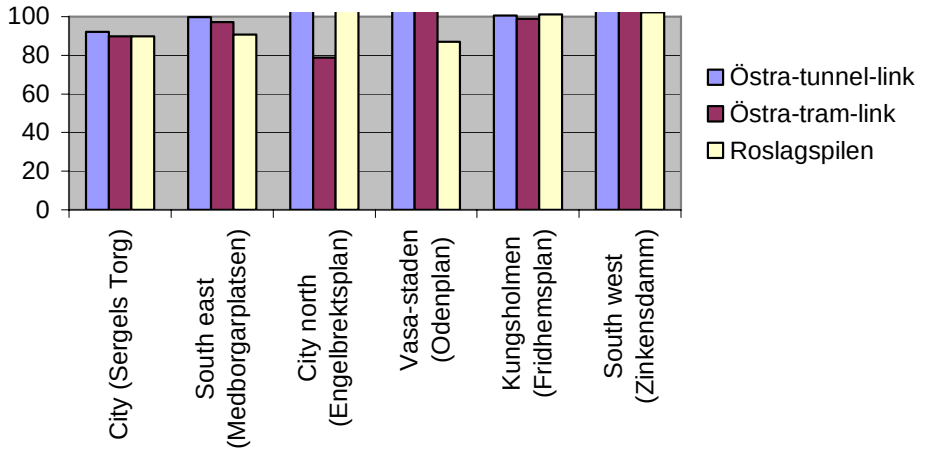

Figure 9: Trip-time change in [%] from Norrtälje, compared to the zero alternative

3.4 Cost-Benefit-Analysis: Östra-tram-link

Since the Östra-tunnel-link seems to be neither faster nor cheaper than the Östra-tram-link, it will not be subject to any further economic analysis. Instead, a closer look at the Östra-tram-link will be taken.

3.4.1 Benefits

To obtain the population, used as initial value for the calculation of benefits, the present number of travellers at Östra station has been multiplied with the expected growth of population in the north east sector of Stockholm, and with the effect of the arrangements mentioned in chapter 1.5, as shown in Table 6.

Table 6: Growth of relevant population

Present number of travellers at Östra station:		20 600 Passengers/day
Forecasted growth of population within 30 years:	+ 40 %	28 840 Passengers/day
Assumed growth due to actions from chapter 1.5	+ 20 %	**34 608 Passengers/day**

Table 7: Elasticity by purpose

	Share	Elasticity
Business, Commuter, Education	65 %	-0,6
Leisure, Shopping	35 %	-0,2

With the

- total number of passengers,
- the allocation of destinations, given in chapter 3.1,
- the time savings per destination and trip, as given in chapter 3.3,
- and the elasticity from Table 7,

the passenger increase can be calculated to 5200 additional travellers, see Table 8.

Table 8: Business and private growth due to shorter trip times in the Östra-tram-link scenario

	Sergels torg	Medborgar-platsen	Engelbrekts-plan	Oden-plan	Fridhems-plan	Zinkens-damm
Initial value	9741	4793	3396	3012	2600	2568
Growth, business	1697	473	852	108	228	20
Growth, private	915	255	460	58	123	11
Growth, total	2612	728	1312	167	350	31

To express the gain in time in monetary units (here: Swedish crowns, SEK), a conversion factor is needed; what [12] suggests is to 36 crowns per hour. Passengers who already travel with Roslagsbanan save the whole time gain, unlike additional travellers.

Table 9: Benefit to the Travellers at Roslagsbanan due to the Östra-tram-link in [SEK/year]

	Benefit, existing travellers	Benefit, new travellers	Sum
Sergels torg	37,404,116	5,.015,.238	
Medborgarplatsen	11,947,483	906,.901	
Engelbrektsplan	20,762,323	4,012,.518	
Odenplan	2,086,159	57,715	
Fridhemsplan	5,544,040	373,712	
Zinkensdamm	462,250	2,788	
Sum	78,206,.372	10,368,872	**≈ 90 million**

The first additional passenger was undetermined before the action, and hence both alternatives, to travel with Roslagsbanan, or not, had the same opportunity costs. The last additional passenger is undetermined after the action, and hence the opportunity costs for travelling with Roslagsbanan is now equal to the costs of the alternative – he does not save

any time. Thus, it has been assumed, that additional travellers gain an on the average 50 % the maximum gain. Table 9 states the benefits to the travellers.

3.4.2 Costs

To find a value for the building costs an internet research for similar projects has been performed. The Stadtbahn in Heilbronn, Germany is a recently built, combined railway/tram line, as part of the Karlsruher model. According to [14] the expenses for the tram part were 29 million DM/km, which equals 136 million SEK/km. Since the length of the Östra-tram-link is 3200 meter, the comparable costs would be 437 million SEK. In addition to that a yearly maintenance cost of 5 % of the value is assumed: 22 million SEK/year

The number of additional vehicles class A32, compared to a situation without tram-link, has been calculated to 14. From [1] it is known, that 26 % of the daily passengers are travelling during the morning peak, between 6 and 9. Thus, 3465 people are travelling per hour during this time, and assuming that 80 % are travelling towards the city, 2772 passengers per hour have to be transported. The vehicle class A32 offers a capacity of 78 seats, and has standing room for 133 people. Thus 40 train sets per hour, or 20 services per hour when double traction (= two train sets per train) is assumed, have to serve Östra-tram-link, to offer a decent quality, which would be a departure every 3 minutes and in each direction. The running time from Östra station to the central station and back again would be 19 minutes. Consequently 14 additional train sets are needed. One train set costs about 18 million SEK [15]; this adds 252 million SEK to the total costs. In addition it is assumed that there will be maintenance costs correspondingly to 5 % of the investment costs: 13 million SEK.

Two people, a driver and a conductor have to be paid per train for the additional time, thus, wages of 200 SEK per hour and person has been assumed, multiplied by 255 departures a working day according to Table 10 and an additional running time of 19 minutes per train. Saturdays and Sundays has been counted as half working days, hence the year equals 300 days. Thus, the costs for personnel can be calculated to 10 million SEK per year.

Table 10 Departures per day

Time period	Trains per hour	Trains per period
5-6	9	9
6-9	20	60
9-15	12	72
15-18	20	60
18-24	9	54

The total investments of 690 million SEK are generating an annuity of 35 million SEK, with the intrest rate assumed to be 5 %. The additional costs per year are thus 46 million SEK, bringing the total costs per year to 81 million SEK.

3.4.3 Cost-Value Ratio

If the total benefits of 90 million SEK are divided by these costs, a cost benefit ratio of 1.1 is achieved. That is not a very good value, but it has to be taken into account that only one kind of benefit has been included, and there are some other essential benefits, such as that the additional capacity between Östra station and city centre may relive the overloaded underground between those two stations.

4 Outlook

To come to a final decision about whether, or how, the project should be carried out more detailed studies have to be conducted. The questionnaire must contain more origin-destination relations, and more travellers have to be interviewed, to get more reliable results. It should also be extended to other means of transport, such as buses, or cars, to gather knowledge about destinations, which now are underrepresented in this questionnaire, as they are presently too unattractive, for travellers by Roslagsbanan.

The assumed number of travellers, given in Table 6, provides a very rough value. The increase of the population has to be checked, and the effects of the presumed arrangements, as given in chapter 1.5, have to be analysed in a separate survey.

A detailed cost-benefit analysis has also to be performed. In this study only benefits in terms of saved weighted trip time have been included. Other values, such as the relief of the underground, which has already reached its capacity limit between the stations of Tekniska Högskolan and T-centralen, and a decreased level of car traffic, due to a more attractive public transportation system, could also be of importance. On the cost side, only imprecise general values have been used.

If the Östra-tram-link would be realised, some questions become important. It can not be denied that a greater part of this link would use very busy streets and intersections, such as Kungsgatan/Sveavägen, and Klarabergsgatan. As the tram traffic would be very dense during peak hours, large variations in running times must be expected; thus, actions have to be taken, to limit that problem. This could be strategies, to lower the level of traffic on the concerned streets, but also strict priority to the trams at intersections, and separate lanes for public transport. Of course, alternative routs for the tram link also have to be checked, to, avoid if possible, the problems with car traffic altogether.

Since it would not be convenient to built high platforms in the city area, and accessibility for disabled persons must be provided, all the platform levels of Roslagsbanan have to be adapted.

A further challenge is the narrow gauge of Roslagsbanan. A decision has to be made, whether

to convert the whole network into normal gauge, or to built the Östra-tram-link as a narrow gauge line. If the existent gauge of 891 mm is kept, special vehicles will have to be built. These vehicles could not be equipped with 100 % low floor, because the wheel-inside-gauge is to narrow to enable a gangway between the wheels. A change of the gauge of the network on the other hand would enable SL to use standard trains, to combine the light-rail networks, and to use the same maintenance vehicles, all over the network.

Other tram-line considerations in Stockholm are the bus-line 4 – this line, with its huge passenger appearance, would be qualified for such a project – and the extension of the historical Djurgarden tram-line to the central station. See Figure 10. These two lines would fit the Östra-tram-link excellently, as it would share the infrastructure with Djurgarden-line from Sergels-torg, and so rise its productivity. On the other hand, some Roslagsbanan-trams could use the tram line replacing the bus-line 4, to get to Odenplan and so add an important change-free connection, as Odenplan will become the most frequented station in the northern inner Stockholm.

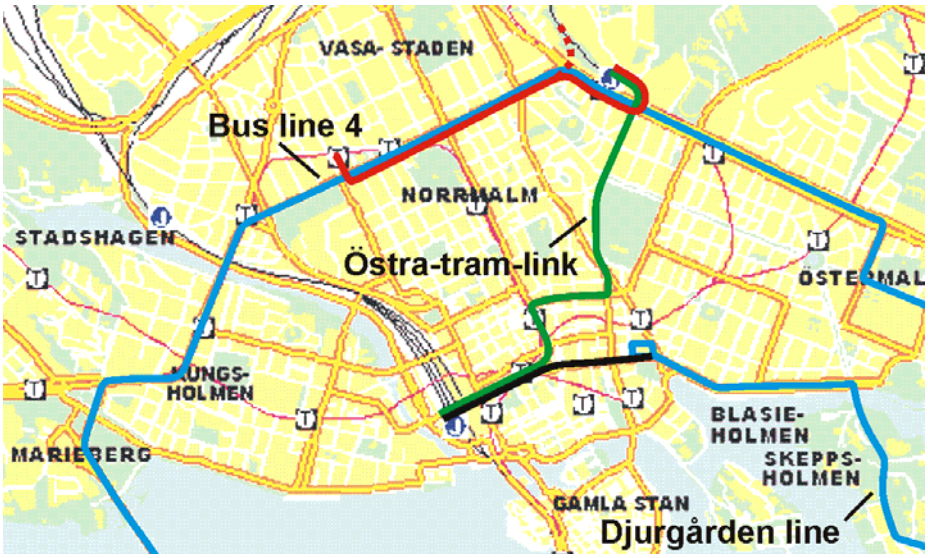

Figure 10: Tram-line considerations

5 Conclusion

Roslagsbanan is a well accepted, suburban light-rail system, which for some sections has already reached its capacity limit due to the lack of double track for most of the line. Furthermore, it has its terminal station outside the city centre; therefore most of the travellers have to change to the underground, which is quite unattractive.

A questionnaire has been conducted with the result that a fourth of the travellers have their destination in the city centre. The others have their final destinations north of the centre and on the island of Södermalm, and nearly nobody changes to the pendeltåg, or continues to destinations south of Södermalm.

Thus, of the five assessed alternatives for an extension of Roslagsbanan into the city, the Östra-tram-link got the best results in terms of the gain in travel-time. It is a tram link, which uses the historical route from Östra station to Engelbrektsplan, and continues to Hötorget, where after it reaches Sergels torg, and the Central station.

The profitability has been assessed by a rough cost-benefit analysis, expressing the benefits, as the sum of the gain in weighted trip time in monetary units, and the costs, by adapting the costs of a comparable project in Germany.

Assuming that the used values are in the right order, in can be concluded that Roslagsbanan, after having performed the necessary changes, is indeed able to cope with its future challenges. The Östra-tram-link could be an integrated part of a future Stockholm tram network.

References

[1] *Fakta om SL och länet år 2004*, (Swedish: Facts about SL and Greater Stockholm of 2004), Stockholms Lokaltrafik AB (SL), 2005, available for download at [*www.sl.se*]

[2] [*www.socialdata.de*], visited 26/05/06.

[3] "The Social-democratic utopia: Stockholm 1945-1980" in *Cities in Civilisation*, by Peter Hall, 1998.

[4] *Därför fungerar inte SL-trafiken* (Swedish: Therefore SL traffic does not work), Mikael Sundström, 2006, from [*www.kollektivtrafikant.org*], visited 26/05/06.

[5] [*www.roslagstag.se*], visited 28/05/06

[6] [*www.stockholmnordost.se*], visited 28/05/06

[7] *Stockholm Nordost – en vision* (Swedish: Stockholm north-east – a vision), UtvecklingNordOst (UNO), 2005, available for download at [*http://nordost.episerverhotell.net/upload/Dokument/5.2-Nordostvision-kartor.pdf*], visited 28/05/06

[8] *Skendöd i Roslagen* (Swedish: Apparent death at Roslagen), Svallhammar, Frank Stenvalls Förlag, 2002.

[9] Långsiktig strategi för Roslagsbanan (Swedish: Long-term strategy concerning Roslagsbanan), Tomas Ahlberg, Stockholms Lokaltrafik (SL), 2005

[10] Upplevd kvalitet i länet hösten 2005 (Swedish: Felt Quality within the County in Autumn 2005) Stockholms Lokaltrafik AB (SL), 2005, available for download at [*www.sl.se*]

[11] [*www.surveysystem.com/sscalc.htm*] and [*www.surveysystem.com/ssformu.htm*] visited 08/06/06.

[12] Incitament i upphandling av kollektivtrafik - Principer för bedömning – Utkast (Swedish: Inventive at tenders of public transportation – principles for evaluation – outline), Kjell Jansson, 2002

[13] BHV 776 - Beräkningshandledning - Hjälpmedel för samhällsekonomiska bedömningar inom järnvägssektorn (Swedish: Tool for economical evaluation within the railway sector), Banverket, 2005

[14] [*http://home.arcor-online.de/guenter.koch/system/stb_heilbronn/stb_hn6.html*] (German: About the implementing of the tram-line in Heilbronn, Germany – Karlsruher Modell), 2001, visited 13/06/06

[15] Sporvägsfordon – teknik, tillverkning och kostnader (Swedish: Light-rail-vehicles – technic, production and prices, Thomas Johansson, VTI notat 48-2004

Abbreviations and Glossary

ATC	Automatic Train Control, train safety system.
KTH	Kungliga Tekniska Högskolan (Royal Institute of Technology) – also the name of the undergrund station at Roslagsbanans Östra station
Öst	Stockholm Östra Station, terminal station of Roslagsbanan.
SL	Stockholms Lokaltrafik AB, the company is responsible for Stockholm's local public transport.
SEK	Currency: Svenska kronor (Swedish crowns)
DM	Currency: Deutsch Mark (German marks)
Modal split	The allocation of travellers (or goods) to different means of transport, especially between public transportation and individual traffic (car).
Roslagspilen	A visionary branch of the Pendeltåg system into the area of Roslagen.
Pendeltåget	Stockholms (heavy-) rapid transit railway