9TH CONFERENCE ON COMPETITION AND OWNERSHIP IN LAND TRANSPORT

USING GEOGRAPHIC INFORMATION SYSTEM (GIS) DOING CBA ON NEW BUS-ROUTE SYSTEMS – AN EMPIRICAL EXAMPLE OF THE CITY OF LINKÖPING

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1 PROBLEM, PURPOSE AND PLAN OF THE STUDY

Bus-routes in many medium-sized cities of Sweden are today too winding around the suburbs on their way to the city centre, and too big buses are used, taking also the user costs into account. In a case study by Jansson (2003) of the bus services of the town of Linköping, possible travel-time savings of 30 % thanks to straighter bus routes with smaller buses was pointed out.

The purpose of this study is to demonstrate further possible improvements of the bus-route system in Linköping by means of CBA, and so far as the effect on walking distances to/from bus stops is concerned, GIS will be used, using micro data, which allows detailed measurements of changes in walking costs following bus-route adjustments.

The route length in Linköping decreases, and the frequency of service will increase, while the average walking distance will go up only very little. Another possible cost of the proposed bus-route system that has to be taken into consideration is the cost of the encroachment effects that will occur in some places where new busways are drawn across car-free residential areas.

First the CBA approach is explained in section 2. Then the existing and a proposed bus route system in Linköping based on the study is presented in section 3. The CBA consequences going from the former to the latter route system is presented in section 4. Finally the CBA is summarized and discussed in section 5.

2 CBA AND LOCAL PUBLIC TRANSPORT

Both the National Rail Administration and the National Road Administration in Sweden use social Cost Benefit Analysis for every infrastructure investment project. Investments in local public transport is hardly ever analysed with CBA, especially not investments in rolling stock (Ljungberg, 2003). However, it would be possible to do CBA also for these investments and there is a CBA manual published by the National Road Administration (Vägverket 2000). Some difficulties exist though (Ljungberg 2001). There are CBA manuals focusing on local public transport published in other countries, for example in USA/Washington (TCRP 2002), and in Norway (Minken, et al 2001), with introductory chapters on welfare economics.

Included in the Swedish CBA manual are instructions to complete CBAs for a large variety of changes and investments in local public transport. Investments in for example information systems, vehicles, bus-lanes and rail would be possible to carry out, but also changes in fare structure and changes in traffic structure.

On the cost side is mostly the investment cost dominating, and the benefit side is clearly dominated by improvements for the public transport passengers. Usually the benefit-side also includes less future investment- and maintenance costs, and a change in revenues and costs as an effect of increased travel. Improved traffic safety and an improvement in environmental consequences is also part of the benefit side, but in most cases only of minor importance. Other positive externalities, for example less traffic congestion and an appreciated city view, or negative externalities like encroachment effects, should also be included, but this is not possible to calculate today with the models used.

The total consumer cost of public transport consists both of a fare (f) and a considerable time cost. This total consumer cost, or generalised cost (GC), is, when the time cost is divided into relevant trip components, defined as

$$(1) \qquad \text{GC} = f + c^1 h^1 + c^2 h^2 + c^3 h^3 \qquad ,$$

where c^x denotes the different value of time for the different trip components h^x (walk-, wait- and riding-time).

The net social benefit (NSB) of a reform can, taking the starting point in for example Sugden and Williams (1978), be expressed as

$$(2) \qquad \text{NSB} = \frac{Q_0 + Q_1}{2}(GC_0 - GC_1) + (f_1 Q_1 - f_0 Q_0) - (C_1 - C_0) \qquad ,$$

where Q denotes trips, C denotes total costs for the bus company, index 0 represents the present system and index 1 represents the new system. The first term on the right hand side in equation 2 equals the change in consumer surplus going from the present to the new system.

The second term equals the change in revenue, and the last term in equation 2 equals the change in total costs for the bus company.

Figure 1 below pictures the two first terms of (2), the gain in consumer surplus (a+b) and the increase in revenue (g) under the assumption of a constant fare, no change in the value of time and a decrease in total time costs going from the present to the new system. Area a represents the gain for existing passengers and area b represents the net gain for new public transport passengers. The change in producer surplus equals the increase in revenue (g) minus the change in total costs for the bus company ($C_1 - C_0$).

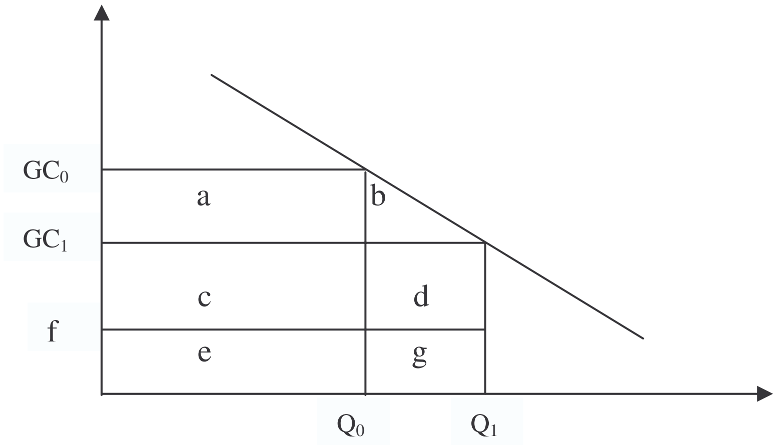

Figure 1 Reduction in Generalized Cost and its welfare consequences (a+b+g) excluding the increased costs for the bus company

3 GIS APPLICATION IN LINKÖPING

Linköping is a middle sized town in Sweden with 113 000 inhabitants in the built up area, and the public transportation system is organised with buses producing six million trips each year.

Information to develop the proposed bus-route system was collected by empirical fieldwork. Data on properties, population data and the existing bus-route system was collected from the municipality of Linköping, and further analysis was done with the GIS program Arc-view. Using Geografic Information Systems (GIS) allows detailed measurements of route- and possible walking distances for all inhabitants in different bus-route systems. (For an introduction in GIS see for example Bernhardsen 2002).

To measure route distances is straightforward, but to be able to measure walking distance in a quantitative study like this some assumptions found in appendix 1 are needed. Since restrictions on walking distance also is of importance in the planning process it will be considered too. Following Reneland (2000), studying change in access to public transportation over time, the change in number of inhabitants living within 400 meters from bus-stops going from the existing to the proposed bus-route system will first be measured.

There after will the change in walking distance between all households and their closest bus-stops doing the same bus-route change be measured, as input for the CBA.

3.1 Existing and proposed bus-route system in Linköping

As the built up area of Linköping has been growing, a military training area in the south and an airfield (SAAB) in north has limited its growth. The built up area is thus spread from north-west to south-east. In figure 2 the density of the population is pictured, were darker colour shows higher density.

Figure 2 Population density in Linköping

In figure 3 below, the existing winding bus-route system and bus-stops is pictured. The route towards Tallboda in the north east is excluded from this study. Bus-routes 201 and 202 are main-lines carrying about half the total bus-trip volume, operated with big articulate buses holding a maximum of 106 passengers. The other routes are operated with normal-sized buses with a capacity of 77 passengers. The number of bus-stops is 196, and the total route length, excluding the Tallboda route, is 105 kilometres, of which 32 are main-line kilometres.

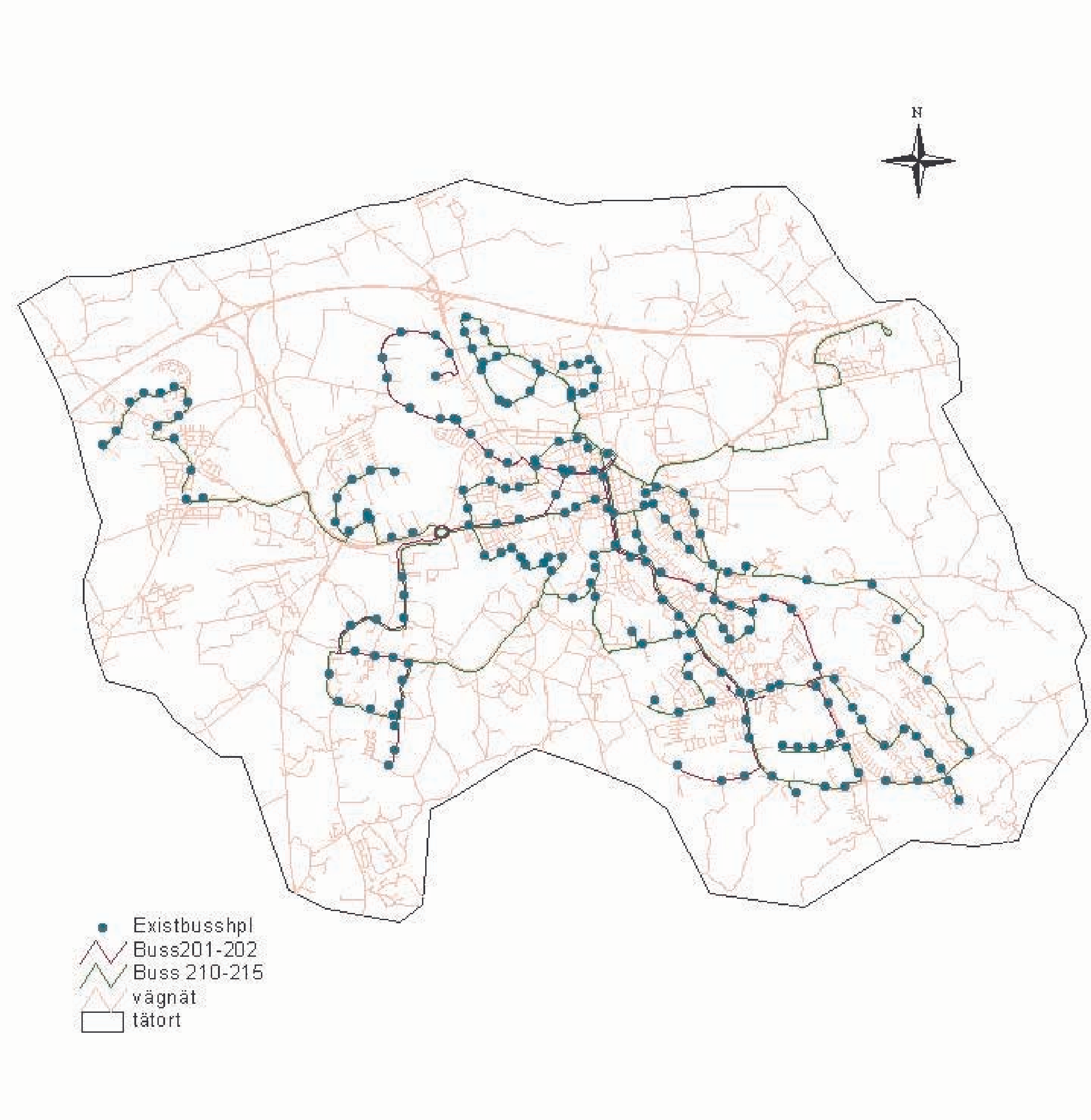

Figure 3 Existing bus-route system in Linköping

The proposed bus-route system, were the bus routes are straightened out is shown in figure 4. It is mainly in the areas Skäggetorp and Ryd in north and in the southern part of Linköping the routes are different. Some of the proposed changes might be controversial: line 201 in the middle of Skäggetorp in north; line 214 through Ryd centre in the middle and through the villa neighbourhoods of southern Berga in the south; and line 202 through Ekholmen also in the south. The proposed bus-route system also includes a change from large articulate buses to normal sized buses on the main lines. The total route length is 96 kilometers, of wich 25 are main-line kilometres (bus 201 and 202), and 161 bus-stops are proposed in this system.

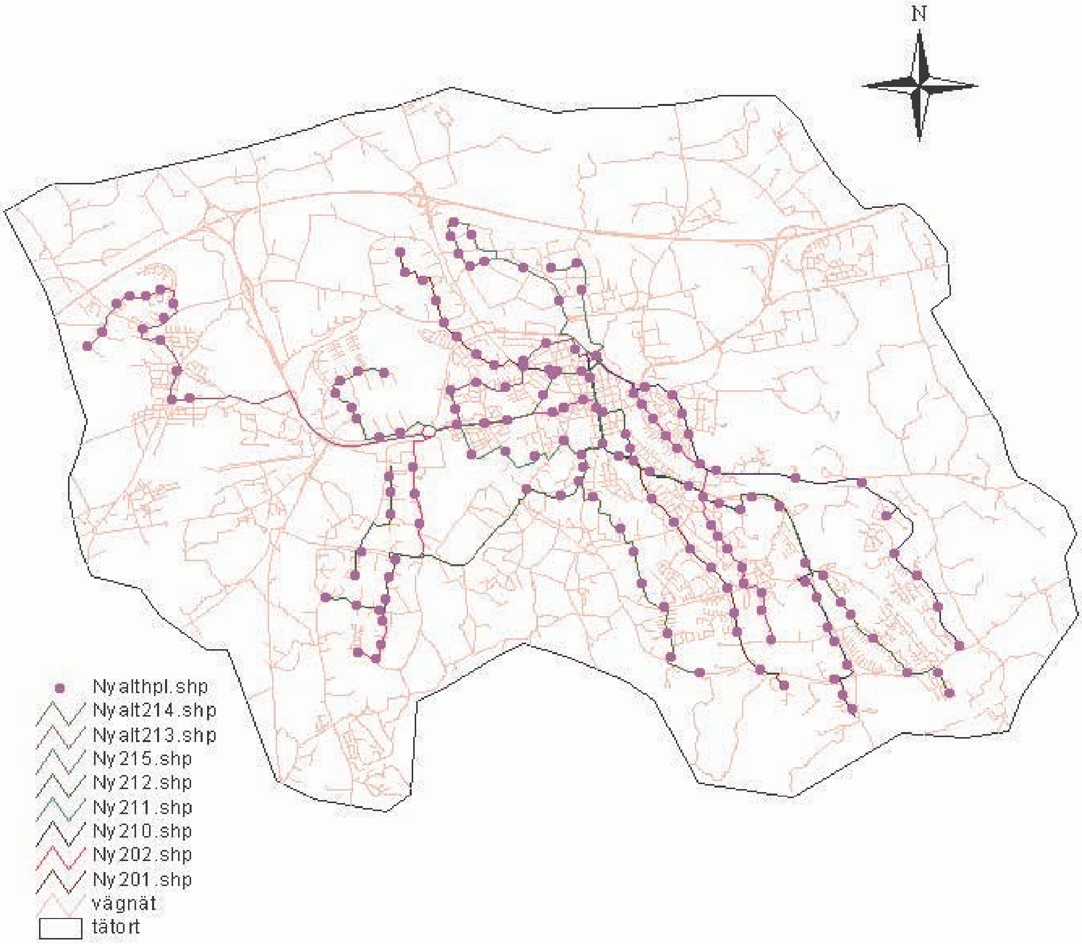

Figure 4 Proposed bus-route system with straighter routes in Linköping

3.2 Access to bus-stops in the existing and the proposed bus-route systems

Some bus-stops have to be moved or taken away when bus-routes are straightened out, and the number of inhabitants living in a certain distance from a bus-stop will change. Table 1 shows the number of inhabitants in different age groups living within a walking distance of 400 meters from the bus-stops in the existing and in the proposed bus-route system.

Age	Existing bus-route system	Proposed bus-route system	Decrease no	Decrease %
0-1	1323	1218	105	8
2-3	1948	1775	173	9
4-5	1726	1518	208	12
6	773	708	65	8
7-9	2768	2486	282	10
10-12	3124	2804	320	10
13-15	3170	2875	295	9
16-18	3113	2873	240	8
19-24	11604	10910	694	6
25-34	17714	16783	931	5
35-44	12147	11118	1029	8
45-54	10919	10069	850	8
55-64	10665	9904	761	7
65-69	3919	3709	210	5
70-79	7085	6735	350	5
80-	6130	6034	96	1,5
Total	**98128**	**91519**	**6609**	**7**

Table 1 Number of inhabitants in different age groups within a walking distance of 400 meters from the bus-stops in the existing and in the proposed bus-route system

The number of inhabitants within a reasonable walking distance (400 meters) of a bus-stop will, on average, be reduced by 7 %. A relatively small share of persons over 65 years of age get worse of in the new bus-route system, and persons in the age between 19 and 34 are also in a large extent staying within a reasonable walking distance from a bus-stop. Looking at the whole population of 113 000 inhabitants within the built up area of Linköping, the existing bus-route system are within a reasonable distance of 87%, compared to 81% in the proposed system.

Considering number of inhabitants living in different distances from the closest bus-stop in table 2, an increase in number of inhabitants living within 100 meter from a bus-stop can be noticed, as well as further away than 300 meters.

	Existing bus-route system		Proposed bus-route system	
Walking distance	Residents	Share	Residents	Share
0-100	8 434	8%	8 626	8%
101-150	13 579	12%	11 852	11%
151-200	25 727	23%	16 732	15%
201-250	19 407	17%	16 464	15%
251-300	17 341	15%	14 547	13%
301-400	13 640	12%	23 298	21%
401-600	7 828	7%	10 106	9%
601-910	1 222	1%	5 550	5%

Table 2 Number of resident living in different distances from the closest bus-stop in the existing and the proposed bus-route system.

3.3 Change in walking distance going from the existing to the proposed bus-route system

For inhabitants living between 0 and 400 meter from an existing bus-stop will the average walking distance to a new bus-stop increase with 47 meters. (Appendix 2 explains how the change in walking distance is measured.)

Looking closer at inhabitants living on different distances from the existing bus-stops in table 3, it can be seen that inhabitants in the interval 151-200 meters will get an increase in walking distance by 100 meter. However, inhabitants living further away than 300 meter from the existing bus-stops will get closer to the new bus-stops.

Existing walking distance	Change in walking distance	Residents
0-100	42	8 434
101-150	58	13 579
151-200	100	25 727
201-250	36	19 407
251-300	27	17 341
301-400	-21	13 640
401-600	-75	7 828
601-910	-50	1 222

Table 3 Change in walking distance to the closest bus-stop depending on existing walking distance to the closest bus-stop

In the main scenario for the CBA will 47 meters be used, and in a sensitive analysis is a larger increase used (58 meters).

4 COSTS AND BENEFITS OF THE CHANGE CONSIDERED

Apart from the investments in infrastructure (some new bus-ways and some other minor investments), the main components of a CBA of the proposed bus-route system in Linköping consists of changes in producer costs, consumer costs, and encroachment effects. Only changes in consumer- and producer costs will be estimated in this study. No calculations of external effects (neither positive, nor negative) are done, but except for encroachment effects they expects to be minor.

4.1 Changes in producer costs and revenues for the bus company

The total route length decrease by 9%, were the larger part is on the main lines, which decreases its length by 22%. On all the other routes the decrease is only 3%. The large articulate buses on the main lines will be changed to more frequent normal sized buses, with 27% less passenger capacity. The route straightening and the total reduced boarding/alighting time on the smaller buses decrease the total round voyage time by more than needed to compensate for the lost holding capacity on each bus[1]. The producers vehicle costs would go down, since a large articulate bus is more expensive (price reduction by 23%), and the fuel consumption higher (20 %)[2]. This would decrease the investment cost for 28 buses with 22.4 million SEK, and the yearly fuel cost with 2 million SEK[3]. However, as a result of reduced riding- and waiting time, the number of passengers will increase. In peak hours must three buses/hour be added on the main lines to meet this increased demand, which will add a yearly cost of 5,4 million SEK for six buses with drivers. The new passengers will add revenues of 6,5 million SEK each year. (Calculations are found in appendix 4).

4.2 Changes in consumer costs

The riding time savings for the passengers on the main lines, carrying about half the total bus-trip volume, will be in the magnitude of 30%. More than two thirds originating from the straighter routes and less than one third from reduced boarding/alighting time (see footnote 1). An average bus trip taking 20 minutes will take 14 minutes after the route change, and the riding-time cost will decrease from 14 SEK/trip to 10 SEK/trip[4]. Not considering the small decrease in route length on the other lines, the riding-time savings of existing traffic summarise to 11.5 million SEK each year. Waiting-time savings amounting to 8 million SEK

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[1] Pass/hour = number of buses * holding capacity on each bus * route speed/route length. The time at bus-stops will be reduced as a result of less passengers boarding/alighting each more frequent normal-sized bus. The bus-stop times could also be reduced by allowing boarding in more doors than the front door using automatic ticket machines. However, it is then important to be aware of possible free riders (Trivector 1999, Vägverket 2004). Differences in acceleration and retardation between normal-sized and large articulate buses could also reduce travel-time, but the constraint is probably passenger comfort and the risk for injuries while accelerating or retarding to fast, and not technical properties inherent in the different bus-sizes. (What acceptable acceleration and retardation is can be found in Wendle (1997), Sundberg Peterson (1989)).

[2] 3.5 million SEK compared to 2.7 million SEK. Fuel consumtion decrease from 9 to 7 (m^3 /10km)

[3] 1 € is approximately 9 SEK.

[4] With a value of time = 42 SEK/hour (SIKA 2002) = 4,5 €/hour.

each year will also be made on the two main lines, since the bus frequency increase as a consequence of decreased total round voyage time and the three added extra buses/hour.

The walking distance will on average rise by 47 meters, which for an average passenger increase walking time by 40 seconds. The total cost of increased walking time sums up to 5,5 million SEK each year.

The generalized cost (GC) will in all decrease by 18 % for an average passenger (from 35 SEK to 29 SEK)[5] on the main lines. An expected price elasticity of –0.4 (Balcombe et al 2004) resulting in a GC elasticity of –1,4 (see appendix 3), gives a calculated trip increase of 23% on the main lines. The increase in consumer surplus adds another 2 million SEK each year on the benefit side as a consequence of the increase in number of trips.

4.3 Changes in encroachment effects

The changes, as mentioned before, that might be controversial is four new bus-ways; (i) the rerouted line 201 in between the apartment blocks of Skäggetorp in north, (ii) line 202 through Ekholmen close to Ekholmen school in the south, (iii) the rerouted line 214 close to Ryd centre in northwest, and (iv) through the villa neighbourhoods of southern Berga (line 214) in the south. It is obvious that these encroachment effects must be considered as a cost in the CBA. The encroachments could be estimated with a stated preference approach (Ivehammar 2005), and added to the CBA.

[5] GC before (walk-, wait-, travel- and price components) 4.1 + 7.2 + 14 + 10.2 = 35.5 SEK, and GC after 5 + 4.2 + 9.8 + 10.2 = 29.2 SEK. (see also appendix 3)

5 CONCLUDING DISCUSSION

The route length in Linköping decrease by 22% on the main lines and by 3% on the other routes going from the existing to the proposed bus-route system. A change to smaller buses will also increase round voyage speed on the main lines, decreasing travel-time in total by 30%. This will increase the frequency and make it possible to uphold the passenger capacity with the same number of smaller buses. However, three more buses/hour will be added on each main line to meet the increased demand. Higher frequency shortens passengers waiting time on the main lines. Walking time will increase on average for all travellers, and the number of inhabitants living within a distance of 400 meters from a bus-stop will only slightly decrease.

Table 4 summarizes the main components of a cost- benefit analysis of going from the existing to the proposed bus-route system in Linköping. The calculations the table is based on is found in Appendix 4. The time-horizon is 40 years, using a discount rate of 4%.

Effect	Cost	Benefit
Change in walking time for existing travellers	108 million SEK	
Change in waiting time for existing travellers		158 million SEK
Change in riding time for existing travellers		228 million SEK
Net benefit for new travellers		39 million SEK
Change in costs and revenue for the bus company[6]		114 million SEK
Investments (some bus-ways and other minor inv)[7]	X	
Encroachment effect	Y	
Sum	108 + X + Y	539 million SEK
Sum		**431 -X -Y**

Table 4 The main components of a cost- benefit analysis of going from the existing to the proposed bus-route system in Linköping (Present value; 4%, 40 year)

[6] Smaller buses +54.6 million, lower fuel consumption +40 million, added buses –107,8 million, increased revenue + 127 million.
[7] The shadow price for tax-money should also be added to the investment cost X and the bus companies changed total costs. A subsidization of approximately 50% and a shadow price of 1,53 SEK per 1 SEK (SIKA 2002) implies a factor 1.26 to multiply the cost changes with.

The initial investment costs X could be estimated to be in the magnitude of 25-40 million SEK, based on the costs of earlier proposed bus-ways (Trivector, 1996).

Not changing from large articulate buses to normal-sized buses could also meet the expected passenger increase of the route straightening. However, if this is done, the riding- and waiting time savings will not decrease as much as calculated in table 4, and the bus companies costs would be changed. The increase in consumer surplus and revenue from the new passengers would also be reduced, since not as many new passengers would be attracted. In all it would reduce the benefit by 192 million SEK in table 4[8].

One effect not considered is that an increased bus patronage could reduce car traffic (assuming that some former car drivers change mode), which should add to the benefits, especially if there is congestion on the roads[9]. Less cars on the road increase speed and reduce travel-time for remaining cars, increasing their consumer surplus. However, if former pedestrians and bicyclists change to bus, they could lose the positive health effect walking and cycling actually have.

A sensitive analysis, with a worst scenario, using an increased average walking distance, a decreased travel-time saving, and a decreased passenger increase, compared with the main scenario, results in a net benefit of 185 -X-Y million SEK[10]. (A table summarizing this CBA is found in Appendix 5).

It can be discussed if the proposed bus-route system is politically possible to implement, since the encroachment effects might cause loud discussions. Part of the bus-ways in both Ryd (line 214) and Skäggetorp (line 201) has been proposed earlier (Trivector 1996), but since residents living close to these possible encroachments objected, they were never built.

Finally, two successful Swedish experiences must be mentioned. The bus-route system in the built up area of Luleå in the northern part of Sweden was changed 2003, mainly with the introduction of main-lines with straighter routes, a very high frequency and the possibility for passengers to coordinate bus changes. The bus companies costs hardly increased, and the increase in number of trips was 17% (Häggström, 2002), but seems not to be an effect of mode change (Berggren, 2004). Sjöstrand (2001) concludes from her analyses that the route changes made in Jönköping in the southern part of Sweden (Holmberg, et al, 1999) reduced the generalised cost (not including the fare) with between 11% and 25 % depending on trip purpose.

[8] Were 62 million occurs from less riding-time savings, 74 million occurs from less waiting-time savings, 24 million from less new travellers, -12 occurs from saved costs and 44 million from less revenue.
[9] See for example Sugden and Williams (1978).
[10] The average walking distance is increased from 47 meters to 58 meters, the travel-time saving is reduced to 15% instead of 30%, and the passenger increase is thus assumed/calculated only to be 10% instead of 23%.

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Appendix 1

Measured walking distance

Actual walking distance follow streets and consider factual obstacles, but in this study, the distance as the crow flies is measured, and converted to walking distance assuming it to be 30% longer (Vägverket 2000, Statens Planverk 1982). Population data is collected on property level, and the distance is measured from a central point on each property (point of gravity) to the nearest bus-stop. Since some properties consists of more than one house, this will be another simplification, see figure A1 below, picturing two houses on a property as seen from above.

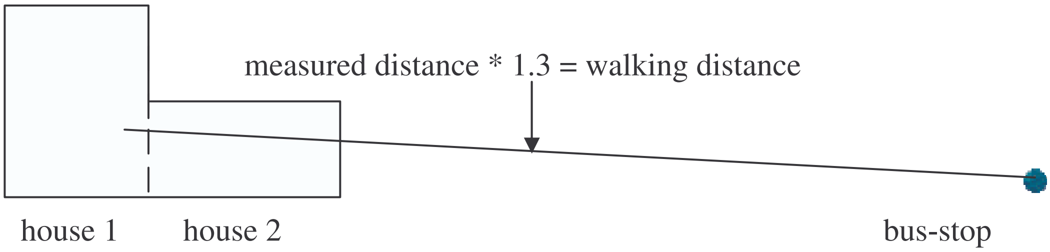

Figure A1 Measured distance from a property consisting of two houses

Only the walking distance between bus-stops and households at either the start or the end of the trip is measured and included in the CBA. However, it has been considered were people travel to when the new bus-route system was designed. Bus-stops around usual trip destinations is hardly not changed, and if they are changed, walking distance have been reduced in some cases. It is therefore assumed that the walking distance at the destination not will change.

Appendix 2

Increase in walking distance going from the existing to the proposed bus-route system

The walking distance to the closest bus-stop will on average increase. Figure A2 below pictures how the distance from existing to new bus-stops will change. The spider diagram to the left shows the distances from all properties within a walking distance of 100 meter from two existing bus-stops[11]. To the right are the distances from these properties to the closest new bus-stop shown.

Figure A2 Distances between properties and two existing bus-stops to the left, and distances between the same properties and the closest new bus-stop to the right

On average the walking distance to the closest new bus-stop for all inhabitants living within 100 meter of the closest existing bus-stop will increase with 42 meter. Increasing the distance from existing bus-stops results in diagram 1, based on table A1 below. The average change in walking distance for all inhabitants in Linköping is 38 meter.

[11] That is a measured distance as the crow flies of 77 meter.

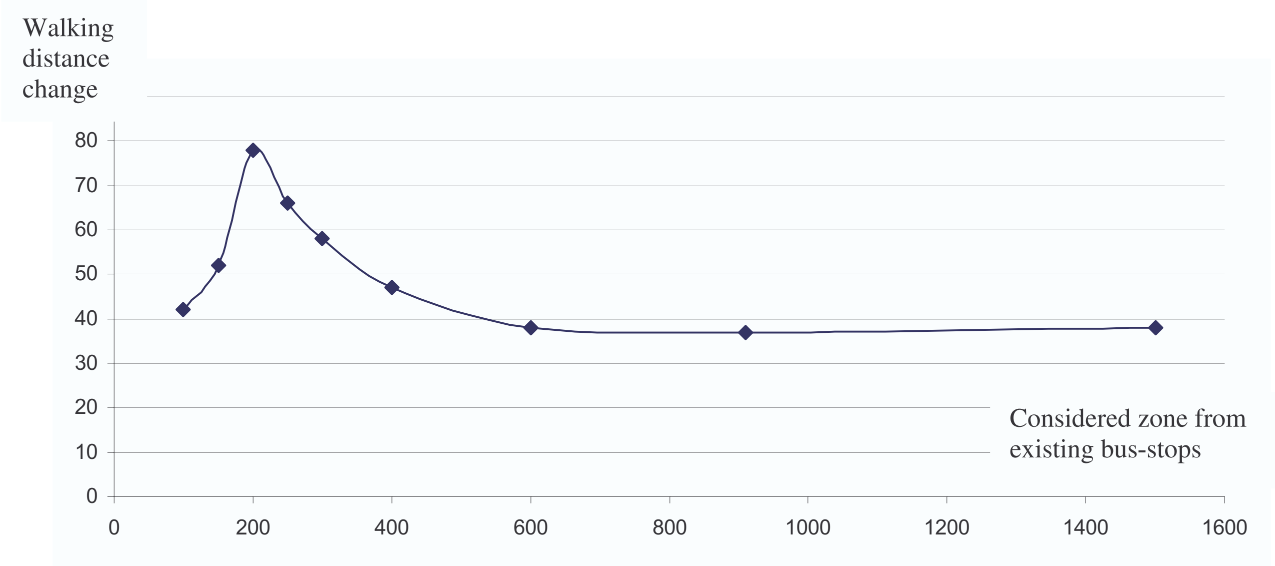

Diagram A1 Average change in walking distance going from the existing to the proposed bus-route system (for all inhabitants between their home and the closest bus-stop) depending on considered distance zone from existing bus-stops

Distance to existing bus-stops; zone	Existing walking distance		New walking distance		Change in walking distance	Residents (no)
	Mean	Spread	Mean	Spread		
0-100	74	20-100	116	8-721	**42**	8 434
0-150	105	20-150	157	8-736	**52**	22 013
0-200	143	20-200	221	8-742	**78**	47 740
0-250	168	20-200	234	8-774	**66**	67 147
0-300	189	20-300	247	8-812	**58**	84 488
0-400	211	20-400	258	8-823	**47**	98 128
0-600	230	20-600	268	8-1076	**38**	105 956
0-910	235	20-910	272	8-1399	**37**	107 178
0-1500	240	20-1473	278	8-2167	**38**	107 718

Table A1 Walking distance between households and bus-stops in the existing and the proposed bus-route system for residents living within a certain distance from existing bus-stops

Appendix 3

Generalized Cost (GC)

Before				
Walk	211 meter, 1.2 m/s	211/1.2 * 2 * 42/(60*60) =	4.1	
Wait	6 min	6*1.7*42/60 =	7.2	
Travel	20 min	20*42/60 =	14	
Fare	average fare/trip =		10.2	
		SUM	**35.5 SEK**	= 3.9 €
After				
Walk	258 meter, 1.2 m/s	258/1.2 * 2 * 42/(60*60) =	5	
Wait	3.5 min	3.5*1.7*42/60 =	4.2	
Travel	14 min	14*42/60 =	9.8	
Fare	average fare/trip =		10.2	
		SUM	**29.2 SEK**	= 3.2 €

Price elasticity (E_P) and GC elasticity (E_{GC})

$E_P = P/Q*dQ/dP = P/Q*dQ/dGC*dGC/dP = P/Q*dQ/dGC*1 = P/Q* E_{GC}*Q/GC = P/GC* E_{GC}$

$E_{GC} = E_P*GC/P = -0.4*35.5/10.2 = -1.4$

Appendix 4

Passengers

Year 2003 a total of 7 983 000 boardings were made in the built up area of Linköping, and 3 654 000 of these were on the main lines (Östgötatrafiken). Assume that 1 out of 4 boardings is a consequence of a bus change.

7 983 000*3/4 = 5 987 250

3 654 000*3/4 = 2 740 500

Shorter riding time

20 to 14 minutes, value of travel time = 42 SEK/hour, main line travellers 2 740 500, 4% 40 år – discount factor (same x every year) 19.79

6 * 2740500/60 * 42 =11.5 million SEK

11.5´´ *19.79 = 227.6 million SEK 227´´ / 9 = 25.28 mil €

Longer walking time

Walking speed 1.2 m/sek, value of walking time = 2* 42 = 84 SEK/hour (Vägverket 2000), all travellers 5 987 250, change in walking distance 47 meter.

47/1.2 = 39 sek

5 987 250*39*2*42/(60*60) = 5.47 million SEK

5.47 * 19.79 = 108 million SEK 108/9 = 12 million €

Shorter waiting time

Peak; existing 12 minutes interval will be 6.25 minutes interval

Off peak; existing 20 minutes interval will be 15 minutes interval

(Peak; existing 5 articulate buses/hour will be replaced by 9.6 normal sized buses/hour)
(Off peak; existing 3 articulate buses/hour will be replaced by 4 normal sized buses/hour)

70% of all trips in peak (7-9, 14.30-18), 30% in off-peak.

Assume; half interval are waiting-time in peak and 30% are waiting time in off peak. This gives a waiting time saving of 2.45 minutes.
Value of waiting time = 1.7 * 42 = 71.4 SEK/hour (Vägverket 2000),
main-line travellers 2 740 500.

2.45*1.7*42*2740500/60 = 8 million SEK

8´´*19.79 = 158 million SEK 158´´/9 = 17.6 million €

New travellers

2 740 500 travellers, 23% increace, GC_{before} = 35.5, GC_{after} = 29.2

2740500*0,23(35.5-29.2)/2 = b (= 2 million)

b *19,79 = 39 million SEK 39/9 = 4.4 million €

Normal sized buses

28 large articulate buses will be changed to 28 normal sized buses. Large articulate (biogas fuelled) bus = 3.5 million SEK (excluding tax), normal sized (biogas fuelled) bus = 2.7 million SEK (excluding tax). Will run for 10 years.

Assume all buses will be bought year 0, 10, 20, and 30. Discount factors 1, 0.67, 0.45, 0.31 (4%, 10, 20 and 30 years).

28*(3.5-2.7) = 22.4 million SEK

year 0	22.4
year10 22.4*0.675 =	15.1
year 2022.4*0.456 =	10.2
year30 22.4*0.31 =	6.9

SUM 54.6 million SEK 54.6/9 = 6 million €

Lower fuel consumption

Each large articulate bus travel 60 000 km each year. Large articulate bus fuel consumption 9 m^3 /10km, normal sized bus fuel consumption 7 m^3 /10km. Fuel price = 6 SEK/ m^3. (Connex)

28*6000*(9-7)*6 = 2 million SEK

2*19.79 = 40 million SEK 40/9 = 4.4 million €

Added buses on the main lines

A round trip will take 60 minutes after the route straightening. Adding three buses on each main line makes six buses only to be used in peak hours (7-9, 14.30-18). The drivers work in a split shift including both peak hours, a full salary for less than full time job is assumed. Normal sized bus costs 2.7 million and last for 10 years. These buses will only travel 25000 km each year and are therefore assumed a rest value of 0.5 million.

Drivers; 6*21000*1.4*12 = 2 116800 (Assumed wage of 21 000/month *1.4 (social security).

Depreciation; 6*220 000 = 1 320000
Fuel; 6*105 000 = 630000
Capital cost; 6*80 000 = 480000 (4% on 2 million)
Service /garage; 6*150 000 = 900000
SUM 5 446800

5,45 million * 19.79 = 107,8 million 108/9 = 12 million €

Increase in revenue

2740500*0,23*10,21 = 6,4 million SEK
6,4*19,79 = 127 million SEK 127/9 = 14 million €

Not changing to normal sized buses

Riding time
22% riding-time reduction instead of 30%, 20 minutes becomes 15.6 minutes
8.4*19.79 = 166 million SEK

Waiting time
Peak 12 minutes interval becomes 9,5 minutes interval
Off-peak 20 minutes interval becomes 15.5 minutes interval
Saved average waiting time = 1.3 minutes
4.2*19.79 = 84 million SEK

New travellers, GC before = 35.5, GC after = 31.7
15% increase in travellers
0.78*19.79 = 15.4 million SEK

Revenue
2740500*0,15*10.2 = 4.2 million SEK

4.2 * 19,79 = 83 million SEK

Appendix 5

Effect	Cost	Benefit
Change in walking time for existing travellers	134 million SEK	
Change in waiting time for existing travellers		84 million SEK
Change in riding time for existing travellers		114 million SEK
Net benefit for new travellers		7 million SEK
Change in costs and revenue for the bus company[12]		114 million SEK
Investments (some bus-ways and other minor inv)	X	
Encroachment effect	Y	
Sum	134 + X + Y	319 million SEK
Sum		**185 -X -Y**

Table A2 The main components of a "worst scenario" cost- benefit analysis of going from the existing to the proposed bus-route system in Linköping (Present value; 4%, 40 år)

In comparison with table 4 is the average walking distance increased from 47 meters to 58 meters, the travel-time saving reduced to 15% instead of 30%, and the passenger increase thus assumed/calculated to be 10% instead of 23%.

[12] Smaller buses +54.6 million, lower fuel consumption +40 million, added buses –35,9 million, increased revenue + 55 million.