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Cost-benefit analysis of the Stockholm Trial

SHORT SUMMARY

A cost-benefit analysis (CBA) is a systematic summary of all the effects and costs of an investment (or similar measure). An analysis such as this is performed in an attempt to ascertain whether an investment is “worth what it costs”: in other words, whether the financial values it creates for society are greater than the financial costs it incurs. This study analyses the benefits and costs to society of the two largest components of the Stockholm Trial: the congestion-charging system and the expansion of bus services.

If viewed solely as a short-term trial which, once terminated, will not subsequently be resumed, the Stockholm Trial represents a disbenefit of some SEK 2.6 billion in socioeconomic terms. Investments in and the operation and administration of the congestion-charging system account for the major portion of this. Taking a short-term perspective is of limited interest, however. It is unlikely to come as a surprise to anyone that the cost of investments in the congestion-charging system cannot be recouped within the duration of the trial period. The value of the experiences gained during the trial and the value of the opportunity this provides when possibly continuing with the system are not included in this calculation.

If congestion charging were to be made permanent, calculations suggest that the effect would be to generate a substantial annual surplus in CBA terms of some SEK 760 million (after deductions for operating costs). The investment cost sustained by society would be “repaid” in the form of socioeconomic benefits within four years. This is a very quick repayment period in comparison with, for example, investments in road infrastructure and public transport, which even under relatively favourable circumstances have a repayment time of between 15 and 25 years.

On the plus side of the balance sheet in this cost-benefit analysis of the congestion-charging system are, for example, shorter travel times (value: SEK 600 million p.a.), improved traffic safety (SEK 125 million p.a.) and the positive effects on health and the environment (SEK 90 million p.a.) Income from the congestion tax is estimated at around SEK 550 million p.a. (after deductions for operating costs). For every krona generated via the

congestion tax, the benefits to society amount to approximately 90 öre (SEK 0.90).

Cost-benefit calculations show that the expansion of bus services will be unprofitable both during the trial period and if the system is made permanent. The benefits are estimated to total SEK 180 million p.a., compared with costs of SEK 520 million p.a. for running the extra services. Some caution should be exercised, however, when interpreting this result. It is not unusual for public transport to be unprofitable in strictly financial terms; for various reasons, however, it is still considered important to provide this service.

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PREFACE

On 2 June 2003 Stockholm City Council adopted a proposal to conduct a trial with environmental charges/congestion charging – “the Stockholm Trial”. On 16 June 2004 the Swedish parliament passed the Congestion Charging Act (SFS 2004:629). This act permits the collection of a congestion tax in Stockholm up to and including 31 July 2006. On 28 April 2005 the government resolved that the trial period with environmental charges/ congestion charging in Stockholm should commence on 3 January 2006. The main parties involved are the City of Stockholm, the Swedish Road Administration and Stockholm Transport (SL). The trial is to be financed by the state.

There are three elements to the Stockholm Trial: the expansion of public transport, environmental charges/congestion charging and more park-and-ride sites in the city and the county.

The objectives of the trial are as follows:

- To reduce the number of vehicles passing in or out of the congestion-charge zone during the morning and afternoon/evening peak periods by 10–15%.
- To improve the flow of traffic on the busiest streets and roads in Stockholm.
- To reduce emissions of carbon dioxide, nitric oxides and other particles into the air in the inner city.
- To improve the urban environment as perceived by Stockholm residents.

The Congestion Charging Secretariat is the City of Stockholm’s project office. Its task, as defined by the government, is to plan, coordinate, provide information about and evaluate the Stockholm Trial. In order both to be able to provide answers to the question of the extent to which the objectives are achieved and also to study the effects of the Stockholm Trial, the Congestion Charging Secretariat has, together with the Swedish Road Administration, County of Stockholm’s Office of Regional Planning and Urban Transportation, Stockholm Transport (SL), various research institutes (among them, the Faculty of Engineering at Lund University [LTH] and the Royal Institute of Technology in Stockholm [KTH]), independent consulting companies (Transek, Trivector, and others) and various of the City’s municipal departments (the City of Stockholm Traffic Office, the Stockholm Office of Research & Statistics, and the City of Stockholm Environment and Health Administration), developed a comprehensive programme for evaluating the results of the trial. The

measurements, analyses and reports have been carried out and produced by public and local government authorities and consulting companies with expertise in the various specialist areas that constitute the evaluation programme. All the reports are published as they are completed on the homepage for the Stockholm Trial, www.stockholmsforsoket.se.

The project leader for the evaluation programme was initially Joanna Dickinson (an engineering graduate). Her role was later taken over by Dr Muriel Beser Hugosson and Ann Sjöberg (Licentiate in Engineering). In addition to the project leaders, Dr Camilla Byström, Annika Lindgren, Oscar Alarik, Litti le Clercq, David Drazdil, Malin Säker and Ann Ponton Klevstedt have also worked with the evaluations.

This report has analysed the costs and benefits to society of the Stockholm Trial both during the trial period and projected over a longer perspective. Dr Jonas Eliasson has been the project leader at Transek AB. Other consultants who have also worked on the report are Matts Andersson, Willy Andersson, Stehn Svahlgård and Anders Wärmark.

The work has been monitored by a reference group consisting of Per Bergström Jonsson (Swedish Road Administration), Dr Henrik Edwards (Vägverket Konsult, formerly of the Swedish Institute for Transport & Communications Analysis, SIKA), Dr Sofia Graan-Voorneveld (Swedish Institute for Transport & Communications Analysis, SIKA), Professor Lars Hultkrantz (Örebro University), Professor Lars-Göran Mattsson (Royal Institute of Technology in Stockholm), Dr Lena Nerhagen (Swedish National Road and Transport Research Institute, VTI), and Dr Staffan Widlert (Swedish National Public Transport Agency). We are most grateful for the significant contribution that the reference group has made to the project in the form of advice, knowledge and good ideas.

Solna, Sweden – June 2006

Marika Jenstav
Managing Director, Transek AB

SUMMARY

A cost-benefit analysis (CBA) is a systematic summary of all the effects and costs of an investment (or similar measure). An analysis such as this is performed in an attempt to ascertain whether an investment is “worth what it costs”: in other words, whether the financial values it creates for society are greater than the financial costs it incurs. To do this, all the effects that the investment may be expected to have on factors such as travel times, traffic safety and emissions are translated into monetary terms via cost-benefit values based on measurements of people’s willingness to pay for shorter travel times, safer traffic, etc. In this way, all the effects – or *benefits* in CBA terminology – can be summarised and compared with the financial outlay, i.e. the cost of the investment. At the same time, various alternative investments can be compared one with the other.

The cost-benefit analysis of the Stockholm Trial is based first and foremost on measurements of traffic volumes and travel times by car, together with passenger statistics from Stockholm Transport (SL). Certain effects, such as those on traffic safety and health, are calculated using models based on the recorded changes in traffic patterns.

Cost-benefit analysis divides the Stockholm Trial into three component parts

The Stockholm Trial can be divided into three component parts, each of which can be analysed individually from a cost-benefit perspective. The first component is the congestion-charging system, plus a few minor investments in road infrastructure (primarily in new or improved traffic signals). Congestion charging, however, accounts for by far the greatest proportion of costs and effects.

The second component is the expansion in public transport and the increased number of park-and-ride sites. The expansion in public transport, which accounts for the greatest benefit and cost in this component, comprises expanded bus services (new bus routes from the suburbs to the inner city and more frequent departures on inner-city trunk routes) as well as more frequent

rail departures and more carriages per train. In this study, we have only evaluated the social cost-benefit ratio of the expansion in bus traffic.¹

The third component is the costs involved in producing and distributing information about the trial and in evaluating the results of the trial.² These costs cannot be dealt with using conventional cost-benefit models, since it is not feasible to assess the values created in purely monetary terms.

Summation of the estimated effects

The table below shows the estimated annual effects in cost-benefit terms of congestion charging and increased bus traffic respectively, *excluding* operating and investment costs.³

¹ This is due to technical difficulties relating to the calculations. The issue is discussed in more detail in section 4.1.

² Information directly related to the payment system (i.e. information produced by the Swedish Road Administration about how to pay the congestion tax, etc.) is not included in the costs for the congestion-charging system.

³ The figures in all tables are rounded off to the nearest million SEK. This is illusory precision: the figures are not rounded off to make the calculations easier to follow.

Table 1. Cost-benefit effects, in SEK millions p.a.

<i>(SEK millions, p.a.)</i>	Congestion tax	Expansion of bus services	Total
Shorter travel times	523	157	680
More predictable travel times	78	0	78
Change in mode of travel	-13	24	11
Congestion tax paid	-763	0	-763
Total effect: road-users	-175	181	6
Reduced climate gas emissions	64	0	64
Health and other environmental benefits	22	0	22
Improved traffic safety	125	0	125
Total effect: other factors	211	0	211
Congestion tax revenues	763	0	763
Public transport revenues	184	0	184
Fuel tax revenues	-53	0	-53
Wear and tear on infrastructure	1	0	1
Maintaining public transport standards ⁴	-64	0	-64
Total public sector income and expenses excl. operating and investment costs	831	0	831
Total surplus of benefits over costs excl. operating and investment costs⁵	867	181	1,048

Reductions in car and bus travel times worth SEK 770 million per year

The value of shorter and more predictable travel times by car is estimated to be worth approximately SEK 600 million p.a. Drivers pay slightly more than SEK 760 million p.a. in congestion tax (the revenue from congestion tax appears as income for the public sector in the lower half of the calculation). The congestion tax encourages certain drivers to change their travel habits. Some choose not to travel due to the cost; others take advantage of the improvements in traffic flow to increase the amount of travelling they do. Overall, this change in travel habits is calculated to generate a disbenefit of SEK 13 million.

⁴ The cost for maintaining the same average standard of comfort on public transport despite increased passenger numbers. Calculated using the average cost-correlation model developed by Banverket (the authority responsible for rail traffic in Sweden), implemented in the SamKalk computational program.

⁵ Not including distortion and opportunity costs (so called tax factors).

The benefits of expanded bus services (new direct routes and increased frequency on inner-city trunk routes) are estimated at SEK 181 million: SEK 157 million of this figure is accounted for by the benefits of quicker and more convenient journeys for existing users of public transport; the remaining SEK 24 million by shorter travel times by bus for travellers who change to this mode of transport as a result of the congestion tax. (The investment in public transport has not, in itself, had any apparent effect on the total number of journeys made by public transport.)⁶ It has not been possible to calculate the value of other aspects of the investment in public transport (i.e. more frequent departures for all types of rail transport): this is due to the complex pattern in which these are spread over the day and across the county as a whole. As a result, comparisons of costs and benefits in this study relate solely to the costs for the expansion in bus services.

Environmental effects worth SEK 90 million per year

The decline in traffic as a consequence of congestion charging is expected to reduce emissions of climate gases from traffic in the County of Stockholm by 2.7%. This effect represents a benefit to society worth SEK 64 million p.a. Other emissions are expected to fall by between 1.4% and 2.8% in the county. The effects on health of these reduced emissions are expected to total approximately 5 life-years saved p.a. (for County of Stockholm as a whole.)⁷ Together with other environmental effects (pollution and environmental damage), this adds up to a cost-benefit value of SEK 22 million p.a.

The investment in public transport has not produced any measurable effects on road traffic. Consequently, we have not included the possible effect that the investment in public transport may have had on reductions in vehicle emissions and road accidents. Emissions from the new buses are negligible in this context, even if certain local effects are noticeable.⁸

⁶ See section 4.1.

⁷ Recent research into the impact of traffic emissions on health suggests that the actual effect may be much greater (maybe 50 times as great). Consequently the benefits to society would also be 50 times greater. We have, however, chosen to err on the side of caution by using somewhat older models for calculating the effects on health.

⁸ City of Stockholm Environmental and Health Administration (2006).

Improved traffic safety estimated at SEK 125 million per year

The reduction in traffic is expected to lead to a 3.6% fall in the number of traffic accidents. The number of people killed and severely injured on the roads is expected to decrease by approximately 15 p.a., while the number of people slightly injured is expected to fall by just over 50 p.a. The benefit to society of these effects is estimated at SEK 125 million p.a.

Public sector income surplus of SEK 830 million, excluding operating and investment costs

The item “Public sector income and expenses” includes increases in ticket revenues for Stockholm Transport (SEK +184 million⁹), the cost for maintaining the same average standard of comfort on public transport¹⁰ despite the increase in the number of passengers following the introduction of congestion charging (SEK –64 million), reduced revenues from vehicle fuel tax (SEK –53 million) and reduced wear and tear on the roads (SEK +1 million). Together with the revenues raised by the congestion tax (estimated to total SEK 763 million), this gives an income surplus of SEK 831 million p.a., *excluding* operating and investment costs.

What costs shall these benefits be compared with?

The investment and operating costs with which these surpluses should be compared depends on the perspective chosen. A cost-benefit analysis differs from most other evaluations of the Stockholm Trial in as much as the perspective must be extended into the future for the analysis to be truly meaningful. For that reason, we have chosen to calculate and analyse the effects of the social costs and benefits of the Stockholm Trial using three different timescales, which at the same time represent scenarios for making decisions supported by the CBA.

⁹ Based on a rough estimate: Stockholm Transport’s (SL’s) own figures are not yet available.

¹⁰ The ambition is to increase the number of seats to keep pace with the number of passengers so that there is no relative increase in the number of standing passengers. The calculation is based on the cost of producing extra seat kilometres in accordance with the key ratio for this developed by Banverket, the authority responsible for rail traffic in Sweden.

The Stockholm Trial itself generates a disbenefit in socioeconomic terms

If we consider only the costs and benefits that arise during the trial period (i.e. levying the congestion tax from 3 January to 31 July 2006, and expanding public transport from 22 August 2005 to 31 December 2006), the costs do, of course, exceed the value of the benefits. As the results and conclusion for this timescale are obvious in advance, this analysis may appear relatively uninteresting and superfluous. The motive for the Stockholm Trial has never been to achieve traffic-related benefits of such magnitude that these alone would justify the costs for the trial. From a political point of view, the motive behind the Stockholm Trial lies instead in the value of the lessons learned. The politicians clearly hope that it will subsequently prove possible to translate these experiences into permanent measures. Because it is so difficult to put a price-tag on the value of such experience, considerations like these are not included in traditional CBA models. The degree to which these values justify the costs incurred is therefore a question that the cost-benefit analysis cannot answer.

That the analysis has been included nonetheless, is due to the fact that it represents one distinctly possible outcome of the decision process that lies ahead. This is because the perspective corresponds to what would happen if the Stockholm Trial were terminated and not resumed in any form.

Table 2. Costs and benefits during the Stockholm Trial (in SEK millions during the trial period).¹¹ NB. The duration of the trial periods for the congestion tax and the expansion of bus services differ.

<i>(SEK millions, during trial period)</i>	Congestion tax	Expansion of bus services	Total	Increased rail services/park-and-ride	Information and evaluation
Surplus of social benefits over costs (excl. operating and investment costs – see Table 1)	506	248	754	(not calculated)	(values n.a.)
Costs during trial excl. residual values	-1,821	-582	2,403	-88	-210
Distortion and opportunity costs ¹²	-708	-308	1,017	-47	-111
<i>Net socioeconomic effect of the Stockholm Trial</i>	-2,023	-642	2,666	---	---

The calculations suggest that the congestion-charging system and the expansion of bus services have cost society approximately SEK 3.4 billion¹³ at the same time as the value of the positive effects during the trial period does not exceed around SEK 750 million. The result is a net cost to society of approximately SEK 2.7 billion, most of which is accounted for by the congestion-charging system itself. To this should be added the value of and costs for other expansions of public transport, together with costs for information and evaluation measures, and the admittedly difficult-to-estimate values represented by the experiences gained from the trial and the opportunities to put these into practice if the scheme is continued.

Making the trial a permanent feature of a traffic solution for Stockholm would produce a net social benefit

The most relevant perspective (as far as Stockholm is concerned) is that the trial has actually been carried out and thus indicates the probable socioeconomic effects of making congestion charging a permanent feature of a traffic solution for the capital for an extended period in the future. In view

¹¹ Benefits during the trial period are calculated based on the estimates of annual benefits in Table 1, multiplying the annual benefits of congestion charging by 7/12 and the annual benefits of public transport improvements by 16.5/12.

¹² The distortion cost is the “hidden” cost of a tax, caused by the fact that the so called tax wedge reduces the efficiency of the exchange of goods and services. The opportunity cost corresponds to the benefit that the resources used could have created if they had been used for another purpose.

¹³ Of which SEK 2.3 billion is “visible” public expenditure and a further SEK 1 billion is distortion and opportunity costs.

of the fact that the trial has actually been carried out, no account is taken of the investments that have been made during the trial period and which cannot be recouped if the trial should be terminated. As is the case with the first perspective (i.e. considering only the costs and benefits of the trial itself), this does not present a full picture of the social costs and benefits of the Stockholm Trial; on the other hand, it does represent what in all likelihood will be the result of the impending decision-making process.

Table 3. Costs/benefits if the Stockholm Trial were to be made permanent.

<i>(SEK millions, p.a.)</i>	Congestion tax	Expansion of bus services	Total
Surplus of social benefits over costs (excl. operating and investment costs – see Table 1)	867	181	1,048
Operating costs	-220	-341	-561
Distortion and opportunity costs	118	-181	-62
<i>Net annual benefit to society if the Stockholm Trial is made permanent</i>	765	-341	424

The operating cost of a permanent solution based on the congestion-charging system is estimated by the Swedish Road Administration to be approximately SEK 220 million p.a.¹⁴ As the system generates a financial surplus, a further item on the plus side is included in the form of reduced distortion and opportunity costs.

From a CBA perspective, the congestion-charging system is very profitable, generating a net surplus of approximately SEK 765 million p.a. after deductions for operating costs.

On the other hand, judged by the same criteria, the expansion of bus services is expected to be unprofitable. Operating the buses costs SEK 522 million a year¹⁵, while the value of shorter travel times does not exceed SEK 181 million a year.

¹⁴ This is the Swedish Road Administration's assessment. It is possible that costs could be reduced further if the existing conditions were relaxed by changes in the law and amendments to system requirements. This is, however, only speculation based on comparisons with similar systems in Norway.

¹⁵ Including distortion and opportunity costs: SEK 341 m + SEK 181 m = SEK 522 m.

Benefits exceed costs overall

Another decision perspective includes the cost of writing off investments in the calculation. In a way, this is the most comprehensive analysis as it does not exclude any costs or possible benefits. However, even if this alternative has the indisputable advantage of being comprehensive and complete, it does smack of a theoretical construction: the perspective is not actually relevant to the situation in Stockholm. It is not possible to undo the effects of the trial, or to recoup the cost of the investments made. This perspective is, however, an interesting one, if only to serve as a pointer for other cities. It is the one that most closely resembles the situation that would have existed if the Stockholm Trial had not yet been carried out, and the planners were instead faced with the decision of possibly implementing the various measures.

Table 4. Costs/benefits if the Stockholm Trial were to be made permanent.

<i>(SEK millions, p.a.)</i>	Congestion tax	Expansion of bus services	Total
Surplus of social benefits over costs (excl. operating and investment costs – see Table 1)	867	181	1048
Operating costs	-220	-177	-397
Distortion and opportunity costs	118	-94	25
Depreciation costs for investments	-50	-3	-53
Distortion and opportunity costs	-26	-2	-28
<i>Net annual benefit to society incl. depreciation on investment costs</i>	690	-95	595

In this model, the investment cost for the congestion-charging system is equal to the entire start-up cost: in other words, not only the costs prior to the start of the system, but also the operating costs during the first half of 2006 together with certain other additional minor costs, such as those for traffic signals and the services of the Swedish Enforcement Agency and the Swedish Tax Agency. This start-up cost also includes, in addition to purely technical investments, system development in a wide sense, educating and training staff, testing, information work, etc. Also included are the Swedish Road Administration's close-down costs for decommissioning the system and evaluating the results during the second half of 2006. This entire initial cost for the system is budgeted at approximately SEK 2 billion (of which SEK 1,050 million was incurred prior to the start of operations).

Investments in the congestion-charging system are depreciated over 40 years, as is customary for traffic related investments.¹⁶ “Operating costs” include all maintenance and reinvestment costs required to operate the system in the future, including the necessary updates of technology and hardware, etc.

If the costs for depreciation are included in the calculation, the congestion-charging system yields a surplus of benefits over costs totalling approximately SEK 690 million p.a.

Another way of placing the investment cost in relation to this annual socioeconomic surplus is to calculate how long it takes before the investment cost has been “repaid” in the form of benefits to society: in this instance, four years. This is a very quick repayment period, compared with, for example, investments in road infrastructure and public transport, which even under relatively favourable circumstances have a repayment time of between 15 and 25 years. The conclusion that congestion charging is profitable for society even if the investment cost is taken into account is therefore not dependent on the length of time over which it is decided to depreciate the investment. To generate a surplus, the system needs to be operative for no more than four years.

The investments that are necessary for the expansion in bus services are negligible in the long-term perspective. One of the reasons for this is that the cost of purchasing the buses is included under operating costs.

Conclusions from the trial period

If the Stockholm Trial is considered as a short-term trial that, once terminated, will not subsequently be resumed, it will incur a net social cost of approximately SEK 2.7 billion (not including the expansion of rail traffic and the creation of park-and-ride sites). The greater part of this disbenefit derives from the initial investment in and the subsequent operation of the congestion-charging system. This perspective is, however, of limited

¹⁶ From a socioeconomic cost-benefit perspective the depreciation period is the entire length of time during which the investment may be expected to create benefits for society, given that it is properly maintained and looked after. This should not be confused with the technical lifetime (“service life”) of the investment: the cost for maintenance and reinvestment is included under “Operating costs” in the table. Nor should it be confused with the depreciation period used for accounting purposes, which is usually considerable shorter – typically 1–5 years.

interest. It is not surprising that the investment costs of a congestion-charging system cannot be recouped during the trial period. The value of the experiences gained during the trial and the value of a possible future continuation are not included in this calculation.

It is somewhat more surprising, however, to note that calculations relating to the expansion of bus services during the trial period do not show any net social benefit from the introduction of this measure. The costs are estimated to be in the region of SEK 900 million,¹⁷ while the benefits are not expected to exceed approximately SEK 250 million.

Looking at things from a narrow, Stockholm-based perspective, however, the Stockholm region stands to benefit by SEK 230 million from the trial – provided that the state pays for the costs of the trial with resources that would otherwise not have benefited Stockholm directly. If, on the other hand, the assumption is made that the costs for the trial are financed by an increase in state (direct) taxation, the trial represents a net disbenefit for the Stockholm region. In this scenario, the region pays approximately 45% of the trial costs, which equates to a value considerably greater than that derived from the trial in the form of social benefits.

Conclusions – making congestion tax a permanent feature of a traffic solution for Stockholm

If the congestion tax were to be made a permanent feature, it is estimated that this would generate an annual surplus of social benefits over costs of approximately SEK 765 million after deductions for operating costs. In other words, making the system permanent would generate considerable values in social benefit.

This means that the investment costs to society of the congestion-charging system would be “repaid” in the form of social benefits within four years. This is a very quick repayment period, compared with, for example, investments in road infrastructure and public transport, which even under relatively favourable circumstances have a repayment time of between 15 and 25 years.

¹⁷ SEK 580 million in operating and investment costs and SEK 310 in distortion and opportunity costs.

Another perspective, which does not take social costs and benefits into account, but focuses solely on hard cash, is the purely financial one. In this perspective the investment costs are covered by income from the system in just over 3.5 years. If the system is to operate for 10 years, it will generate a net income of approximately SEK 3.5 billion. If it is operated for 20 years net income will be almost SEK 9 billion.¹⁸

If the focus is narrowed to concentrate solely on the direct effects of congestion charging on road-users, the result is a disbenefit of SEK 175 million p.a., as it is not considered that reductions in travel times alone compensate for the increase in travelling costs for the average road-user. It is only when the income from congestion charging is used to benefit residents/road users directly through investments in traffic infrastructure or in other ways, that any net social benefit is created. This means that the way in which the income is used is extremely important when deciding which groups are “winners” and “losers” respectively.

Conclusions – making the expansion of bus services a permanent feature

The figures do not suggest that the expansion of bus services will be profitable from a socioeconomic perspective. The benefits are calculated at SEK 180 million p.a., compared with operating costs of SEK 522 million p.a. (including distortion and opportunity costs). Some caution should be exercised, however, when interpreting this result. It is not unusual for public transport to be unprofitable, but for various reasons, it is still considered important to provide this service. For this reason, it would be advisable to carry out a more in-depth analysis about possibly making the investment in expanded bus services a permanent feature of a traffic solution for Stockholm.

¹⁸ Neither figure takes into account interest rates or traffic growth.

1 INTRODUCTION

The Stockholm Trial consists of several components; most significantly, the expansion of public transport, the introduction of environmental charging/congestion tax and the creation of a number of park-and-ride sites in the city and the county. The Stockholm Trial also includes comprehensive evaluation and information programmes and certain comparatively minor investments in traffic infrastructure (for example, new traffic signals).

In 2005 Transek AB was given the task of calculating and analysing the costs and benefits to society of the Stockholm Trial and of showing the geographical and demographical impact of these effects. One important aspect of this assignment has been to devise a methodology for these calculations and analyses that is specifically adapted to the unique conditions that prevail in the Stockholm Trial.

What is a cost-benefit analysis?

A cost-benefit analysis (CBA) is a systematic summary of all the effects and costs of an investment (or similar measure). While a private financial analysis, a business economic analysis or a national economic analysis focuses on the effects on the individual's, the company's or the state's finances respectively, a cost-benefit analysis includes in principle the sum total of the effects that an investment has on all the individuals in a society. To do this, all the effects that the investment may be expected to have on factors such as travel times, traffic safety and emissions are translated into monetary values via cost-benefit values based on measurements of people's willingness to pay for shorter travel times, safer traffic, etc. In this way, all the effects – or *benefits* in CBA terminology – can be summarised and compared to the financial outlay, i.e. the cost of the investment. At the same time, various alternative investments can be compared one with the other. In practice, however, not even a cost-benefit analysis takes into account all the effects involved: for certain costs/benefits, no sound methods have (as yet) been developed to calculate their effect, for others the effect is deemed to be negligible, and for others again it is difficult to envisage how these could be quantified at all. When a measure may have effects that for some reason or other cannot be evaluated, the calculation may be complemented with a discussion about the implications of these non-quantifiable effects.

Cost-benefit methodology can in principle be employed as a tool for evaluating and prioritising all manner of public measures and investments, but it is primarily within the transport sector that its use has been long established. The cost-benefit perspective is a well integrated component in Swedish transport policy. Against this background, it is clear therefore that the socioeconomic effects of the congestion-charging trial in Stockholm and the ways in which these impact on different geographical areas and different population groups represent an important aspect of the evaluation of the Stockholm Trial.

The estimated effects are based on actual measured data

In a cost-benefit analysis effects are usually assessed with the aid of predicted effects and what are known as “effect correlations” based on statistical computations of the effects that a specific measure produces. This particular cost-benefit evaluation is somewhat unusual in that it is based primarily on actual *recorded* changes in traffic volumes, travel times and passenger statistics from Stockholm Transport (SL). Certain effects, such as those on traffic safety and health, are calculated using models based on these recorded changes in traffic patterns with the help of the usual effect correlations.

Effects valued in actual prices or willingness to pay

What are known as “*cost-benefit values*” are needed to convert the effects into their financial equivalents. Where available, these are based on market prices. In other instances, other methods are used as a basis for estimating what value Swedes ascribe to the effects of a particular measure: for example, studies of what a representative selection of the population is willing to pay to achieve a certain effect or benefit.

In analyses of the Stockholm Trial we have endeavoured to follow the calculation principles and calculation values that are used in, for example, national infrastructure planning and developed within the framework of what are widely known as ASEK norms.¹⁹ It has been deemed advantageous to

¹⁹ ASEK is a Swedish abbreviation for the Working Group for Cost-Benefit Calculations within the framework of which the Swedish Institute for Transport & Communications Analysis (SIKA) and the national authorities in Sweden responsible for travel by land, sea and air collaborate to issue recommendations concerning calculation values, analytical methods, etc. See SIKA (2003).

adopt ASEK recommendations as far as possible as these represent the result of many years' research and development, have been subjected to rigorous external inspection and are widely accepted in the transport sector.

ASEK recommendations have been developed in the first instance for state infrastructure planning in order to make it easier to determine the merits of various national proposals competing for resources and compare the effects of different types of measure. In consequence, these recommendations are not always ideally suited to the parameters of the Stockholm Trial: not only is the Stockholm region not typical of Sweden with regard to, for example, population density and traffic volumes, but the trial is specifically designed to achieve certain effects, one of them being to reduce congestion. Cost-benefit methodology is also being continuously developed and certain more recent or improved methods which are in the process of becoming integrated into ASEK practice are particularly relevant in the case of Stockholm. There is, after due consideration, good reason to deviate from the general ASEK recommendations in three areas: the evaluation of travel times, the unpredictability of travel times and the calculation of the effects on health.

In these three instances the special conditions that prevail in Stockholm and the specific aims of the Stockholm Trial have been deemed sufficient to motivate a departure from normal practice. At the same time, it should be made clear that adapting to a specific analysis situation in this way is fully compatible with ASEK's general recommendations and that several of the modifications that have been adopted in the analysis of the Stockholm Trial are in line with current development work taking place within ASEK. The details of how travel times, travel time unpredictability and the effects on health have been evaluated and calculated are described in Chapter 4.

The analysis divides the Stockholm Trial into three parts

The Stockholm Trial can be divided into three parts, each of which forms the subject of its own individual cost-benefit analysis. The first element is the congestion-charging system plus a few minor investments in road infrastructure (first and foremost, new or improved traffic signals). The charging system also includes services in the form of customer service, etc. (whose prime purpose is to make it as simple as possible to use the system) and the various functions that are required for collecting the tax. Investments

in road infrastructure relate primarily to traffic signals and equipment to regulate access to the Essingeleden Bypass. These measures have been coupled with the congestion-charging system for the simple reason that it is difficult to ascribe a separate value to the benefit that they represent. The congestion-charging system itself does, however, account for by far the greatest portion of the costs and effects.

The second element comprises the expansion of public transport and more park-and-ride sites. The expansion of public transport, which constitutes the greatest cost and benefit, consists of a number of new bus routes from the suburbs to the inner-city area and more frequent commuter, underground and suburban trains. It is possible to separate these benefits from the benefit of other measures as these improvements in public transport were made prior to the introduction of the congestion-charging system. In this particular study, however, we have only calculated the cost-benefit value of the increase in bus services.²⁰

The third element comprises information about and the evaluation of the trial. The costs incurred for this are reported and discussed separately as the values created are not quantifiable in monetary terms. Their purpose is rather to explain the form the trial itself takes and the motives behind it, and to produce the documentation required to facilitate the democratic decision-making process concerning congestion charging.

Redistribution effects described in a separate report

A traditional cost-benefit analysis does not include socioeconomic redistribution effects in the form of an examination of how costs and benefits are distributed among different elements within society. However, the measurements and other information that are required to calculate profitability (in a cost-benefit context) can also be used to describe how the effects are redistributed.

A separate report published in August 2006 analyses the redistribution effects of the Stockholm Trial by using calculations of how, for example, the tax levy, the costs incurred by households and companies in adapting to the

²⁰ This is due to technical difficulties with regard to the calculation. This issue is discussed in greater detail in section 4.1.

new situation created by congestion charging, changes in travel times and the use of the revenues from the tax generated by the trial are distributed according to gender, income bracket, type of household, employment and geographical region.

2 RESULTS

This chapter reports the results of the cost-benefit analysis of the Stockholm Trial. The method behind the various values is explained in Chapter 4.

The results have been rounded to the nearest full million SEK per year. In the vast majority of instances this produces values with an unrealistically high precision, but if the rounding off is done at too early a stage there is the risk of introducing a rounding-off error (especially as the size of the items recorded varies).

The analysis endeavours consistently to differentiate between costs and benefits that can be attributed to the congestion-charging system (including certain minor investments in road infrastructure), those attributable to the investments in public transport (including the park-and-ride sites) and those arising from the information and evaluation work that also forms part of the trial as a whole. The benefits of investments in public transport are restricted here, however, solely to those arising from the expansion of bus services. This is because it has not been possible to calculate the benefit of park-and-ride sites and the increases in the various forms of rail traffic.

In the following account the term “driver” is used to refer to the drivers of all types of vehicle on the roads, including the drivers of commercial vehicles such as heavy goods vehicles, taxis, etc.

The following effects are included in the cost-benefit analysis:

Effects on road-users:

- Changes in travel times
- Changes in travel
- Changes in travel cost
- Effects on the unpredictability of travel times

Effects on all residents:

- Traffic safety effects
- Effects on health of reduced traffic emissions
- Other environmental effects of reduced traffic emissions

- Changes in traffic emissions of climate gases

Effects on public income and expenditure:

- Revenue from congestion tax
- Changes in revenue from fuel tax
- Changes in revenue from public transport ticket receipts
- Costs for maintaining an unaltered level of comfort in public transport despite increases in passenger numbers
- Changes in infrastructure operating and maintenance costs
- Investment costs and operating costs for the various components of the Stockholm Trial
-

Effects on the collection and use of public funds

- Distortion effects of the tax levy²¹
- The opportunity cost of the resources²²

Certain effects are difficult to measure or evaluate. The most important effects that are not included in the calculation (in most instances because it is not possible to calculate them) are as follows:

- Quicker bus journeys as a result of reduced congestion
- Time taken and administration for paying the congestion charge
- Certain effects on the labour market
- Noise
- Information and evaluation

These effects are discussed briefly at the end of this chapter.

2.1 Travel times and travel costs

The direct effects for road-users of the measures introduced in the trial may be divided into five categories. The first three relate to the congestion-charging system itself; the remaining two to the expansion of bus services.

²¹ In transport planning contexts in Sweden this is usually denoted “tax factor 2”, and in a more general economic context “marginal cost for public funds”.

²² In transport planning contexts in Sweden this is usually denoted “tax factor 1”, and in a more general economic context “shadow price for public funds”.

1. The effect on the cost of travelling by car: the congestion tax makes certain car journeys more expensive.
2. The effect of the congestion tax on travel patterns: certain travellers choose not to travel by car at times during which and places where the congestion charge applies; others take advantage of the improved traffic flow to make more or different journeys by car.
3. The effect on travel times by car: certain car journeys are quicker as a result of reduced congestion; other journeys may take longer than before due to the fact that some traffic has chosen a different route.
4. The effect on travel times using public transport: new bus services and more frequent commuter rail services reduce travel times for certain journeys by public transport. Using public transport may also be more convenient than before, thanks, for example, to a reduction in the number of changes that travellers need to make.
5. The effect on travel patterns: certain travellers choose to make more or other journeys using public transport.

The above effects are described in detail in other reports.²³ In this current context we will content ourselves with reporting the cost-benefit value of the effects (in the table below). For a description of how the effects on travel times and travel are calculated and evaluated in a cost-benefit analysis, you are referred to Chapter 4, section 4.1.

Table 5. Value of effects related to road-users (in SEK millions p.a.).

	Congestion charging	Expansion of bus services	Total
Shorter travel times	523	157	680
More reliable travel times	78	0	78
Changes in travel	-13	24	11
Congestion tax payments	-763	0	-763
<i>Total effects on road- users</i>	-175	181	6

²³ 1-3 in "Evaluation of the effects of the Stockholm Trial on road traffic", City of Stockholm Traffic Office (2006). 4-5 in "SLs insats i Stockholmsförsöket" (= "SL's contribution to the Stockholm Trial"), SL (2006).

Effects of the expansion in bus services worth SEK 180 million p.a.

The new direct bus routes have made journeys by public transport quicker and more convenient for many passengers (fewer changes, etc.). The cost-benefit value of this expansion in bus services is calculated at SEK 180 million. SEK 157 million of this figure is accounted for by the benefits of quicker and more convenient journeys; the remaining SEK 24 million by the increase in the number of travellers who choose this mode of transport. It has not been possible to calculate the value of other aspects of the investment in public transport (i.e. more frequent departures for all types of rail transport) due to the complex pattern in which these are spread over the day and across the county as a whole (see section 4.1).

Shorter and more reliable travel times for road travel worth almost SEK 600 million...

The congestion-charging system has reduced congestion on the roads and, as a result, reduced travel times by road. The cost-benefit value of shorter travel times is calculated at SEK 523 million p.a. Less congestion on the roads also leads to more predictable travel times, a benefit which is calculated to have a value of SEK 78 million p.a.

Congestion charging has meant that certain travellers have changed the pattern of their travel or refrained from making journeys that they made previously. On the other hand, improved traffic flows have enabled certain drivers to choose to travel at better times or along better routes than they were able to do before. To some extent these effects offset one another: the net sacrifice can be evaluated as a disbenefit of SEK 13 million.

Finally, the congestion tax itself leads to an aggregate increase in the cost of travelling by car of SEK 743 million p.a. This same figure appears as an income item for public sector finances elsewhere in the calculation.

... but drivers pay SEK 760 million in congestion tax

If we focus exclusively on the direct effects that the congestion tax has on road-users, we arrive at a cost of SEK 175 million p.a. This is because

calculations show that shorter travel times alone do not fully compensate for the costs that the congestion tax incurs for the average driver.

The net effect, of course, varies from driver to driver. For drivers who value their time highly, the value of shorter travel times may well exceed the cost of the congestion tax they pay: for others, the opposite may be true. However, as the calculation deals only in the most basic terms with the fact that drivers ascribe different values to their travel times (specifically, the only differentiation made in the calculations is that between private and commercial traffic/vehicles used for business trips), it is reasonable to assume that the value of the gains represented by shorter travel times is an underestimate.

There may also be drivers who enjoy the benefits of shorter travel times, without having to pay the congestion tax: in the first instance, these are drivers of vehicles exempted from the congestion tax, but they also include drivers whose journeys take place entirely within the congestion-charge zone. These drivers are the net winners of the congestion-charging trial.

2.2 Environment, health and traffic safety

In addition to effects which have a direct impact on road-users – i.e. changes in travel times and the cost of journeys – the changes in the traffic also have effects on the environment and on traffic safety. The table below summarises the cost-benefit values of these effects. These effects concern all residents, not only road-users directly affected by changes in the traffic system.

Table 6. Value of environmental, health and traffic safety effects
(in SEK millions p.a).

	Congestion charging	Expansion of bus services	Total
Reduced climate gas emissions	64	0	64
Effects on health and the environment	22	0	22
Improved traffic safety	125	0	125
Total traffic safety and environment	211	0	211

As the expansion of public transport has not led to any demonstrable reduction in road traffic, it has been assumed that this measure has not had any effect on the environment, health or traffic safety.

Climate gases

A reduction in traffic as a result of congestion charging leads to reduced traffic emissions. Calculations suggest that climate gas emissions from traffic in the County of Stockholm will fall by 2.7% (43 kilotonnes)²⁴, which represents a cost-benefit value of SEK 64 million p.a.

Health and the environment

Other emissions that are harmful to the environment or human health²⁵, are calculated to fall by between 1.4% and 2.8% in the county and by approximately 14% in the inner city. Evaluating the effects of these reductions on public health, the natural environment and pollution depends on where the emissions are generated. Emissions in the Stockholm inner-city area, for example, affect the health of many more people than those along roads in rural areas. This means that the reductions in emissions that congestion charging leads to are accorded what is, relatively speaking, a high cost-benefit value. The effects on health of these reduced emissions are calculated to equate to approximately 5 life-years saved p.a.²⁶ Together with other environmental effects (pollution and environmental damage), this adds up to a cost-benefit value of SEK 22 million p.a.

Traffic safety

Reductions in traffic volumes lead to fewer traffic accidents. While it must be acknowledged that increased speeds tend to make the consequences of the accidents that do happen more severe, this effect is significantly less than the benefit represented by the reduction in the number of accidents. Calculations

²⁴ City of Stockholm Environment and Health Administration (2006).

²⁵ The health effects are mostly a consequence of airborne particles, but also of sulphur dioxide and hydrocarbons. (It was previously believed that nitric oxides also had an effect on health.) "Other" environmental effects include pollution (caused by particles, nitric oxides and sulphur), effects on the natural environments (caused by nitric oxides, sulphur dioxide and hydrocarbons) and ozone depletion (caused by nitrous oxide, N₂O).

²⁶ Recent research into the impact of traffic emissions on health suggests that the actual effect may be much greater (maybe 50 times as great). Consequently the benefits to society would also be 50 times greater. We have, however, chosen to err on the side of caution by using somewhat older models for calculating the effects on health.

suggest that the total number of traffic accidents in the county will fall by around 170 or 3.6% p.a.²⁷ The number of people killed and severely injured on the roads is calculated to fall by approximately 15 p.a., while the number of people slightly injured is expected to fall by just over 50 p.a. The value of these effects is SEK 125 million p.a. The major factor when evaluating the cost of accidents is the willingness to pay for a reduction in the risk of being injured on the roads; other factors (damage to property, loss of income, loss of production, etc.) are accorded lesser values.

2.3 Investment and operating costs

Investment and operating costs for the Stockholm Trial

The budget for the entire Stockholm Trial is SEK 3.8 billion. Total costs for the trial are estimated (at the time of writing) to be slightly less than this – approximately SEK 3.5 billion. In order to arrive at the actual cost to society for the trial, various residual values must first be deducted from this total, namely the values of certain investments that can continue to be used after completion of the trial. The greatest single residual value is the value of the buses purchased by SL. After deductions for residual values the cost of the Stockholm Trial is approximately SEK 2.7 billion. The three tables below show the cost items, divided up according to congestion charging/road infrastructure investments, public transport/park-and-ride sites and information/evaluation respectively.²⁸ These costs are discussed in greater detail in section 4.4.

²⁷ As is the case with the effects on health and the environment, the effects on traffic safety have been calculated using models based on the actual measured changes in the traffic.

²⁸ As is the case with all the other tables in this report, the figures can give an incorrect impression of precision. The costs are *not* known to the nearest SEK million at the time of writing. Such precision is merely to obviate any problems caused by rounding off in the totals.

Table 7. Costs for the congestion-charging system and investments in road infrastructure during the Stockholm Trial (in SEK millions).

Congestion-charging system (budgeted)	1,880
Traffic investments	94
Swedish Enforcement Agency	15
Swedish Tax Agency	24
Total expenditure for congestion charging and investments in traffic infrastructure	2,013
Residual value, traffic investments	-92
Residual value, congestion-charging system (uncertain)	-100
Total cost for congestion charging and investments in traffic infrastructure during the trial	1,821

Overall expenditure for the congestion-charging system and certain minor investments in road and traffic infrastructure, together with costs incurred by the Swedish Enforcement Agency and the Swedish Tax Agency, has been calculated at SEK 2,013 million. Approximately SEK 1,050 million of this total relates to costs prior to the introduction of the trial at the beginning of 2006. The Swedish Road Administration's costs for implementation and operation for 2006 total slightly more than SEK 800 million. It has proved possible to reduce the purely operational costs for the system, which are now calculated to run at a level of SEK 300 million p.a.²⁹ The Swedish Road Administration's costs also include costs for decommissioning the organisation and technical systems and for evaluating the results during the second half of 2006 (on completion of the congestion-charging trial). After deductions for residual values, the socioeconomic cost of the trial has been calculated at SEK 1,791 million.

²⁹ Birger Höök, personal contact.

Table 8. Costs for public transport and park-and-ride sites during the Stockholm Trial (in SEK millions).

SL's bus depots	124
SL's park-and-ride sites	35
SL's other investments	21
Operating costs, expansion of bus services	458
Operating costs, expansion of underground services	32
Operating costs, expansion of commuter trains	38
Operating costs, expansion of suburban trains	13
SL's purchase of buses	580
City of Stockholm park-and-ride sites/cycle parking facilities	37
Total expenditure for public transport and related costs	1,337
Residual value, buses	-580
Residual value, park-and-ride sites	-88
Residual value, bus depots	0
Total cost for public transport and related expenditure during the trial	669
<i>Of which, the cost for the expansion of bus services during the trial</i>	<i>582</i>

Overall expenditure for public transport and park-and-ride sites totals SEK 1,337 million. This figures does, however, include the expenses incurred by SL for the purchase of new buses, the residual value of which is as great as their purchase cost since the depreciation cost is included under “operating costs” in the table above. The residual value for the bus depots has been estimated at 0, which may be slightly over-pessimistic. The biggest actual cost item is SL’s operating costs for the expansion of public transport during the trial. After deductions for residual values the socioeconomic cost for the expansion of public transport during the trial period is calculated as SEK 669 million. The cost for the expansion of bus services alone (the one and only item for which we can calculate a corresponding benefit) has been calculated to total SEK 582 million (depots + operating costs).

Table 9. Costs for information and evaluation during the Stockholm Trial (in SEK millions).

Congestion Charging Secretariat's personnel	40
Evaluation	72
Information	88
Other	10
Total expenditure for evaluation and information during the trial	210
Residual value, evaluation and information	0
Total cost for evaluation and information during the trial	210

The overall cost for evaluation and information is slightly more than SEK 210 million. Information from the Congestion Charging Secretariat is intended to explain the purpose of the trial, whereas the Swedish Road Administration is responsible for information relating to payment routines, etc. Costs incurred by the Congestion Charging Secretariat will help to build up a body of knowledge that is likely to be of lasting value for, for example, research and public debate, and which can serve as the basis for future decisions. In the language of CBA terminology this clearly represents a substantial “residual value”. However, as it is not possible to translate this value into purely financial terms, the comparison between costs and benefits must be made in some other way.

Operating/investment costs if congestion charging is made a permanent feature of a traffic solution for Stockholm

One highly relevant question is what the cost would be for the various measures that are included in the trial, if congestion charging were to be made a permanent feature of a traffic solution for Stockholm. In this respect, however, there can be no certainty with regard to the details: decision-makers have the choice of making permanent only certain aspects of the trial system and/or redesigning the system to a greater or lesser extent.

According to SL, the annual costs for permanently maintaining the expansion of SL's public transport services at the level seen during the trial would be approximately SEK 400 million. This includes not only the new bus routes, but also more frequent services for commuter trains, underground trains, the Roslagsbanan suburban train, etc. Operating costs for the various types of public transport are shown in the table below. Of course, it is always

possible to make permanent only one or more alternatives within this expansion of public transport, should this be deemed more appropriate.

Table 10. Estimated cost for making the expansion of public transport permanent³⁰

	Seat kilometres (millions p.a.)	Cost for expansion of traffic (SEK millions p.a.)
Bus	315	341
Underground	20	24
Suburban trains	8	10
Commuter trains	24	29
Total	367	403

The Swedish Road Administration estimates that it should be possible to reduce operating costs for the current system to around SEK 220 million p.a.³¹ This would cover the costs of operating and maintaining the current system as it stands today. It is possible that costs could be reduced further if, for example, changes in legislation and system specifications enabled the introduction of a system like those in operation in Norway (see section 4.5 for a discussion of this).

In certain decision-making situations it may be relevant to take into account the depreciation costs for investments made. In the situation in which Stockholm's decision-makers currently find themselves, there is some justification for regarding the investments as "sunk costs" (in other words, monies which cannot be recouped). However, on the other hand, a calculation that includes depreciations on the initial investment can be relevant as pointer for other cities that may be considering introducing similar systems. This question is discussed in greater detail in Chapter 3.

As the investment cost for the congestion-charging system, we have chosen to use the entire "start-up cost": i.e. the cost prior to the introduction of the system and the operational costs during the first year (2006). The budget for this (plus certain other costs for traffic signals, etc. and the termination and

³⁰ Information provided by Nils Hedvall, SL.

³¹ Information provided by Birger Höök, Swedish Road Administration.

evaluation of the trial period in 2006) is approximately SEK 2 billion (see Table 7).

The depreciation period for the investment in the congestion-charging system has been set at 40 years, which is customary for traffic investments. In this sense the “investment” covers the initial cost for planning and commissioning the system – system development, staff training, etc. – plus operating costs during the first year (2006). “Operating costs” also include all subsequent costs for maintenance and reinvestment that are essential to operate the system, including any necessary technology and hardware updates. (For further details, you are referred to the discussion of this in section 4.5.)

Operating costs and depreciation costs in the event that the system is made a permanent feature of a traffic solution for Stockholm are summarised in the table below. As investments costs for the expansion of bus services are restricted solely to the new bus depots, this particular item is negligible in such a long-term perspective as this. Investment costs for the new buses themselves are already included under operating costs.

Table 11. Depreciation and operating costs (in SEK millions p.a.)

	Congestion-charging system	Expansion of bus services
Operating costs	220	341
Depreciation costs	50	3

2.4 Other public sector income and expenses

In addition to the costs for the congestion-charging system and the investment in public transport, public sector income and expenses are affected by several other factors. These are summarised in the table below.

Table 12. Public sector income and expenditure, excluding operating and investment costs (in SEK millions p.a.)

<i>(SEK millions p.a.)</i>	Congestion charging	Expansion of bus services	Total
Congestion tax revenues	763	0	763
Public transport revenues ³²	184	0	184
Fuel tax revenues	-53	0	-53
Wear and tear on infrastructure	1	0	1
Maintaining standard of comfort on public transport ³³	-64	0	-64
<i>Total public sector income and expenditure, excl. operating and investment costs</i>	831	0	831

Income from the congestion tax is estimated to total SEK 763 million p.a. The same item appeared as a loss (cost item) for road-users earlier in the calculation.

While it would appear that the introduction of congestion charging has led to an increase in passengers of around 4% for SL, there is nothing to suggest that the expansion of public transport services as such has increased passenger numbers. Taken all round this means that congestion charging has increased SL's ticket revenues by slightly more than SEK 180 million p.a.

Taxes account for approximately two thirds of vehicle fuel costs. As a result of the introduction of congestion charging, the number of vehicle kilometres travelled in the County of Stockholm has fallen by 2.8%.³⁴ The calculated effect of this on fuel tax revenues means a reduction in public sector income of SEK 53 million p.a., which is entered as a disbenefit under this heading (the reduced costs for road-users are taken into consideration under the heading "Travel times and travel costs above"³⁵). Reduced wear and tear on the roads is estimated to produce a saving of approximately SEK 1 million p.a.

³² The calculation of these revenues assumes that average ticket receipts from each "new" SL passenger are the same as the average ticket receipts from each existing SL passenger.

³³ The cost for maintaining the same average standard of comfort on public transport despite increased passenger numbers. Calculated using the average cost-correlation model developed by Banverket (the authority responsible for rail traffic in Sweden), implemented in the SamKalk computational program.

³⁴ See "Evaluation of the effects of the Stockholm Trial on road traffic", City of Stockholm Traffic Office (2006).

³⁵ Note that while they are "taken into consideration" above, they do not appear explicitly in the calculation as it is assumed that there is no change in the cost of fuel per kilometre.

The costs for maintaining the same overall standard on public transport despite the increased number of passengers as a consequence of congestion charging is estimated to be SEK 64 million p.a. This calculation is an estimate; based on the average cost-correlation model developed by Banverket, the authority responsible for rail traffic in Sweden. The principle is to estimate the cost for increasing the number of seats to keep pace with the increased number of passengers.³⁶

2.5 Distortion effect and opportunity cost

Distortion effects of the tax levy

In virtually every instance, taxation leads to a change of behaviour among those being taxed. Where congestion charging is concerned, this change is desirable: individual road-users are made aware of the costs they create in terms of (first and foremost) congestion and traffic emissions. In the case of most taxes, however, a change is not desirable: so called tax wedges lead to households working less, redistributing their consumption patterns, choosing to produce themselves the goods and services that are taxed despite the fact that someone else can do so more effectively, and so on. Similar adaptations to taxation occur in companies, as well.

The conclusion to be drawn from this is not that taxes should not be levied: the benefit derived from tax revenues can be greater than the cost of levying them. Instead the conclusion should be that one should always bear in mind what are known as the *distortion effects*³⁷ that arise from the imposition of a tax. An increase in public sector expenditure creates increased distortion effects and, as a result, a negative item in the calculation. If public sector expenditure falls, the result is a reduction in distortion effects and consequently a positive item in the calculation. This, in turn, means that other taxes can then be reduced (or that other forms of public sector consumption can be implemented to the corresponding extent).

³⁶ The calculation is based on what it costs to produce extra seat kilometres according to Banverket's key ratios for these costs. The cost-correlation model is implemented in the SamKalk calculation tool.

³⁷ In transport sector economics these distortion effects are denoted as "tax factor 2" and in the economics textbooks as "marginal cost for public funds". The recommended value of "tax factor 2" is 1.3 (i.e. it "costs" SEK 1.30 to collect SEK 1.00). See SIKÅ (2003)

For this reason the net result of public sector income and expenditure is multiplied by a factor of 1.3 in the calculation. This net value represents the amount that the public sector needs to raise in increased taxes (if the net value is a negative one) or the amount by which the public sector can reduce its tax levy (if the net value is a positive one). In this particular calculation the net value is made up of the total of the items for congestion tax revenues, public transport revenues, fuel tax revenues, wear and tear on the road infrastructure, and the costs for maintaining the standard of public transport.

Alternative uses of the resources

When you investigate the benefit of a measure, you must bear in mind that the resources you employ to enjoy this benefit have an alternative use which could also create benefits. This is known as an *opportunity cost*³⁸ and is added to the calculation on all resources that are consumed. In this particular calculation, the resource consumption items are the cost of vehicles excluding tax (the tax portion of the cost of the vehicles is merely a transfer), wear and tear on the infrastructure and operating and investment costs.

2.6 Effects that are difficult to evaluate

Not all effects are included in a cost-benefit calculation. In certain cases this is because no sound methods have (as yet) been developed to calculate these effects; in other instances it is difficult to envisage how these could be quantified at all. The following effects are not included in the calculation for a variety of reasons.

Quicker bus journeys

One natural consequence of reduced congestion on the roads is that buses can move more quickly along their routes. This not only improves punctuality, but in the longer term (in theory, at least) it can also lead to reduced operating costs, as fewer buses may be sufficient to serve the needs of the travelling public. It has not been possible to take full advantage of this benefit during the trial period as most of the buses have been operating to

³⁸ In transport sector economics this opportunity cost is denoted as “tax factor 1” and in the literature of economics as “macroeconomic shadow price”. The recommended value is 1.23 (SIKA, 2003).

timetables that there has been no opportunity to reschedule. However, average speeds for several of the bus services from the suburbs into the city centre have been considerably higher than they were before the trial started. In the longer term, if congestion charging is made a permanent feature, it will probably be possible to reschedule bus timetables to make better use of the improvements in traffic flow. This is a benefit and should, in principle, be recognised in the calculation. However, the data necessary to calculate the value of this benefit are not available.

Time required and administration for paying congestion tax

The time required to pay the congestion tax should be regarded as a cost incurred by both companies and private individuals in the cost-benefit analysis. For companies there are also certain administration costs. This represents an item that should be included on the cost side of the calculation, but the data necessary to calculate the value of this cost are not available

Certain labour market effects excluded from the calculation

As the cost-benefit calculation includes the value that individuals accord to the time they spend travelling, indirectly this also provides information about the benefit to the individual of gaining access to a larger labour market (as a result of the reduction in travel times). However, certain other benefits for society are not ascribed a value in the calculation. These include the effect that arises when an individual is able to use the benefits of improved travel conditions to choose a better paid job in a different location: this also benefits society as a whole in the form of an increase in tax revenues (as a result of the tax “wedge”, the individual does not enjoy the full financial benefit of his or her new and better paid position). In the longer term there will also be dynamic effects: for example, it may be reasonable to expect that people who use improvements in travel times to find employment better suited to their ability and aspirations will increase their productivity more quickly.

It is difficult to determine what effect congestion charging has on the labour market in general terms. On the negative side, access to the labour market as a whole is reduced (otherwise there would be no reduction in traffic). On the positive side, access improves for high-income earners, who are those who

pay the most tax. If the revenues generated were used to reduce income tax it would be possible to show that the effects on the labour market would always be positive.³⁹

Noise

In principle it is possible to evaluate noise in monetary terms. This has not been done in this project, however, as an evaluation of noise needs to be based on very specific calculations and would consequently require considerable resources for projects such as the Stockholm Trial that has an impact on traffic over such a wide area. According to the noise assessment study conducted by the City of Stockholm's Environment and Health Administration, the effects of any reduction in noise are likely to be small.⁴⁰

Information and evaluation

The benefit of information about and the evaluation of the Stockholm Trial is difficult to quantify as it comprises items such as "increased knowledge with regard to congestion charging", "empirical basis for research", etc. Consequently this benefit is not included in the calculation.

2.7 Compilation of results

The table below summarises all the costs and benefits with the exception of operating and investment costs. All figures are in millions of SEK p.a.

³⁹ Parry and Bento (2000).

⁴⁰ City of Stockholm, Environment & Health Administration, 2006b

Table 13. CBA analysis: benefits and costs (in SEK millions p.a.)

<i>(SEK millions p.a.)</i>	Congestion charging	Expansion of bus services	Total
Shorter travel times	523	157	680
More reliable travel times	78	0	78
Changes in mode of transport	-13	24	11
Increased travel costs	-763	0	-763
Total effects on road-users	-175	181	6
Reduced climate gas emissions	64	0	64
Effects on health and environment	22	0	22
Improved traffic safety	125	0	125
Total other effects	211	0	211
Congestion tax revenues	763	0	763
Public transport revenues ⁴¹	184	0	184
Fuel tax revenues	-53	0	-53
Wear and tear on infrastructure	1	0	1
Maintaining comfort on public transport ⁴²	-64	0	-64
Total, public sector income and expenditure excl. operating and investment costs	831	0	831
Total cost-benefit surplus excl. operating and investment costs⁴³	867	181	1,048

Benefits and costs during the trial

The trial period for the congestion-charging system extends over only 7 months, whereas the investment in public transport extends over 16.5 months. This means that the trial period will produce results that equate to approximately 7/12 and 16.5/12 respectively of the annual benefits of these measures. The overall result is shown in the table below. As the calculation of the benefits for public transport is restricted solely to the expansion of bus services, in order to facilitate comparisons we have chosen to show only the cost relating to the expansion of bus services.

⁴¹ The calculation of these revenues assumes that average ticket receipts from each "new" SL passenger are the same as the average ticket receipts from each existing SL passenger.

⁴² The cost for maintaining the same average standard of comfort on public transport despite increased passenger numbers. Calculated using the average cost-correlation model developed by Banverket (the authority responsible for rail traffic in Sweden), implemented in the SamKalk computational program.

⁴³ Not including distortion and opportunity costs (so called tax factors).

Table 14. Benefits and costs during the Stockholm Trial (in SEK millions during the trial period).

NB. The duration of the trial periods for the congestion tax and the expansion of bus services differ.

<i>(SEK millions, during the trial period)</i>	Congestion tax	Expansion of bus services	Total	Increased rail services/park-and-ride.	Information and evaluation
Surplus of social benefits over costs (excl. operating and investment costs – see Table 13)	506	248	754	(not calculated)	(values n.a.)
Costs during trial excl. residual values	-1,821	-582	2,403	-88	-210
Distortion and opportunity costs ⁴⁴	-708	-308	1,017	-47	-111
Net social cost of the Stockholm Trial	-2,023	-642	2,666	---	---

The trial itself represents a disbenefit in cost-benefit terms for society as a whole: large costs are incurred without any opportunity of recouping these during the trial period. Calculations suggest that the Stockholm Trial has cost society approximately SEK 3.4 billion⁴⁵ at the same time as the value of the positive effects during the actual trial period do not amount to more than some SEK 750 million. The result is a disbenefit of approximately SEK 2.7 billion, most of which is attributable to the congestion-charging system. To this must be added the value and costs of the expansion in public transport together with those for information about the system and evaluation of the trial, and the (admittedly, difficult to estimate) value of research and experiences that can be deemed to be of value when producing the data and documentation on which future decisions in this matter may be based.

⁴⁴ The distortion cost is the “hidden” cost of a tax, caused by the fact that the so called tax wedge reduces the efficiency of the exchange of goods and services. The opportunity cost corresponds to the benefit that the resources used could have created if they had been used for another purpose.

⁴⁵ Of which SEK 2 billion is “visible” public expenditure and a further SEK 1.2 billion is distortion and opportunity costs. These figures are exclusive of the costs for information and evaluation.

Benefits and costs in the event that the trial was made permanent

Table 15. Benefits and costs in the event that the Stockholm Trial was made a permanent feature of a traffic solution for Stockholm.

<i>(SEK millions p.a.)</i>	Congestion tax	Expansion of bus services	Total
Cost-benefit surplus (excl. operating and investment costs – see Table 13)	867	181	1,048
Operating costs	-220	-341	-561
Distortion and opportunity cost	118	-181	-62
<i>Cost-benefit surplus p.a. if the system is made permanent</i>	765	-341	424
Depreciation costs on investments	-50	-3	-53
Distortion and opportunity cost	-26	-2	-28
<i>Cost-benefit surplus incl. depreciation costs</i>	690	-346	344

The congestion-charging system would generate a surplus of benefits over costs of approximately SEK 690–765 million p.a., depending on whether or not the calculation took account of the depreciation period. The expansion of bus services would incur a disbenefit in the cost-benefit analysis: costs (including distortion and opportunity costs) amount to around SEK 520 million p.a., while the calculated benefit is no more than SEK 180 million p.a.

3 CONCLUSIONS

3.1 Conclusions from the Stockholm Trial

The trial itself represents a cost-benefit loss

If one considers only the trial period itself, the costs incurred do, of course, exceed the value of the benefits gained. The calculations suggest that the congestion-charging system and the expansion of bus services have cost society approximately SEK 3.4 billion⁴⁶ at the same time as the value of the positive traffic-related effects during the trial period does not exceed around SEK 750 million. The result is a net cost to society of approximately SEK 2.6 billion, most of which is incurred by the congestion-charging system.

As the result and the conclusion are already known, this analysis may seem to be of little interest and superfluous to requirements. That it has been included nonetheless is due to the fact that it represents what may very well be one possible outcome of the forthcoming decision-making process. The fact is that this perspective corresponds to what will happen if the Stockholm Trial is terminated for good and not resumed in any form.

At the same time, the motive for the Stockholm Trial has never been to achieve traffic-related benefits during the trial period of such magnitude that these alone would justify the costs of the trial. From the political perspective the justification has tended to emphasise the value of the experiences to be gained from the Stockholm Trial, and the political aspiration has, of course, been that these experiences might subsequently be implemented in the form of permanent measures. As values like these are difficult to translate into monetary terms, they do not form part of a traditional cost-benefit analysis. The extent to which these values can motivate the costs incurred by the trial is therefore a question which the cost-benefit calculation is unable to answer.

⁴⁶ Of which SEK 2.4 billion is “visible” public expenditure and a further SEK 1 billion is distortion and opportunity costs. Both the benefits and the costs exclude the costs of rail traffic, park-and-ride sites and information and evaluation.

The expansion of bus services is unprofitable from a cost-benefit analysis perspective

It should come as little surprise that the congestion-charging system is not able to generate benefits for society during the course of the trial period that outweigh the costs of investments. More surprising is the observation that the expansion of bus services does not seem to be profitable from a cost-benefit perspective, neither during the trial period nor in the event that congestion charging should be made permanent.

The current cost-benefit analysis takes into account only the expansion of bus services, namely the direct buses and the increased frequency of buses operating on trunk routes in the city. Society's costs for expanding bus services are calculated at SEK 520 million p.a.⁴⁷, whereas the benefit (mostly in the form of shorter travel times for existing passengers) totals SEK 180 million. The expansion of bus services thus seems distinctly unprofitable in the overall cost-benefit perspective. During the actual trial period there is also an additional cost for provisional bus depots of SEK 124 million.

Even so, there is good reason to treat this conclusion with some caution. Firstly, because it is difficult to use models to calculate the benefits of the changes in the frequency of services, etc. that constitute a major part of the buses' benefit in cost-benefit terms. This means that the figure of SEK 180 million is not necessarily an accurate one. Secondly, and more significantly, it should be borne in mind that few public transport measures are profitable in an overall cost-benefit perspective. The reason for this has long been the subject of debate, even among specialists in the area. In brief, suffice it to say that certain experts believe that existing methods of calculation seldom succeed in correctly evaluating public transport measures, while others maintain that many public transport measures are indeed unprofitable in the traditional sense, but that they are nonetheless justified by political desires to achieve a fairer distribution of income among different groups in society. (Political considerations of this nature are not part of a cost-benefit analysis.)

⁴⁷ SL's costs for operating the buses total approximately SEK 340 million, to which must be added just under SEK 180 million in distortion and opportunity costs.

Stockholm is a net beneficiary from the trial – provided that the state stands for the costs

From a narrow, Stockholm-based perspective, the Stockholm Trial produces a net benefit for the region (assuming that the state covers the costs of the trial). Taking into account only the costs and benefits of the effects on road-users, traffic safety, health and the environment,⁴⁸ the trial generates a surplus of benefits over costs of some SEK 230 million that accrues to the residents of the County of Stockholm. To this must be added the value of the buses purchased by SL (SEK 580 million): at the time of writing it is uncertain who will be liable for this cost.

However, even if the state does cover the costs of the trial, a substantial proportion of the state's income – 40–50% of direct tax revenues⁴⁹ – is generated within the Stockholm region. Whether or not the Stockholm Trial represents a benefit in cost-benefit terms for the Stockholm region depends on how you describe who stands for the costs. If it may be assumed that the state would have collected the same amount of money in taxes from the County of Stockholm even without the Stockholm Trial, and that these same funds would otherwise have been divested elsewhere had not the Stockholm Trial taken place, then the conclusion is clear: Stockholm has reaped a socioeconomic benefit of some SEK 230 million from the trial. On the other hand, if one were to assume that the tax revenues used to finance the trial would, under other circumstances, nonetheless have accrued to Stockholm to the same extent as which the county contributes tax (either in the form of reductions in the taxes levied, or in the form of other state measures to benefit the area), then Stockholm has actually stood for more than SEK 1.1 billion of the costs, plus almost SEK 600 million in distortion and opportunity costs.

⁴⁸ Since this perspective is strictly limited to Stockholm, no account is taken of the effects of the reduction in climate gases.

⁴⁹ “With regard to the total of all household and business income from work and capital, 20% of Sweden's taxpayers were resident in [Stockholm] in 2002; they earned 29% of the total of Sweden's income and contributed 44% of the state's direct tax revenues”: Inregia, 2004. Skärpt beskattning av Stockholmsregionen. (= “Increased Taxation of the Stockholm Region”) Report 2004:3 published by the Stockholm Chamber of Commerce.

3.2 Conclusions relating to making the congestion tax a permanent feature

A permanent congestion tax generates a large surplus each year in cost-benefit terms

The value of the socioeconomic effects of the congestion-charging system is estimated to amount to almost SEK 870 million p.a. This can be compared to estimated operating costs of SEK 110 million p.a. (SEK 220 million in pure operating costs and a positive effect of SEK 110 million in the form of reduced distortion and opportunity costs). This means that, if congestion charging were made permanent, it would generate a substantial cost-benefit surplus of some SEK 770 million each year the system was in operation.

Congestion charging is profitable in cost-benefit terms even when investment costs are taken into account

There is also some relevance in considering the depreciation costs for the investments made. In the situation in which Stockholm currently finds itself, it is true that there is some justification for regarding the investments as “sunk costs” (i.e. costs incurred that cannot be reversed). On the other hand, a calculation that takes the investment costs into account may serve as a pointer for other cities that are considering introducing similar systems. To some degree, this also produces the most complete and correct picture of the socioeconomic profitability of the congestion-charging system as a whole.

The investment cost for the congestion-charging system – or more properly, the “start-up” cost, as this figure also includes operating costs for the first year – is calculated to be almost SEK 2,000 million (just under SEK 1,100 million prior to the start of the system and a budget of almost SEK 900 million for 2006). To this are to be added distortion and opportunity costs, which produce a total investment cost to society of just over SEK 3 billion.

If one assumes, as is customary in the transport sector, a calculation period of 40 years⁵⁰, the depreciation cost for the investment is approximately SEK 75 million p.a. (SEK 25 million of which are distortion and opportunity costs). The result is that the congestion-charging system (when charged with

⁵⁰ Note that maintenance and reinvestment costs are included under the heading of Operating costs.

depreciation on the investments) generates a cost-benefit surplus of around SEK 690 million p.a. In other words, the congestion-charging system produces a significant socioeconomic benefit even if the cost of the investment is taken into account.

Benefits of congestion charging cover investment cost in just over four years

Another way of placing the investment cost in relation to this annual surplus is to calculate how long it takes before the investment cost has been “repaid” in the form of benefits to society.

As the cost-benefit surplus (i.e. benefits minus operating costs) amounts to around SEK 765 million p.a., the investment cost will have been paid for (in the cost-benefit perspective) within four years. This is a very quick repayment period, compared with investments in road infrastructure and public transport, which – even under relatively favourable circumstances – have a repayment time of 15–25 years.

A third way of comparing the annual surplus to the investment cost is through what is known as net present-value (NPV)⁵¹, which is always greater than 0 for an investment that is profitable from a cost-benefit perspective. For the congestion-charging system the NPV is 5.3.

In monetary terms the investment pays for itself in 3.5 years

A distinction must be made between the time taken to repay the investment cost in the form of socioeconomic benefits and the time taken to repay the cost of the investment in purely financial terms (i.e. the length of time required for income to cover costs).

With income of slightly more than SEK 760 million p.a. and operating costs of SEK 220 million p.a., it will take just over 3.5 years for net income to cover the investment cost. After that, net income is calculated to be slightly

⁵¹ Net present-value = (present value of benefits – investment cost)/investment cost. The present value of the benefits, assuming 1.3% benefit indexation, 4% discount rate and a 40-year calculation period, is SEK 19.2 billion. The investment cost is SEK 1.98 billion, which is multiplied by 1.53 to represent distortion/opportunity costs. $(19.2 - 1.98 \times 1.53) / (1.98 \times 1.53) = 5.3$.

more than SEK 540 million p.a. (not taking into account any growth in traffic.) This means, for example, that net income for 10 years' operation will total approximately SEK 3.5 billion (not taking into account interest or any growth in traffic): net income over 20 years will be close to SEK 9 billion.⁵²

3.3 Other conclusions

The congestion-charging system has a high level of gearing

Few people would endorse the implementation of a measure that would deliver a very limited but nonetheless positive benefit for society as a whole, if that measure had a very severe impact on a certain, small group of people at the same time as the benefits it generated for the vast majority were virtually negligible. As far as congestion charging is concerned, it seems fair to assume that many people would believe that the benefits it produces must be in reasonable proportion to the redistribution of money that the system involves. For that reason, it may be desirable to compare the benefit to society that congestion charging brings with the total tax revenues generated by the system: this enables us to determine how great the effect achieved by this measure is in terms of each krona (SEK 1.00) of congestion tax paid/received.

The cost-benefit surplus from congestion charging has been calculated as SEK 690 million p.a. after deductions for operating and investment costs. Income is calculated at just over SEK 760 million p.a. This means that the congestion-charging system has a gearing of 0.90. For each krona that is redistributed within the system, the benefits that accrue to society are worth SEK 0.90. This is an extremely high value: model-based studies have often suggested values of around SEK 0.30 in terms of socioeconomic benefit for each krona collected from congestion charging. The reason for this is twofold: not only have these studies seldom taken into account any effects other than those directly related to road-users (thus neglecting the benefits of improved traffic safety and a healthier environment), but model-based

⁵² These figures should be regarded merely as arithmetical results. A true financial analysis would also need to take into account interest costs and/or interest income together with traffic growth.

studies also tend to underestimate the degree to which traffic flow is improved and the size of the area over which this improvement extends.

The calculation does not take all costs and benefits into account

A number of benefits and costs are not taken up in the calculation. We would like to mention two of these omissions in particular: namely the work done by companies and individuals to pay the congestion tax, and the fact that different road-users have different time values.

The calculation does not take into account the time, trouble and administrative expense incurred by drivers in paying the congestion tax. In many instances this is probably negligible (as in the case of drivers of private vehicles using a transponder). However, in other circumstances, it can be a considerable burden (as in the case of a freight forwarder with a large number of vehicles, who wishes to debit each customer individually with the correct amount of congestion tax). Significant as this cost may be, we know of no way of quantifying it.

One benefit not included in the calculation is road-users' different time values. In simple terms, congestion charging "sorts" road-users into two groups: one that is willing to pay in order to get to where it wants to go more quickly, and one which is unwilling to pay and therefore changes its travelling habits. This "sorting mechanism" means that those drivers who remain on the road value their time more highly than those who disappear.⁵³ Not accounting for this in the calculation (which assumes that all drivers of private cars value their time in the same way), results in an underestimation of the socioeconomic benefit.

It is important to bear in mind, however, that most road-users belong to different "groups" at different times. These theoretical road-user groups should not, however, be confused with socioeconomic groups such as high-income and low-income households.

⁵³ Provided that their average second-best alternative is equally good (in other words, no systematic covariance between time values and the quality of the second-best alternative).

The winners are determined by how the revenues are used

If we focus solely on the direct effects of congestion charging on road-users, the result is a disbenefit of SEK 175 million p.a., since for the average road-user savings in travel times alone do not compensate for the increase in travelling costs. It is only when the income from congestion charging is used to benefit residents/road users through investments in traffic infrastructure or in other ways, that any net socioeconomic benefit is created. This means that the way in which the income is used is extremely important when deciding which groups are “winners” and “losers” respectively.

4 METHODS AND MEASUREMENT DATA

This chapter describes the data and the methods of calculation that have been used. The descriptions of the methods of calculation are, in part, rather technical and are therefore intended, in the first instance, for specialists. A non-specialist's introduction to the theory of cost-benefit analysis and methodology may be found in the SIKA report "Den samhällsekonomiska kalkylen - en introduktion för den nyfikne" (= "Cost-benefit analyses – an introduction").⁵⁴ This publication explains the basic ideas and methods behind cost-benefit analysis. A more specialised publication, although this too is, for the most part, suitable also for non-specialists is the ASEK report, "Review of Cost Benefit Calculation – Methods and valuations in the transport sector".⁵⁵ The main focus here is on how the cost-benefit values have been developed. For a more detailed study of the theory of cost-benefit analysis, see Bohm (1996).

4.1 Basis for calculations and data sources

All calculations of effects are based on measurements carried out for the most part in April 2005 and April 2006. The results of traffic flow monitoring and travel time monitoring serve as the most important sources of data,⁵⁶ but passenger statistics from SL have also been used. Certain effects, such as the anticipated effects on traffic safety, have been calculated using models, but are always based on the changes in traffic that have been measured and reported.

The vast majority of effects (with the exception of certain effects on public transport) are based on measurements made on an average weekday in April compared with the corresponding April day in 2006. These effects are then adjusted to annual values using a factor of 240.

An overview of the main effects on road traffic

The two most important sources of data for the effects on road traffic are measurements of traffic and measurements of travel times. The map below

⁵⁴ The report 2005:5 (in Swedish only) may be downloaded from www.sika-institute.se.

⁵⁵ SIKA Report 2002:4; may be downloaded from www.sika-institute.se.

⁵⁶ Measurements of traffic flow and travel times are described in "Evaluation of the effects of the Stockholm Trial on road traffic", City of Stockholm Traffic Office (City of Stockholm Traffic Office, 2006).

shows changes in traffic between April 2005 and April 2006. The thickness of the links indicates the volume of traffic along the link, while the colours indicate the change in percent. On most of the major links (in effect, this means the ones where a colour is visible) the traffic flows have been monitored, although some are calculated using models based on measurements recorded for the adjacent links. For this reason, caution should be observed when interpreting the details on the map. Notwithstanding this, the main picture is clear: there have been substantial reductions in traffic volumes in the inner city and on most approach roads. Traffic on the Essingeleden Bypass is more or less unchanged or slightly higher. Traffic on Södra länken (bypass tunnel) is significantly higher, but it is unlikely that this increase is due solely to the introduction of congestion charging. (The bypass is so new that traffic volumes on this route are still showing an upward trend.)



Figure 1. Change in traffic volumes (weekday 24-hr period), from April 2005 to April 2006.

On the map below we have chosen instead to show the change in travel times in percent (the width of the links still indicates the volumes of traffic). In this instance, too, most of the travel times on the major link roads have been monitored; some have been calculated using models. For this reason, caution should be observed when interpreting the details on the map, particularly as travel times vary much more from day to day than traffic volumes do. The main picture remains the same as that recorded for traffic flows: travel times in the inner city and on most approach roads have

become much shorter. Travel times on the Essingeleden Bypass and Södra länken are longer or more or less the same as before. On the E18 European highway north of the Bergshamraleden link, travel times have increased: however, there is some uncertainty about this measurement as monitoring has taken place on certain days only.

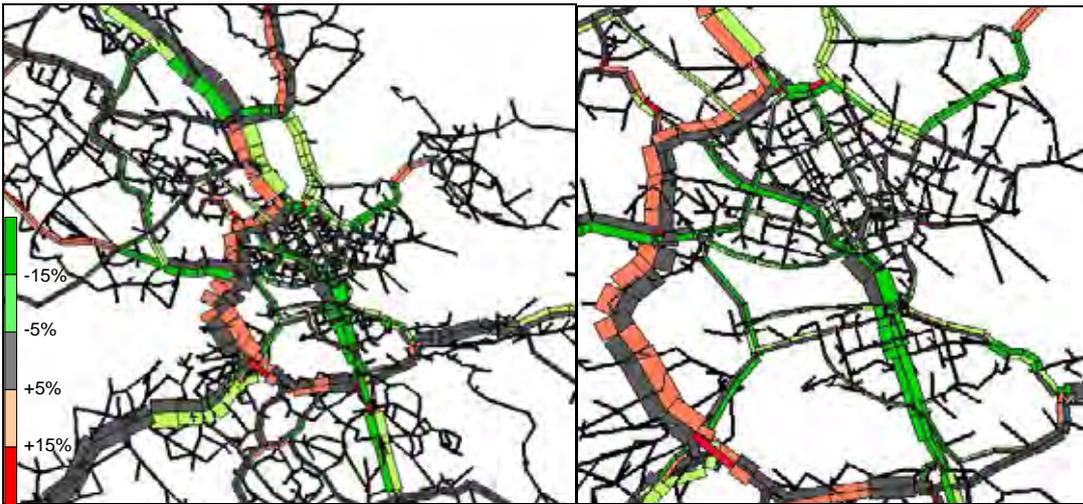


Figure 2. Change in travel times (morning peak period), from April 2005 to April 2006. Inner-city segment enlarged on the right.

How much of the reduction in traffic is due to the introduction of congestion charging?

Travel is also affected by other factors, such as fuel prices and the economic cycle. With the help of time series analyses it is (in principle) possible to calculate how these factors affect travel. A calculation made as part of the present project suggests that traffic volumes in our out of the congestion-charge zone would have fallen by just under 1% from 2005 to 2006 if congestion charging had not been introduced. This reduction is due chiefly to increases in fuel prices between spring 2005 and spring 2006. An increase in the level of employment tends to lead to more traffic on the roads, but as the reduction in traffic caused by increases in fuel price is greater in this instance, a calculation of the net effect shows a reduction.

Table 16. The effect of other factors on traffic passing in or out of the congestion-charge zone, 2005–2006.

Factor	Mean value Feb – April 2005	Mean value Feb – April 2006	Relative change	Elasticity calculated a/c to model	Estimated effect on traffic
Employment in County of Stockholm	940,500	980,000	+4.2%	0.852	3.6%
Fuel price	10.50	11.40	+8.6%	-0.304	-2.6%
Vehicles in County of Stockholm	754,300	759,100	+0.6%	-	-
Vehicles per person in work	0.8020	0.7745	-3.4%	0.508	-1.7%
Total					-0.9%

We have not adjusted the traffic measurements on the basis of this: the effect is so small that it is not recorded in the calculations.

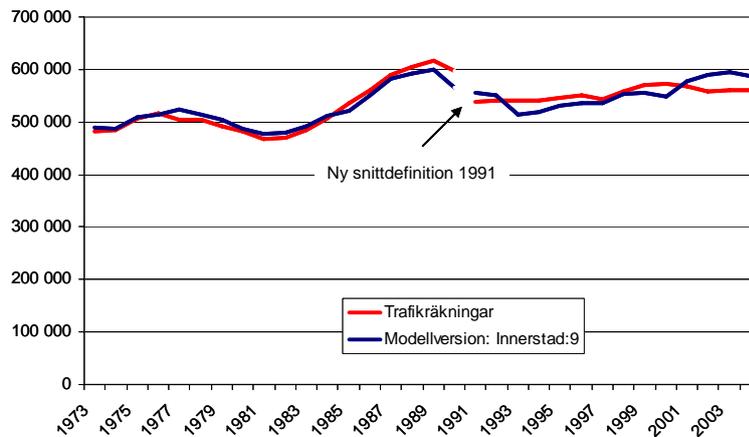


Figure 3. Traffic in or out of the charging zone – Actual (*Trafikräkningar*) and according to model calculations (*Modellversion*) 1976 – 2004 (number of vehicles, average 24-hr weekday period based on information for the respective year).

How much has public transport usage increased as a result of the Stockholm Trial?

Investments in public transport (park-and-ride sites and the expansion of bus and rail services) do not appear to have had a discernable effect on the total number of journeys made by public transport in autumn 2005. This does not mean, however, that they have had no effect at all – merely that any effect is

too small to show up in either the survey of travel habits conducted in autumn 2005 or SL's passenger statistics. While it is highly unlikely that investments in public transport would have *no* effect on the total number of journeys made by public transport, there are not (as yet) sufficiently detailed analyses and statistics to identify any increase. Based on the SL on-board survey conducted on buses in autumn 2005, it is possible to calculate that the number of new public transport journeys on the new direct buses (routes 471 and 474) would total a maximum of around 4,500 embarkations per weekday⁵⁷ – probably considerably fewer. However, SL's statistics are rounded off to the nearest 5,000 embarkations. In consequence, it is not possible from the available statistics to identify any increase as a result of the expansion of bus services. It is correct to say that, overall, the number of journeys made with SL did rise by approximately 2% between autumn 2004 and autumn 2005, but calculations show that this increase may be explained in full by rising fuel prices.

A comparison of the figures for spring 2005 and spring 2006 would indicate that congestion charging has increased travel by public transport by around 4.5%. This assessment is based on the following:

- Travel by public transport was approximately 6.5% higher in spring 2006 than in spring 2005.
- The increase in fuel prices from spring 2005 to spring 2006 has been calculated to have increased travel by public transport by 1.7%.⁵⁸ This means that the rise due to congestion charging was 4.7%.
- Travel by public transport rose sharply immediately after the start of the new year. A comparison between spring 2006 and autumn 2005 shows a rise of approximately 4.3% (average Sept–Dec compared with average Jan–Apr). Fuel prices were more or less the same in spring 2006 as in spring 2005.

⁵⁷ Embarkations per weekday on these buses totalled 29,000. 6% of passengers stated that they previously made the same journey by car; 10% stated that they “did not previously make this journey”. 16% of 29,000 is 4,600. However, as the on-board survey did not capture data with regard to travellers who, for various reasons, stopped using public transport between the two monitoring points, this figure represents the *maximum* net increase.

⁵⁸ The price of petrol rose 11% between spring 2005 and spring 2006 (mean value Jan–Apr). Cross elasticity is assumed to be 0.15 (Transek, 1998).

By how much would congestion charging have reduced road traffic if there had been no investment in public transport?

Throughout the entire report the effects of congestion charging and the expansion of bus services are dealt with separately. It is understandable to ask whether it really is possible to make a distinction between the effects in this way. One way of formulating the question is to ask whether the introduction of congestion charging would really have reduced traffic on the roads by as much if no investments had been made in public transport. While it is true, as shown above, that the expansion of public transport has not (as yet) had any demonstrable result on the number of journeys made by public transport,⁵⁹ it is nonetheless conceivable that it has reinforced the effect of congestion charging by making the shift from private car to public transport less striking than it would otherwise have been. If that is so, a portion of the socioeconomic benefits of congestion charging should instead be recognised as an effect of the investment in public transport.⁶⁰

Nonetheless it remains our assessment that this effect, if it exists at all, must be relatively small. Even back in autumn 2005, 6% of the travellers on the new buses were “converted” motorists (according to SL’s on-board survey). This corresponds to approximately 1,700 embarkations a day. While there was no change in this proportion during spring 2006, there was a rise in the number of bus passengers, so now the converted motorists accounted for approximately 2,300 embarkations. The *maximum* extra effect that the buses can have contributed is, in other words, approximately 600 embarkations a day – assuming, of course, that these converted motorists would otherwise have continued to use their cars and not, for example, chosen another form of public transport. This should be compared with the fact that the number of passages over the congestion zone cordon fell by approximately 100,000 or around 22%. The contribution to this reduction that was made by the expansion of bus services can have been no more than 600 fewer passages, or 0.1 percentage points of the total.

⁵⁹ Note that we are talking here of the effect that is *apparent so far*. It is quite possible that more detailed statistics and analyses will, in the fullness of time, be able to demonstrate an effect.

⁶⁰ Note that the effects of congestion charging already include a cost item for maintaining the same general standard of comfort (i.e. seats per traveller), so it is not this effect that the discussion concerns.

Calculating travel time savings on public transport

Calculations of the value of shorter travel times on public transport have been made (by Christer Svantesson, ÅF) using the VIPS traffic model, which is the tool that SL usually uses for its forecasts and evaluations. Calculations of travel time savings are based on traffic conditions during the morning peak period. In contrast to the calculation of travel times by car (which are based on the actual monitored traffic flows and on travel times per 15-minute segment), the calculations here are based on a model for the “average” morning rush hour during the period 6 a.m. – 9 a.m.

It is true that calculating these figures solely on the basis of the conditions that prevail during the morning peak period is a simplification of the actual situation, but it still probably produces a result of the right magnitude. The fact that public transport operates to schedule, for example, tends to make it more “homogeneous” than other road traffic: travel times and traveller numbers do not vary to anywhere near the same extent as they do for other forms of road traffic. There are, of course, variations, but the model has been constructed so that the “average hour” for which it produces data nevertheless gives a fairly accurate picture of the true situation.

On the other hand, simplifying the facts in this way does render the model unable to reflect the effect of minor details in timetabling changes (for example, one or more extra departures just before or after the absolute peak in the traffic) or changes in the level of comfort (for example, more long trains in order to increase the number of seats available for travellers). This in turn means that the model does not, in fact, recognise the benefit of the very increases in service that SL has implemented in rail traffic as part of the Stockholm Trial. The benefit of the direct buses and the inner-city bus routes is, by contrast, reflected relatively well by the model.

This is the reason why SL’s expansion of rail traffic is not dealt with in this cost-benefit analysis. The same applies also to the park-and-ride sites, as the benefit of the opportunity to park and ride is not included in the model.

4.2 Travel times and travel costs

The direct effects for road-users of the measures introduced in the trial can be divided into five categories. The first three of these categories relate to

the congestion-charging system per se; the remaining two relate to investments in public transport.

1. The effect on the cost of travelling by car: the congestion tax makes certain car journeys more expensive.
2. The effect on car travel times: certain car journeys are quicker as a result of reduced congestion; other journeys may take longer than before, due to the fact that traffic has chosen a different route.
3. The effect on drivers' journeys: certain travellers choose not to travel by car at times during which and places where the congestion charge applies.
4. The effect on travel times using public transport: new buses and more frequent commuter rail services reduce travel times for certain public transport journeys. There may also be an improvement in the convenience of using public transport, thanks, for example, to a reduction in the number of changes that travellers need to make.
5. The effect on travel patterns: certain travellers choose to make more or other journeys using public transport.

Below follows first an account of how the value of these effects is calculated in principle, and then how travel time is evaluated. Finally there is a detailed description of the calculation of the various components. The final description in particular is fairly theoretical and intended primarily for those with a special interest in this field.

Theoretical calculation of the value of the effects

Clarification of the symbols used

- | | |
|----------|--|
| l | link index (where "link" refers to a particular stretch of road for journeys made by car, whereas for public transport it refers to the entire route from start to terminus in a specific OD relation) |
| r | time period (the 24 hours in a day are divided into 15-minute segments) |
| T_{lr} | number of car journeys on link l during time period r (where $T_{lr} = 0$ if l is a public transport route) |
| S_{lr} | number of journeys with public transport on link l during time period r |

t_{lr}	journey by car or public transport depending on link l during time period r
c_{lr}	congestion tax (if any) on link l during time period r
θ_{lr}	average time value for all vehicles on link l during time period r . This depends on the composition of the traffic. In this study the only distinction drawn is that between private vehicles and commercial traffic/business trips.
θ_k	average time value for all public transport road-users. We simplify matters for ourselves by assuming that all public transport passengers share the same time value.

Let index 0 denote the status before the start of the trial (spring 2005) while index 1 denotes the situation when all the measures in the trial have been implemented (spring 2006). The various components are evaluated as follows:⁶¹

1. The increased travel costs for drivers are the same as the revenue raised by the congestion tax. i.e. $\sum_{lr} T_{lr}^1 c_{lr}$.
2. The value of the savings made in terms of travel times by car are the total difference in “before and after” travel time per link, multiplied by the remaining traffic volume and travel time value, i.e. $\sum_{lr} T_{lr}^1 (\theta_{lr}^0 t_{lr}^0 - \theta_{lr}^1 t_{lr}^1)$. Note that the travel time value θ_{lr} differs in principle from link to link and time to time, and is different before and after: we simplify this in our calculations, as we will explain later.
3. The value of public transport travel times is calculated in corresponding fashion as $\sum_{lr} S_{lr}^0 \theta_k (t_{lr}^0 - t_{lr}^1)$. Here we use weighted travel times,⁶² where changeover time for connections and waiting time are weighted more heavily than the time spent riding on board. Instead of travel after the introduction of the measure, for technical reasons with the regard to the calculation, travel time before the introduction of the measure is used in this instance; this makes no difference when adding together item (3) and item (5) below.
4. The value of the change in car travel is calculated as the volume of road traffic that has disappeared (or in some case, the rise in traffic)

⁶¹ The valuation is the standard “rule-of-a-half” divided according to means of conveyance and separated into existing traffic and new traffic. “Rule-of-a-half” is the standard measure of consumer surplus assuming that it is possible to neglect any kink in the demand curve and income effects.

⁶² Known in Swedish as “kresu-tider” these weighted times reflect the fact that, for example, one minute’s waiting time is typically equivalent in “inconvenience” to two minutes of travelling time.

multiplied by half of the change in travel time plus the travel cost.⁶³

The expression then becomes $\sum_{lr}(T_{lr}^0 - T_{lr}^1)(\theta_{lr}^0 t_{lr}^0 - \theta_{lr}^1 t_{lr}^1 - c_{lr})/2$.

5. The value of the amount of new travel on public transport is calculated as the number of “new” (i.e. additional) public transport journeys multiplied by half of the improvement in travel time, i.e. $\sum_{lr}(S_{lr}^1 - S_{lr}^0)\theta_k(t_{lr}^0 - t_{lr}^1)/2$.

In the calculation we separate the effects into ordinary road traffic effects (1, 2, 4) and public transport effects (3, 5). In practice, part of the new increase in public transport travel is attributable to the effect of congestion charging, and part to the reduction in ordinary road travel as a result of the measures implemented for public transport. To simplify matters it is assumed that the increase in public transport journeys is due solely to the improvement in public transport, and that the reduction in other road travel is due solely to the introduction of a congestion tax. This simplification is of no consequence with regard to the sum total of the value of the measures implemented, but affects only the way in which the effects of the various measures are apportioned. The simplification is probably insignificant in this context: the measures implemented with regard to public transport produced no measurable effects on road traffic during autumn 2005, before the introduction of congestion charging.

Valuation of travel time

The concept of what is known as “travel time value”, which appears in several contexts in the formulas above, is of central importance in all transport sector financial analyses. The underlying principle for cost-benefit valuations is that the travel time value shall correspond to what the road-users concerned would be prepared to pay for the equivalent saving in travel time. This willingness to pay depends, of course, on the type of journey, when it is made and whether the saving in time relates to time spent actually travelling, waiting (for public transport) or queuing (in congested traffic). It

⁶³ The derivation that proves that this is a correct approach for calculating the consumer surplus can be found in any economics textbook (for example, Varian, 1992). The intuitive explanation is that certain of the drivers who have “disappeared” have chosen another alternative (other means of transport, other destination, etc.) that is more or less equivalent in value to the one they have forsaken as a result of the congestion tax; other drivers choose an alternative that is more or less equivalent in value to their original choice including the cost of the congestion tax. On average the “vanished” drivers will experience a deterioration equal to half the total increase in price (i.e. congestion tax + change in travel time).

is often the case that the willingness to pay on average usually corresponds more or less to an individual's salary after tax. This accords with both intuition and theoretical deliberations: if an individual's time value is lower than his/her hourly wage, it is "worth" increasing the individual's working hours (and vice-versa) or accepting a longer travel time to a better paid job.⁶⁴ In the long term it may therefore be said (in somewhat simplified terms) that there is a "trade-off" between shorter travel times and higher wages – partly in the form of longer working hours, and partly as a result of having access to a greater number of potential jobs within a given travel time. The value of shorter travel times is therefore a good indicator of how economic growth is affected by a specific measure or investment.

Recommendations about what time values to use are produced by the national Working Group for Cost Benefit Calculations in Sweden (known by the abbreviation for its Swedish name, ASEK). These so called ASEK values are used for, among other things, drawing up priorities between different alternatives in national investment planning work. The time values that ASEK recommends are simplified averages of the actual time values, where – for reasons of simplicity and impartiality – no distinction is made between, for example, the different reasons for the journeys made or geographical variations across the country. This is essential to be able to compare and equate calculations for a variety of possible investment projects. In the case of the Stockholm Trial, however, it is the actual time values of the road-users concerned that are relevant. If this were not so, the value of travel time savings would cease to be a good indicator of (potential) economic growth, as it must be possible to "trade off" shorter travel times against more hours worked, lower unemployment and a better "pairing" between workers and jobs on the labour market. For this reason it is essential that time values accurately reflect conditions (such as average salary levels) on the relevant regional labour market.

According to ASEK's most recent recommendations, travel time should be accorded a value of SEK 42/hour for all private journeys (within a region).

⁶⁴ In reality, of course, it is not always easy for individuals to "choose" their working hours and the length of travel time to work they will accept for the salary they are paid (at least in the short term). In the long term, however, and against the background of the national economy as a whole, there tends to be an adjustment between the choice of travel times, working hours and the "matching" of employees to their place of work so that the value of travel time corresponds roughly to an individual's hourly wage after tax.

This contrasts with the time values usually recorded for Stockholm drivers of around SEK 60–70/hr.⁶⁵ The following factors are among those that may be cited to explain the difference between the time values of the road-users themselves and the ASEK recommendations: business trips have a higher time value than other journeys; there are more people with high salaries in Stockholm than in the rest of the country; and the effect of what is usually described as “self selection”, namely that those travellers who value their time highly tend to use quicker, more expensive modes of transport, which in this particular case, usually means cars. (The same person can, of course, also value his/her time differently in different situations: there is a considerable difference between the value of leisure time spent walking and time spent travelling to work on an ordinary weekday morning.)

ASEK’s recommendations for business trips is that time savings for these are valued at SEK 190/hour. This, too, is a low value – for the country as a whole and for Stockholm in particular. Business travel time value should actually correspond to the employer’s hourly wage cost for an employee: i.e. hourly salary plus social security costs and other overheads. There is hardly anyone who would deny that today’s evaluation of business travel time is too low, at least when it comes to short trips within a region (which, in principle, are made entirely during normal working hours). Pending more research about how these issues should be resolved, ASEK has, however, chosen not to amend its recommendation, which unfortunately leaves us with no statistical basis on which to propose any other evaluation. The same time value is used for commercial traffic. Goods time (in other words, the value of time savings for transporting freight over and above the cost of the driver and the vehicle in which the freight is conveyed) is valued at SEK 10/hour in accordance with ASEK’s recommendation.

In principle a distinction should be made between the average time values on different links. In the calculations presented in this study, however, we have used just one single average time value for all vehicles on the roads. This is because the data required to carry out a more detailed calculation was not available. The result is that the value of the time savings is somewhat underestimated as the calculations do not reflect the phenomenon that traffic with high time values chooses quick/expensive routes while traffic with low

⁶⁵ See, for example, Transek (2003).

time values chooses slow/cheap routes. The following time values have been used, with the source for the value indicated in the right-hand column:

Table 17. Time values for road traffic.

Time value, private journeys	SEK 65/h	Bilisters värdering av förseningar och trängsel (= "Drivers' evaluations of delays and congestion") Transek (2003)
Occupancy rate: private cars, private journeys	1.26 people	Fördelning av olika fordonsslag (= "Distribution of different types of vehicle") Transek (2006)
Time value, business trips	SEK 190/h	ASEK 3
Time value, lorries	SEK 190/h	ASEK 3
Goods time value (added to value for lorries)	SEK 10	ASEK 3
Proportion of business trips	20%	Based on calculations in RES, the Swedish national travel habits survey (1994-2001), according to which business trips represent 15% of the total number of car journeys in the county
Proportion of lorries	16%	Fördelning av olika fordonsslag (= "Distribution of different types of vehicle") Transek (2006)
Average time value per vehicle	SEK 122/h	

Calculating the benefits to road-users of congestion charging

To calculate the benefits to road-users of congestion tax, the following values must be obtained for each traffic link (l):

- Traffic flow (journeys made by car) per link, measured in 15-minute time segments "before" and "after" (T_{lr}^0 , T_{lr}^1)

- Travel time per link, measured in 15-minute time segments “before” and “after” (t_{lr}^0, t_{lr}^1)
- Congestion tax per link, measured in 15-minute segments (c_{lr})

Given this, the benefit to road-users travelling by car can then be calculated, split into items (1), (2) and (3) with the assistance of the following formulas.

Travel costs

With regard to the item $\sum_{lr} T_{lr}^1 c_{lr}$ (“total congestion tax paid”) it is simplest to take this information directly from the Swedish Road Administration’s revenue recognition rather than using model calculations. Revenue from congestion taxes on an average day in April was SEK 3.18 million. Adjusted to produce an annual value, this gives a figure of SEK 763 million p.a. The item $-\sum_{lr} (T_{lr}^0 - T_{lr}^1) c_{lr} / 2$ (which forms part of the item “value of the change in car travel”) is calculated directly from information about traffic volumes passing in and out of the charging zone in April 2005 and April 2006 respectively, multiplied by the average congestion tax actually paid per vehicle.

Traffic flows

Traffic flows per link measured in 15-minute time segments (T_{lr}) are monitored along a large number of roads within the framework for the road traffic evaluation programme. The traffic flow for other roads must be calculated using the models. This is done using what is known as “matrix calibration”, a method employed for calculating unmonitored traffic flows given a number of monitored traffic flows plus a start approximation for the OD matrix (taken from a traffic-forecasting model).⁶⁶ From this traffic flow input data, it is possible to calculate the traffic volume over a 24-hour period. The next step is to calculate the traffic flow for each link measured in 15-minute time segments with the aid of 12 different “day profiles”. These day profiles, indicating how large a proportion of the total daily (24-hour) flow that passes each quarter of an hour, are calculated for 12 categories of link, where the categories are based on the relation between morning and afternoon traffic volumes, geographical area (inner city, inner suburbs, outer suburbs) and the daily (24-hour) total for the road in question. Two separate

⁶⁶ The algorithm used is described in Spiess (1990)

“before” and “after” profiles are then calculated for each of these 12 categories.

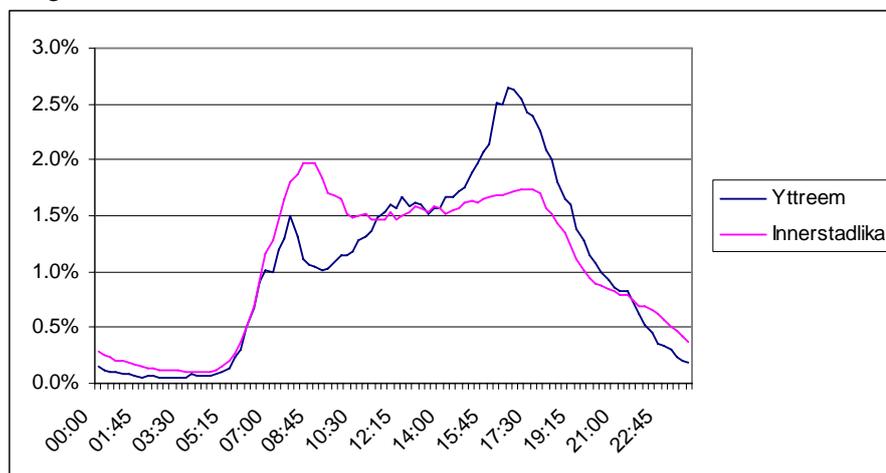


Figure 4. Day profiles for traffic flows (2 of a total of 24).

In the figure the blue line (*Yttreem*) shows “Outer suburbs / Maximum afternoon/evening traffic density / No fees” and the red line (*Innerstadlika*) shows “Inner city / Similar traffic density / No fees”. The percentages indicate how great a proportion of the daily traffic flow that passes for each of the 15-minute time segments shown.

Travel times

For travel times there is unfortunately no parallel to the idea of matrix calibration. Instead we use the actual travel times in the 15-minute time segments monitored by the Traffic Office’s travel time cameras, floating car surveys and the MCS detectors on the E4/Södra länken bypass.⁶⁷ For links where details of travel time measurements are lacking, model calculations are used to calculate travel times for the morning and afternoon/evening peak periods; these then serve as a basis, and a travel time day profile (the relationship between morning and afternoon/evening travel and congestion-free travel time) is created based on measured travel times using the same logic as for the traffic flows.

⁶⁷ The evaluation of travel times is available in the Traffic Office report (2006).

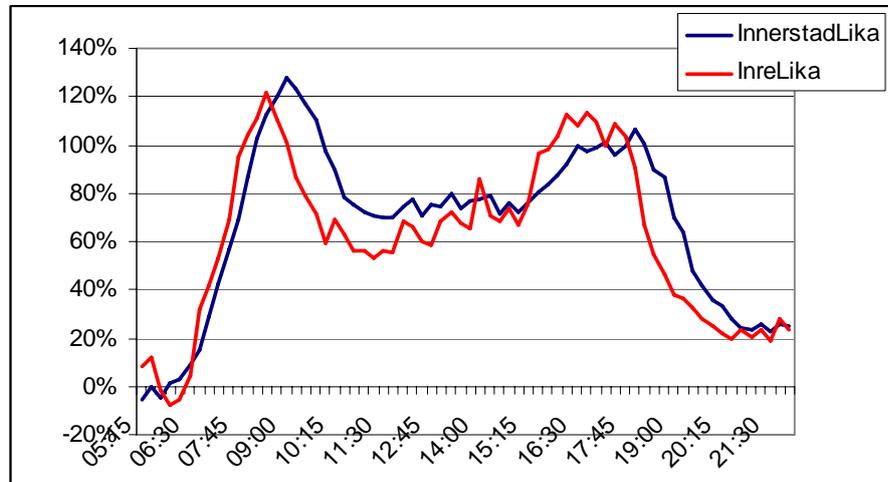


Figure 5. Day profiles for travel times (2 of a total of 24).

In the figure the red line shows “Inner suburbs / Similar traffic density / No fees” and the blue line shows “Inner city / Similar traffic density / No fees”. 100% signifies average peak period (morning and afternoon/evening respectively); 0% signifies congestion-free travel time.

Calculating the benefits to road-users of the investments in public transport

The calculation of item (3) – the value of shorter travel times by public transport = $\sum_{ir} S_{ir}^0 \theta_k (t_{ir}^0 - t_{ir}^1)$ – has been carried out (by Christer Svantesson, ÅF) using the VIPS traffic model. This is the modelling tool that SL itself usually uses for its forecasts and evaluations. The calculation of travel time savings is based on the prevailing conditions during the morning peak period. In contrast to the calculation of travel times for other road traffic, which are based on traffic flows and travel times measured in 15-minute time segments, for this application an “average” morning peak period is modelled. The model calculates that travel time savings in morning peak-period traffic (6 a.m. – 9 a.m.) total approximately 3,700 hours (calculated in weighted travel time, i.e with higher weightings for time spent changing within or between modes of transport and for time spent waiting). The measures included in the model are the new direct bus routes (which give a travel time saving of 2,850 hours), more frequent departures on inner-city bus trunk routes (travel time saving: 500 hours) and more frequent departures for the Tvärbanan express tramway service (travel time saving:

350 hours). The saving in travel time is then adjusted for the day as a whole (24-hour period) by a factor of 3⁶⁸ and for the year by a factor of 240.

The calculation of item (5) – the value of the amount of new travel on public transport = $\sum_{lr}(S_{lr}^1 - S_{lr}^0)\theta_k(t_{lr}^0 - t_{lr}^1)/2$ – is based on the fact that travel on the new direct buses increased by 30% from the beginning of autumn 2005 to the middle of spring 2006 (from 10,000 passengers to 13,000).⁶⁹ If it may be assumed that the greatest portion of this increase consists of “new” journeys, this makes it possible to calculate the value of the newly generated travel.

4.3 Environment, health, traffic safety

Emissions of climate gases

The City of Stockholm’s Environment and Health Administration has calculated (and also monitored) the reduction in various types of airborne emissions.⁷⁰ It has been calculated that the introduction of congestion charging will reduce emissions of carbon dioxide from city traffic by 43 kilotonnes p.a. As carbon dioxide emissions are estimated to cost SEK 1.50/kg, this equates to a total saving of SEK 64 million p.a.

Health effects

The City of Stockholm’s Environment and Health Administration has also calculated the reduction in emissions harmful to human health and the effect that this change has on mortality rates. Lena Nerhagen of the Swedish National Road and Transport Research Institute (VTI) has subsequently calculated the socioeconomic cost for various types of emissions, based on the Swedish variant of the European ExternE model.

⁶⁸ Taken from SL’s embarkation counts for the direct bus services, Between 6 a.m. and 9 a.m. just under 10,000 embarkations are made on these buses, compared to a total of approximately 28,000 for the 24-hour period as a whole.

⁶⁹ SL (2006)

⁷⁰ City of Stockholm’s Environment and Health Administration (2006).

Table 18. Reductions in and socioeconomic valuations of various types of emission. (Effects on health only.)

	Reduction (%)	Reduction (tonnes)	Valuation kr/kg	Social value (in SEK millions p.a.)
Particles from erosion of road surface	1.4%	27.7	218	6.0
Exhaust particles	2.5%	2.3	1646	3.7
VOC's	2.8%	127.0	11	1.4
Benzene	2.8%	1.0	3.37	0.0

The effects on health total SEK 11 million p.a.

Other emissions

The value of the reduction of other harmful emissions (including their effects on nature) has been calculated with the aid of the Swedish Road Administrations' effect correlations which are implemented in the calculation tool SamKalk. For input data SamKalk uses the slope-adjusted traffic flows: i.e. traffic flows that, as far as possible, correspond to the monitored flows and for the remaining (unmonitored) links are calculated according to the model to correspond to the monitored flows. According to SamKalk these "other" environmental effects have a cost-benefit value of SEK 11 million p.a.

Traffic safety

The traffic safety effects have been calculated with the help of SamKalk, based on slope-adjusted traffic flows.

4.4 Investment and operating costs

This section describes the costs of the various components of the Stockholm trial: first, the costs for the trial itself and then estimates of what the costs would be if the various components were to become a permanent feature. A distinction is made between the costs for the congestion-charging system (which includes certain minor investments in road infrastructure, as it is not possible to differentiate the effects of these two components), the cost of the

expansion of bus services and commuter rail traffic, and the cost for information and evaluation. It is important to distinguish between the expenditure for the trial, which also includes the expenditure for certain investments, and the (socioeconomic) cost of the Stockholm Trial, which takes account of the fact that certain components of the trial have a residual value that extends beyond the trial period. This item includes the buses that have been purchased and investments made in the road infrastructure.

Costs for the Stockholm Trial

There is as yet no official summary of the costs for the Stockholm Trial. The budget for the entire trial is SEK 3.8 billion. The total costs for the trial are estimated (at the time of writing) to be slightly less than this figure – approximately SEK 3.5 billion. In order to arrive at the actual cost to society for the trial, various residual values must first be deducted from this total, namely the values for certain investments that can continue to be used after the conclusion of the trial. The greatest single residual value is the value of the buses purchased by SL. After making deductions for the residual values, the cost for the Stockholm Trial amounts to approximately SEK 2.7 billion. The various items that make up this total are described below.

In the first instance this compilation uses information provided by the various organisations and bodies responsible for the trial: in some instances, information from the media is used. Some details are uncertain due to the fact that they are based in part on forecasts. (At the time this report was written, the Stockholm Trial was still taking place.) Other sources of uncertainty arise from the fact that it is not always easy to draw a dividing line between measures introduced as a consequence of the decision to implement the Stockholm Trial and measures which would have been implemented nonetheless.

The congestion-charging system and measures to improve the roads

As the Stockholm Trial is (at the time of writing) still taking place, no final accounts for the costs incurred have yet been drawn up. The Swedish Road Administration has forecast the total costs for its own involvement with the trial for the period with effect from June 2004 up to and including December 2006 at around SEK 1,930 million. SEK 50 million of this figure relates to investments in the national road network. Up until December 2005 (when

the system was put into operation) costs totalled approximately SEK 1,050 million. In addition to costs for hardware and technical development, this figure also included information and substantial investments in training and education, for example for the large customer service department. The total budget of the Swedish Road Administration includes a further SEK 800 million or so up until the end of 2006. The Road Administration's costs also include costs for dismantling the organisation and the technical system and for evaluating the trial during the second half of 2006 (after the completion of the congestion-charging trial). It has been possible to rationalise actual operating costs during the course of time, so the Swedish Road Administration estimates that, based on measures implemented during the trial period, it would be possible to reduce operating costs to around SEK 300 million p.a. In the calculation we have assumed a total cost for investments, initialisation and commissioning of SEK 1,880 million (plus the Swedish Road Administration's own investment of SEK 50 million in roads).

If a decision were made to terminate the congestion-charging system for good, the system would probably have a residual value in the form of hardware and computer systems, together with a fund of "know how" that is more difficult to evaluate in monetary terms. This makes the total residual value extremely uncertain: Transek has estimated it at a figure of SEK 100 million. This value affects only the cost-benefit calculation for the Stockholm Trial itself, which is, in any case, of comparatively little interest.

Approximately SEK 50 million of the Swedish Road Administration's budget has been used for investments in certain roads, in particular access control measures for the Essingeleden Bypass. These measures do, of course, possess an enduring value that extends beyond the Stockholm Trial. As it is customary to depreciate traffic investments over a period of 40 years, we have recognised a residual value of SEK 49 million for these investments.

The budget for the cost of appeals, reviews, etc. during the trial period is SEK 39 million, of which SEK 15 million goes to the Enforcement Service and SEK 24 million to the Swedish Tax Agency.⁷¹

⁷¹ This information derives from an article in the business daily, *Dagens Industri*.

The City of Stockholm has invested SEK 44 million to carry out a number of measures to improve traffic flow on roads and streets in the city. These measures do, of course, have an enduring value that extends beyond the Stockholm Trial. As was the case with the Swedish Road Administration, we have assumed a 40-year depreciation period, which leaves a residual value of SEK 43 million.

Expansion of public transport and park-and-ride sites

During the Stockholm Trial public transport has been expanded with increases in both buses and rail traffic. “Rail traffic has been reinforced with a limited number of new departures during the morning and afternoon/evening peak periods and the introduction of longer trains for off-peak services. As far as buses are concerned, 14 new direct bus routes offering high levels of comfort operated between the city centre and the outlying municipalities, two new trunk routes to the city centre were introduced and the frequency of services for existing direct buses to and from the city and existing trunk routes within the city was improved. This expansion of bus services necessitated the purchase of 197 new buses and 15 new or extended depots. A number of measures to improve the flow for buses in traffic to and from the inner city have also been implemented.”⁷²

SL estimates that it has incurred expenses of SEK 720 million in connection with the trial: SEK 180 million of this figure relates to investments and SEK 540 million to operating costs. The greatest investments have been in new bus depots (SEK 124 million) and park-and-ride sites (SEK 35 million). The major additional expense as far as operating costs are concerned is the expansion of bus services (SEK 518 million).⁷³ Transek estimates that the residual value of SL’s investments is SEK 50 million (the majority of SL’s investments were intended solely and specifically for the trial).⁷⁴ The socioeconomic cost of the various measures implemented by SL during the Stockholm Trial is therefore SEK 670 million.

⁷² From SL’s own report on the Stockholm Trial. (SL, 2006)

⁷³ This information is based on SL’s official budget forecast.

⁷⁴ Personal contact with Eric Tedesjö, SL.

Table 19. Calculated cost of expansion in public transport, by mode of transport.⁷⁵

	Expansion of traffic in seat/km (annual basis) in millions of km	Cost of expansion of traffic (annual basis) in millions of SEK
Bus	315	341
Underground	20	24
Local trains	8	10
Commuter trains	24	29

As the calculations of benefits to road-users relate solely to the expansion of bus services, this is the cost that is relevant for comparisons.

Sweden's Ministry of Finance reports that it has paid out SEK 1,400 million to SL for the Stockholm Trial.⁷⁶ As the details of the agreement between SL and the state have not been made public, it is not possible for us to check this amount using the usual formal channels. According to the Ministry of Finance, the difference between the SEK 720 million that SL recognises in its accounts and the SEK 1,400 million that the ministry has paid out is explained by the fact that SL does not include VAT of around SEK 100 million or the cost of purchasing the buses. This would suggest that the cost of the buses is SEK 580 million. As a rough estimate, this would seem to be a reasonable figure. Neither the VAT nor the SEK 580 million for the purchase of the buses is included in the socioeconomic cost for the Stockholm Trial. VAT is not included because this is simply a transfer; the purchase of the buses is not included because this has already been included in SL's operating costs. (The buses have a residual value on completion of the trial that corresponds to their purchase price less one year's operating costs: to include the SEK 580 million would be to include the figure twice in the accounts.)

The City of Stockholm has invested SEK 37 million in park-and-ride sites and cycle parks. These, too, possess a residual value beyond the end of the Stockholm Trial. We have estimated this value at SEK 36 million. It is quite

⁷⁵ Information provided by Nils Hedvall, SL.

⁷⁶ Personal contact with Erik Bromander, Ministry of Finance.

probable that this is an underestimate of their true cost as the value of the land used for these parking sites is not included in the cost: although the land used was already owned by the City of Stockholm, it has an opportunity cost which has not been included. The same applies to SL's park-and-ride sites.

Information and evaluation

The budgeted costs for the City of Stockholm's Congestion Charging Secretariat comprise the costs, first and foremost, for the administration's personnel and offices (SEK 37 million), evaluations (SEK 72 million) and information (SEK 88 million).⁷⁷ To this can be added costs of approximately SEK 3 million which arose prior to the formation of the Congestion Charging Secretariat and other budgeted costs of SEK 10 million. This means that the total cost for evaluation and information is SEK 210 million. Information from the Congestion Charging Secretariat aims to explain the purpose of the trial, whereas the Swedish Road Administration is responsible for providing information to explain actual payment routines etc. (cost: approximately SEK 50 million, included in the Road Administration's expenditure for the congestion-charging system above). The Congestion Charging Secretariat's costs are an investment in building up knowledge which will probably be of lasting value for future research and the public debate and can also serve as a basis on which to make future decisions. In cost-benefit terminology this represents a clear residual value. However, as it is not possible to calculate this value in monetary terms, the comparison between cost and benefit must be made in some other way.

Costs if the measures are made permanent

One relevant question is what the cost would be for the various measures that are included in the trial, if congestion charging were to be made a permanent feature of a traffic solution for Stockholm. In this respect, however, there can be no certainty with regard to the details: the permutations are simply too great with regard to which components of the system should be made permanent and exactly how this would be done.

Costs for a permanent congestion-charging system

It is difficult to predict how high the operating costs for the congestion-charging system may be in the longer term. The prime reason for this is that

⁷⁷ This information is taken from the agreement between the state and the City of Stockholm.

this depends on changes that may be imposed by legislation and/or system requirements.

The Swedish Road Administration estimates that operating costs for the current system could be reduced from the present figure of around SEK 300 million to around SEK 220 million p.a. This reduction could be achieved by, for example, more efficient payment routines and reduced customer service facilities as a result of better and more efficient payment routines. Despite this substantial reduction in operating costs, the current system remains relatively expensive to operate in comparison with those in Norway that, with regard to technology, design and function, share certain similarities with the Stockholm system. By way of comparison, the system in Oslo, which is the same size as Stockholm's (approximately 90 million passages p.a. compared to Stockholm's approximately 80 million passages p.a.) costs around SEK 145 million in operating costs and administrative expenses.

The main reasons for the higher operating cost of the Stockholm system are as follows:

1. The requirement to treat each day's congestion tax transactions separately instead of, for example, accumulating each vehicle's payments in the form of one single transaction per month.
2. The requirement to deal with each day's congestion tax transactions on the same day (which is connected to the payment conditions and forms of payment, etc.)
3. The requirement for operational reliability and the high proportion of vehicles that must be identified.
4. Relatively high costs per transaction. Payments made via Pressbyrån kiosks and 7-eleven convenience stores are considerably more expensive to administer than those made using other forms of payment.
5. The exception for vehicles travelling to and from Lidingö ("The Lidingö Exemption") means, in principle, that all vehicles must be identified in order to avoid missing a "Lidingö Exemption" vehicle. This is one of the main reasons for the very high criteria with regard to operational reliability and vehicle recognition. This also leads to major problems if it is necessary to close a control point temporarily, for service, etc. Also the fact that the system is governed by taxation

legislation disallows any counter-performance requirements in order to benefit from the rule for exemptions (for example, that vehicles wishing to make use of their right to invoke the “Lidingö Exemption” must be fitted with a transponder).

The costs involved if the system were to be made permanent are governed to a great degree by whether or not a decision is made to change one or more of these current system requirements. The figure for operating costs quoted by the Swedish Road Administration, which is the one we use in our calculations, relates to the present system with the current payment routines, the Lidingö Exemption, etc.

However, the Stockholm system also has certain features that reduce costs compared with similar Norwegian systems. The costs for administering and operating the system depend to a great extent on how payment is collected (many of the Norwegian control points are manually operated and therefore more expensive to run) and the amount of traffic (many of the Norwegian control points process relatively low volumes of traffic which makes it difficult to reduce the price per passage). The cost for the Oslo system is SEK 1.60 per passage. The Swedish Road Administration’s estimate for future operating costs for the Stockholm system suggests a cost of SEK 2.80 per passage.⁷⁸ Other Norwegian systems with a similar design incur more or less the same operating costs. Even if there are several aspects to the Stockholm system that inflate the costs in comparison with the system in operation in Oslo, other aspects of the Stockholm system reduce the costs. It is not unreasonable to envisage that operating costs in the long term will fall compared with the Swedish Road Administration’s current estimate – at least if certain details are amended with regard to the conditions that apply in the form of legislation and system requirements.

Depreciation period for investments

From a cost-benefit perspective, the depreciation period for an investment depends on the investment’s functional lifetime, in other words how long the investment will continue to provide benefits for users. This is not the same as the investment’s technical lifetime: in the case of the congestion-charging system, the technical lifetime is significantly shorter than the functional

⁷⁸ These details are taken from a summary of costs, income and the number of passages for Norwegian operators (Norwegian Directorate of Public Roads).

lifetime, as it may be assumed that the system's hardware (computers, cameras, etc.) will need to be replaced or updated at regular intervals. Maintenance and reinvestment costs like these are covered by the estimates for operating costs given above. The value of the investment itself does not reside primarily in the physical equipment, but in the fact that a technical system has been designed, established and installed, complete with payment routines, database management systems, etc. Values such as these are not dependent on the lifetime of the hardware itself, but endure even if it has become necessary to replace various components over a period of time. As far as traffic investments are concerned, it is customary to count on a functional lifetime of 40 years, and there is no reason to believe that a congestion-charging system in Stockholm would cease to provide benefits for users any earlier than that. One way of looking at the investment cost is to regard it as a "start-up cost" – the cost up to the time the system starts plus the costs during the first year (when certain costs for "fine-tuning" the system and other higher than normal operating costs are incurred). Once the system is in operation, it is estimated that the operating cost stated will be sufficient to maintain the system for, in principle, as long as is required. Another question is whether there are any plans to change the system's functionality in the long-term perspective: this is not included in the operating costs. Instead a new calculation will then have to be made, with new estimates of costs and benefits.

Costs for making the expansion of public transport a permanent feature

According to SL, the cost of permanently expanding public transport to the level maintained during the Stockholm Trial would be SEK 400 million p.a.⁷⁹ This figure includes not only the new bus routes, but also more frequent services for commuter trains, underground trains, the Roslagsbanan suburban train line, etc. It is, of course, possible to choose to make only certain of these improvements permanent, if this is deemed more appropriate. Transek has endeavoured to calculate how the costs involved are divided up among the various forms of transport, as our own calculations of the benefits provided refer solely to the bus services. Assuming that "Stockholm Trial vehicles" cost the same as SL's other vehicles (a reasonable assumption over the longer term), it is possible to calculate the

⁷⁹ Personal contact with Eric Tedesjö, SL.

following costs (cost per seat kilometre is taken from SL's Annual Report for 2005):

Table 20. Estimated cost of making the expansion of public transport a permanent feature.

	Cost per seat kilometre	Expansion of traffic (seat km)	Cost for expansion of traffic
Underground	SEK 0.68	150	101
Commuter train	SEK 0.30	287	85
Suburban train	SEK 0.65	61	40
Bus	SEK 0.66	268	177

In the table above, the costs amount to SEK 403 million p.a. This agrees with SL's own estimate.

SL's investments in bus depots etc. are temporary in nature and intended to apply only for the duration of the trial. Transek estimates that more or less the same amount of money (SEK 124 million) would be required if these were made part of a permanent solution.

4.5 Other public sector income and expenditure

Public transport ticket revenues

When calculating SL's increased ticket revenues, we assume that the expansion of bus services has not led to any increase in ticket receipts, whereas the introduction of congestion charging has increased them by 4.5% (see section 4.1). In the absence of any better information on which to base our findings, we therefore assume that the average receipts from each "new" passenger are the same as the average receipts from each existing passenger. In 2005 SL's ticket revenues totalled SEK 4,079 million.⁸⁰ This would mean that the introduction of congestion charging has generated an annual increase in ticket revenues of 4.5% x 4,079 million = SEK 184 million p.a.

⁸⁰ Fakta om SL och länet 2005 (= "Facts about SL and the County of Stockholm, 2005"), SL (2005).

Fuel tax revenues

According to calculations made by the Swedish National Road and Transport Research Institute (VTI) of the change in road use as a result of the congestion tax⁸¹ there has been a reduction in the County of Stockholm of 443,000 vehicle kilometres travelled per weekday (24-hr period), based on traffic flows calibrated as described above. As revenue from taxation per vehicle kilometre travelled is currently SEK 0.50, this means that fuel tax revenues to the public purse have fallen by SEK 53 million p.a. as a result of the introduction of congestion charging.

Wear and tear on infrastructure

The costs for the wear and tear on infrastructure have been calculated with the help of SamKalk, based on slope-adjusted traffic flows calibrated in the same way as described above. The costs for wear and tear have been calculated to fall by SEK 1 million p.a.

⁸¹ Traffic Office (2006).

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Personal contacts

Birger Höök, Swedish Road Administration.

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