Bypass Stockholm, the environment and climate - a case study in road planning

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Foreword

The Division of Environmental Strategies Research (acronym “fms”) at KTH Royal Institute of Technology has the aim of contributing to long-term solutions, knowledge building, and debate on strategic environmental problems. This is done primarily through multi-disciplinary studies. The division's focus area is the intersection of environmental issues, social change, and technological change. We work mainly in three areas: future studies, tools for environmental assessment and management, and change processes. Within the area of future studies we use a systems-analytical approach with various types of scenario techniques, such as “backcasting” and external scenarios. Here the concept of sustainable development is a starting point. Within the area of environmental assessment and management, we use diverse types of environmental systems-analytical tools, such as life cycle assessment (LCA), strategic environmental assessment (SEA), life cycle cost analysis (LCC), and cost-benefit analysis (CBA). We also study how these tools can be used for environmental management at various levels. The area of change processes includes studies on behaviour, lifestyles, policy instruments, and measures. Among the application areas for the research are transport, energy, cities, buildings and infrastructure, sustainable consumption, waste management, and defence.

We have made research on large cities, Stockholm's traffic situation and Bypass Stockholm [Förbifart Stockholm], both as a part of comprehensive studies of how Sweden can achieve a sustainable transport system (e.g. Steen et al, 1997; Åkerman et al, 2000; Åkerman and Höjer, 2006; Åkerman et al, 2007), and sustainable urban development (Gullberg et al, 2007), and as a case study of how cost-benefit analyses are made in the transport field (Finnveden and Sterner, 2007).

On 31 March 2009 the KTH Academy of Urban Planning and Design arranged a seminar on Bypass Stockholm. One of us (GF) was invited to speak under the title “Bypass Stockholm and the environment”. This report builds on that presentation. We are grateful for all the views and comments we have received from colleagues at universities and civil servants at several different agencies before, during, and after that seminar.

Sections 2.1 and 2.2 build on “Finanskris och klimatkris – Några paralleller och kopplingar” [“Financial crisis and climate crisis – some parallels and connections”] that is authored by GF and intended as part of an anthology published by Sparbanksakademien in autumn 2009.

Financial support from Stiftelsen Futura has been used for this work.

This report is a translation of the Swedish report. The translation was made by Aaron Thomas.
Summary

Bypass Stockholm is a planned road west of Stockholm's inner-city. The purpose of this report is to provide some reflections on Bypass Stockholm's environmental impacts and how these have been treated in the Swedish Road Administration's analyses. There has not been a possibility for a comprehensive and complete investigation. Instead, we take up some aspects, in particular with connection to our earlier research.

Among the conclusions are:

- Bypass Stockholm leads to increased emissions of greenhouse gases.
- The Swedish Road Administration has underestimated the increase in greenhouse gas emissions from Bypass Stockholm.
- The official road analysis recommended the option that was worst in terms of several of the transport policy goals including environment and climate.
- Bypass Stockholm leads to increased transport volumes. These increases are very likely underestimated by the Swedish Road Administration, and that leads to the congestion being underestimated also.
- Bypass Stockholm leads to an urban structure that is more ineffective in terms of energy use and climate impact.
- Travel times do not decrease with Bypass Stockholm compared to alternatives, and it has not been shown that accessibility increases.
- Bypass Stockholm leads to encroachment onto natural and cultural environments.
- The cost-benefit analysis (CBA) contains large uncertainties and holes. One cannot draw the conclusion, with the existing data, that Bypass Stockholm would have a positive net utility.
- The utility (as measured by a CBA) of Bypass Stockholm has not been compared with that of alternatives.
- Bypass Stockholm is estimated to cost 25 billion SEK. Possibly these resources can be used in a more effective manner.

This study can also be seen as a case study of how integration of environmental issues works in practice. Then one can conclude that neither environment, nor climate, nor sustainable development is included among the project goals that the Swedish Road Administration formulated. This turns out to be essential, because the project goals are later used to select alternatives. The transport policy goals are formulated by the Swedish Parliament and can be seen as an expression that several different aspects, environmental issues among them, must be integrated into transport policy. However, it is unclear what significance these transport policy goals have had in the process, because the option that was worst with reference to several of the goals was chosen. The project therefore displays a poor integration of environmental issues.

The project goal that the Swedish Road Administration formulated was to find a road corridor. That is, the target was not to find a solution that from a comprehensive perspective would be a good solution to Stockholm's transport problems. It is interesting to note that there does not appear to be any actor that has the responsibility to develop such proposals. In the absence of such an actor it is essential that different actors work together. In this case one may note that several Swedish state authorities have been critical in their referral commentaries of the Swedish Road Administration's proposal and analysis.

From a methodology perspective, the conclusion can also be reached that, in connection with environment impact assessments, strategic environmental assessments, and socio-economic assessments, marginal data rather than average data should be used, for example for the use of electricity.
One may also note that the Swedish Road Administration's analysis confirms that the construction of roads can be associated with energy use and greenhouse gas emissions that can be significant. It is thus important that these be included in environmental impact assessments, strategic environmental assessments, and CBAs in a correct manner.
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1. Introduction

Bypass Stockholm is a planned road west of Stockholm's inner-city. The plans are described on the Swedish Road Administration's website (www.vagverket.se/forbifartstockholm) where a number of documents about the road are available. Among these are the Road Analysis (Swedish Road Administration, 2005) and a cost-benefit analysis (CBA) from 2006 (Transek, 2006). Based among other things on these materials the Swedish Road Administration proposed in a 2008 communiqué that the Swedish Government give permission for Road Corridor Bypass Stockholm. Later that year the Government Offices requested supplementary information from the Road Administration. This was delivered in March 2009 (Swedish Road Administration, 2009). These include new traffic prognoses and CBAs. Among other interesting documents at the Swedish Road Administration's website are commentaries from several different actors on many of these documents.

The purpose of this report is to offer some reflections on Bypass Stockholm's environmental impacts and how these have been handled in the Swedish Road Administration's analyses. No possibility for a comprehensive and complete investigation has existed. Instead, we take up some aspects, above all with connection to our earlier research. Through this case study we also wish to contribute to other discussions. More specifically we wish this report to contribute to:

- discussions on advantages and disadvantages of Bypass Stockholm
- discussions on how the environmental aspects of road investments will be assessed in environmental impact assessments, strategic environmental assessments, and CBAs
- discussions on how planning of larger infrastructure projects is done

The next section provides background on the climate issue and the transport sector. Sections 2.1 and 2.2 can be read cursorily by readers primarily interested in Bypass Stockholm.
2. Background

2.1 Climate changes

Carbon dioxide is the gas that contributes most to the human-influenced greenhouse effect (IPCC, 2007). Levels of carbon dioxide have increased from the pre-industrial value of approximately 280 ppm (parts per million, stating how many molecules per million molecules are constituted by carbon dioxide, in this case) to 379 ppm in 2005. Levels also continue to rise by approximately 2 ppm per year. These levels exceed the natural variation that the planet has had for the last 650 000 years (180 to 300 ppm), according to measurements in ice cores (ibid.). Thus, today we are engaging in a gigantic experiment. Humanity has not experienced these levels before.

The temperature on Earth has increased by approximately 0.8 degrees Celsius (°C) between the end of the 1800s and the beginning of the 2000s (ibid.). This increase cannot be explained only by natural variations. On the contrary, there is agreement with the models that include human influence via carbon dioxide and other climate gases (ibid.). The temperature is also expected to continue increasing. If levels in the atmosphere were to remain constant, which would require that nearly all emissions ceased immediately, the temperature would be expected to increase by an additional 0.6°C. A scenario with limited emissions reductions, resulting in increased amounts in the atmosphere, is expected to lead to a temperature increase of 4°C, with a probability interval of 2.4 - 6.4°C through the end of this century (ibid.). These temperature changes can be compared with the temperature change between ice age and pre-industrial period that was also approximately 4°C. Beyond the temperature increase, which will not be evenly distributed over the planet, other types of changes in the climate are expected, e.g. increased periods of drought in certain areas, increased precipitation in others, increased heatwaves, etc.

The climate system is an example of a complex system. That means among other things that there are feedbacks among parts of the system that can reinforce or balance each other. Sometimes one speaks of “tipping points” where a system shifts over into another state. This means that rather small changes can have large effects if the system is close to a “tipping point”. Let us illustrate some aspects of the climate system.

There are feedbacks among various parts of the system. One feedback is that the warmer it gets, the less carbon dioxide can be absorbed by land and water bodies (IPCC, 2007). That is, the warmer it becomes, the more carbon dioxide remains in the atmosphere and so contributes to an increased heating. A higher temperature can also lead to increased emissions of greenhouse gases that are today trapped in the ground, which increases the feedback.

There are different time scales in the system. Emissions occur here and now and can increase or decrease. The effects, however, happen over a long time-horizon. The carbon dioxide that is released now remains in the atmosphere for a long time and produces effects on temperature and sea levels for more than a thousand years, as a result of the time it takes for the system to assimilate the gas (IPCC, 2007).

There can exist points where the system changes character and it is difficult to go back to the original system state. One such example hinges on the Greenland ice sheet. At a certain temperature, the Greenland ice sheet's mass would begin to decrease, and if that temperature held for a long time period then practically the entire Greenland ice sheet could disappear, which would lead to the sea level rising by circa 7 meters. The temperature increase at which this is expected to happen is in the range of 1.9 to 4.6°C, from a baseline of pre-industrial levels (IPCC, 2007). Once the ice has melted, it is difficult to get it back. Presumably that would require a new ice age. Other
examples of such threshold effects in the climate system that are discussed are a possible collapse of the Gulf Stream, disappearance of land-based ice in parts of the Antarctic, a possible transformation of the Amazon's rainforests into savannah, and emissions of climate gases from defrosting permafrosts or so-called hydrates (Rummakainen and Källén, 2009).

There are systems that are difficult to predict. One such system is the Gulf Stream. During the century 2000-2100 it is expected to decrease by circa 25% (IPCC, 2007). It is judged as improbable that it would undergo a sudden large change during this century. Beyond that, however, the uncertainties are too large to make any judgements (IPCC, 2007).

Climate changes lead to socio-economic costs. The so-called Stern Report calculated that the costs for the greenhouse effect can range between 5 - 20% of GNP (Stern, 2007). A new appraisal today would likely lead to higher figures because more recent climate research points to larger effects from today's emissions levels than were previously believed (Rummakainen and Källén, 2009).

Among the effects that are expected from the greenhouse effect are (Stern, 2007): increased intensity of storms, forest fires, droughts, heat waves, fresh water shortages due to shrinking glaciers and droughts, flooding risks for large cities, and falling or lost harvests in many countries which risk leading to famines. In a number of countries, limited warming can be expected to lead to increasing harvests, but with larger warming this can change to decreased harvests. Overall, large changes in many ecosystems are expected, which among other things leads to the extinction of many animal and plant species. Warming is expected to lead to a range of various health effects, in addition to mass migrations of people. The latter can be associated with harder competition over raw materials, which can also lead to increased conflict risks.

The costs from the greenhouse effect are not evenly distributed. It harms coming generations more than present ones. It harms the poor more than the wealthy. Nor is it primarily those people who have caused the emissions who will be harmed by the effects. It is not therefore those people who in the first place should be required to cover the costs for reducing the emissions who are affected by the costs that result from not reducing the emissions. This means that there is an ethical dimension of the climate issue that is interesting. That the largest costs occur further ahead in time entails also that traditional CBAs can give the conclusion not to invest much resources to prevent climate change. If the discount rate chosen were sufficiently high, then the present value of future effects would be very low, even if they are large.

From scientific theory and policy perspectives there are a number of interesting aspects of the climate issue. The climate is a global system and we have only one exemplar of it. That means that we cannot make controlled experiments before we carry out changes in the system. Instead we are forced to rely on models and proven experience. Thus the time-scale becomes an interesting issue also. In the climate system, we can see changes first only after decades and centuries. If later one wished to implement countermeasures, much of the freedom of action would already have been used up because the amounts already emitted remain to a large extent and affect the climate for several centuries thereafter. That means that a policy cannot work of waiting and seeing what happens and then taking measures if developments were not going in the right direction.

Thus, the climate system is complex and therefore partly unpredictable. Despite that, demands are sometimes made in the climate discussion for predictability. In order to make decisions, it is occasionally demanded that the researchers be in agreement, and that effects should be predictable for centuries ahead. This shows that the use of scientific results in politics constitutes a complicated relation wherein several aspects are significant (Juntti et al, 2009). One aspect is the nature of scientific results: if an area of science is described as uncertain there is a tendency to reduce its significance. Another aspect is how the problems to be solved are formulated and by whom they are
formulated. Whether a transport policy is formulated to solve transport problems or climate problems has significance, of course, for what areas of science are permitted a role in the discussion, and what alternatives are seen to be interesting. Power relations then become significant for, among other things, how the problems are formulated and what solutions are discussed (ibid.).

2.2. Measures and instruments

In order to limit climate change, extensive reductions of emissions are required. There is a political consensus in the EU with respect to the so-called 2°C target, i.e. that climate change should be limited to 2°C increase compared with pre-industrial temperatures (Sweden Government Offices, 2009). However, it cannot be excluded that even lower temperature increases would produce serious effects (ibid.) To have a reasonable chance of meeting the 2°C goal, global emissions reductions of 35% by 2030 compared to the 1990 level are required (McKinsey, 2009). For Sweden's part, this could entail emissions reductions of 75 - 90% by 2050 (see Åkerman et al 2007) and continued reductions thereafter. To meet the 2°C target, the timing of reductions is also important. A 10-year delay in taking measures will, practically speaking, make it impossible to meet the 2°C target (McKinsey, 2009). Subsequent research also shows that it can be more difficult than has earlier been judged to meet the 2°C target, because among other things nature's ability to absorb carbon dioxide becomes less effective (Rummukainen and Källén, 2009).

Surveys of different types of measures that can be taken to reduce the emissions of greenhouse gases show that there is no single measure that solves the problem. On the contrary, a multitude of different measures is needed (e.g. McKinsey, 2009). It requires among other things more energy-efficient technologies for heating, for industry, and for transport. Additionally it requires production of heat and electricity from sources with lower emissions, e.g. from renewable raw materials. It also requires changes in land-use. Some of the measures are such that they can be implemented now, while others require more research and development.

Meeting the targets requires policy instruments. Because different measures need to be taken, and these are placed on different time-scales and cost-levels, there is a need for many different instruments. Policy instruments are usually divided into four main categories: information, regulations, physical planning, and economic instruments such as taxes, grants, and emissions trading (e.g. Sterner, 2002, Lindén, 2005). Often, different combinations of instruments are required in order to achieve both a desired effect on emissions and acceptance among citizens and other actors (Söderholm, 2008).

Reducing emissions in line with the 2°C target has been estimated to cost approximately 1% of global GDP in 2030 (McKinsey, 2009). For Sweden's part, the costs are calculated by the Swedish Government's Long-Term Survey at between 0.2 - 3% of Sweden's GNP in 2030, depending on how the measures are implemented (Hill et al, 2008). Other estimates point to 2 - 3% of EU's GDP (Commission on Sustainable Development, 2009). It will also require investments that correspond to maybe 5 - 6% of total investments.

These estimates can be viewed in relation to future costs of a changed climate if nothing today were done to reduce emissions. In the Stern Report (Stern, 2007), it is estimated that the costs could amount to 5 - 20% of GDP. New climate research in the most recent years indicates that this is more likely an underestimation than an overestimation. It is worth noting that there is no conflict here between ecological and economic sustainability. A powerful reduction of greenhouse gas emissions is a necessary condition for avoiding worsened economic development in time. However, there is of course some conflict between short-term and long-term economic interests.
2.3 The Transport Sector

The transport sector stands for a large share of society's emissions of greenhouse gases. In 2005 the direct emissions from transport, including emissions from international aviation and maritime transport caused by the Swedish population's consumption, accounted for 40% of Sweden's emissions (Åkerman et al, 2007). Additional to this are emissions caused by the construction of roads and other infrastructure, the manufacture of vehicles, and the production of fuels. Research points to the possibility that these can in total account for a large part of transport's emissions (Jonsson, 2005).

Sweden's emissions of greenhouse gases have, since 1990, been relatively constant and decreased only marginally. However, the shares of emissions among different sectors have changed. The emissions from housing have decreased, while the emissions from the transport sector have increased. It is above all freight transport and international aviation that have increased.

As mentioned above, significant reductions of greenhouse gases are needed now. In Sweden, the government's target is that emissions should decrease by 40%, of which 2/3 in Sweden, by 2020, and that the net emissions should be zero by 2050 (Sweden Government Offices, 2009). This involves significant changes in trends. Achieving these goals will require powerful economic instruments (ibid.).

An interesting question in this context is how much can be achieved with new technologies. Currently there is an ongoing fuel-efficiency improvement in the passenger-car fleet, primarily via rapid increases in the share of diesel cars. Hybrids (without possibility to be charged with electricity from the grid) have also been introduced, but they account so far for less than 1% of the passenger-car fleet. These technologies support possibilities for a fuel efficiency improvement of 15 - 30%. The emissions of greenhouse gases decrease by the corresponding amount. For achieving significantly larger emissions reductions, the most promising pathway is through electricity-powered cars and biofuels.

Pure electric vehicles and so-called plug-in hybrids that can be run on both grid electricity and a combustion motor are today discussed intensely. A larger introduction in the future of such vehicles would produce significant environmental gains, though not as large as is sometimes asserted (Åkerman et al, 2007). Electric vehicles have low energy consumption and low operating costs when they are run on grid electricity. Purely electric vehicles can in the future function as niche vehicles, but what the car industry hopes for most are plug-in hybrids. Because these are equipped with both an electric motor and a combustion engine, they function well for both short and long trips. However, there are a number of problems with plug-in hybrids (ibid.), which are not yet available to buy in Europe. It is mainly a question of there needing to be the development of better batteries that are both cost effective and have sufficient length of life. The purchase costs for plug-in hybrids will be significantly higher than for ordinary cars. Today's estimate is that the added cost relative to a corresponding conventional car will be in the range of 100 000 SEK. Even in the longer term, when the technology has developed, the purchase cost is likely to be significantly higher. Cost growth for sought-after battery metals, primarily lithium, can contribute to that. This means that for plug-in hybrids to gain a wide adoption, it will likely require either much higher fuel costs than today (20 - 30 SEK/litre petrol) or substantial public subsidies (much higher than an eco-car premium of 10 000 SEK). The Swedish Energy Agency has judged that it will likely take many years for the market for electric vehicles to become large in relation to the markets for other car types (Swedish Energy Agency, 2009).

The gains with plug-in hybrids from a climate perspective depend on how the electricity used for operation is produced. Also important is how much electric operation (using grid electricity) is used
relative to the combustion motor. One aspect in this context is that electric operation in itself does not provide any waste heat that can be used to warm the passenger compartment, which means that in a colder climate, additional energy is required. Compared with traditional vehicles, both the energy consumption and the environmental impact associated with production of vehicles will increase somewhat.

The use of biofuels can reduce carbon dioxide emissions. Today's biofuel production, however, leads to emissions of greenhouse gases to varying degrees (e.g. Åkerman and Åhman, 2007). Second-generation biofuels are often cited that can be produced from raw cellulosic materials with lower emissions of greenhouse gases. These still require development, however, and are not yet on the market. But even when this technology is developed, it will entail relatively large transformational losses. Only 40-70% of the bioenergy input can be transformed into usable fuel.

The supply of biofuels depends on a number of different factors: partly on how much there is available globally, and partly on how much is needed for other sectors of society. It is conceivable that the competition for land in the future will intensify because we will need to produce more food, energy, and materials, at the same time as land-based ecosystems (as discussed above) will be subjected to increased pressure as a result of climate changes; and at the same time we will need to set aside land for nature reserves and preservation of biological diversity. Therefore, it is important to use the limited amount of accessible bioenergy so that it gives as large a climate benefit as possible. It is worth noting in this context that a unit of biomass input produces a twice as large climate benefit when it replaces coal in a power station than when it is used for vehicle fuel. And this is largely true of future processes for fuel production also.

Future scenarios can be developed by combining the estimates of transport volume increases, the assessments of technological development, and the projections of different fuel supplies. Such scenarios can then be compared with greenhouse gas targets. Åkerman et al (2007) in that way conclude that it is possible to combine today's transport volumes with projected technological development and meet the target levels for greenhouse gases in 2050. However, technological development is not sufficient to handle the increased traffic volumes that are forecast.

The conclusion from the previous paragraph is that we must break today's trends of increased traffic volumes. Technological development is important but not sufficient. Countering the climate threat requires – according to the above – a combination of various instruments. In the area of transport, economic instruments are important, but physical planning has a key role also in avoiding increasing traffic volumes. This is in line also with Sweden's Climate Bill, that states that “Long-term investments in infrastructure and other public planning need to be directed toward creating conditions for development toward an overall more energy efficient transport system” (Sweden Government Offices, 2009).

### 3. Analysis and discussion of Bypass Stockholm

#### 3.1 Choice of alternatives

The Swedish Road Administration has proposed in its statement to the Government that permission be granted for Bypass Stockholm (Swedish Road Administration, 2009). It is interesting to study what alternatives were considered, and why Bypass Stockholm was recommended.

In the Road Analysis (Swedish Road Administration, 2005), it is stated that “the purpose of the road analysis is... to find the road corridor that best...” meets a number of goals that are listed. None of these goals touches on climate, environment, or sustainable development.
In the Road Analysis, three main alternatives are analysed:

- Bypass Stockholm without congestion charges
- Diagonal Ulvsunda without congestion charges. This is also a road alternative but located closer to Stockholm's inner-city than Bypass Stockholm.
- The Combination Alternative that includes congestion charges, public transport investments, and less road construction.

The Combination Alternative was analysed by the Road Administration despite the fact that it is established that it is not the most competent organisation to perform that analysis. The system for congestion charges included in the Combination Alternative is not the system that is used today. The structuring of the Combination Alternative has also met criticism (e.g. Swedish Society for Nature Conservation, 2009).

In the Road Analysis, the Combination Alternative is later rejected. The motivation is that it is not considered to meet the project goals.

Here several key observations are possible. Already in the goal formulation it is set down that a road must be found. Other solutions for the foreseen transport problems are not of interest. In the Supplementary Report (Swedish Road Administration, 2009), it is stated also that “the Combination Alternative does not offer sufficient road capacity.”

The main purpose of the Road Analysis was thus, according to the above, to find a road corridor. At the same time, there are the transport policy goals to adhere to. These entail that the transport system must both be effective from a socio-economic perspective and be long-term sustainable. The transport goals also contain six specifications that address accessibility, quality, safety, environment, regional development (that should counteract long transport distances) and equality. In addition, there is a policy goal that the share of public transport trips should increase. In the Road Analysis, there is no direct evaluation made with regard to the transport policy goals, but several aspects of these are taken up, as summarised below.

The concept of accessibility has no single definition and can be interpreted in different ways. One interpretation is to look at travel times. Another is to look at the share of the county's workplaces that can be reached from various municipalities by car and by public transport within 30 and 45 minutes, respectively. These aspects are analysed in the Road Analysis, but a measure is also used that combines travel times with the number of trips and costs for the trips.

These different measures for accessibility produce different results in the Road Analysis (Swedish Road Administration, 2005). If one looks at travel times, then the Combination Alternative is better than Bypass Stockholm for travel from the south and north. For travel from the west, however, Bypass Stockholm has shorter travel times (ibid.). If one looks at the share of passengers who reach workplaces by car within a certain amount of time, then the Combination Alternative is better than Bypass Stockholm for the municipalities of Stockholm, Haninge, Huddinge, Botkyrka, Tyresö, Solna, Sundbyberg, Sollentuna and Täby (ibid.). For municipalities Ekerö and Järfalla, Bypass Stockholm is better. However, even for the share of passengers who reach workplaces by public transport, the Combination Alternative is better (ibid.). If accessibility is measured as a combination of travel times, costs and number of trips, then Bypass Stockholm is better, however (ibid.).

The transport goal of “quality” is not directly discussed in the Road Analysis, so it is difficult to assess here.
Traffic safety is, according to the Road Analysis (ibid.), better with the Combination Alternative than with Bypass Stockholm.

Environment and climate are, according to the Road Analysis (ibid.), better with the Combination Alternative than with Bypass Stockholm.

The goal of regional development is not evaluated directly in the Road Analysis so it is difficult to assess here.

For equality, the Combination Alternative is better than Bypass Stockholm according to the Road Analysis (ibid.).

The share of public transport travel is higher with the Combination Alternative than with Bypass Stockholm.

The comprehensive goal of socio-economic effectiveness (CBA) cannot be evaluated because there has not been any CBAs made for the Combination Alternative. Nor can the sustainability goal be evaluated easily, as no integrated discussion of sustainability is made. However, it is possible to note that the ecological dimension of sustainability can be evaluated via the environmental criterion, for which the Combination Alternative is better, according to the above.

The results for the transport goals are summarised in Table 1. This analysis shows that the Combination Alternative presents several advantages. Based on the transport policy goals, it is difficult to understand why the Road Administration has recommended Bypass Stockholm.

Table 1. Evaluation of transport policy goals based on the Road Analysis (2005)

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Bypass Stockholm</th>
<th>Combination Alternative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accessibility (share of workplaces)</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Accessibility (Road Administration's measure)</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Quality</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Traffic safety</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Environment, Climate</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Regional development</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Equality</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Share of public transport</td>
<td>+</td>
<td></td>
</tr>
</tbody>
</table>

That accessibility is improved with Bypass Stockholm is put forward by the Road Administration (2009) as an argument in favour of Bypass Stockholm and against the Combination Alternative. However, this is dependent on the choice of accessibility measure, as shown above. Additionally, it can be noted that the conditions have changed since the Road Analysis (2005), so it is uncertain what the result would be today. In that analysis, it was assumed that the Combination Alternative had congestion charges, but not the Bypass Stockholm alternative. Because costs are included in the Road Administration's accessibility measure, this negatively affects the Combination Alternative. However, in today's Bypass Stockholm option, congestion charges are counted in, which means that the option recommended today is not the same one that was evaluated in 2005. We do not know, therefore, what the answer would be today. The CBA from 2006 (Transek, 2006) was criticised because, among other reasons, it did not include congestion charging in its baseline scenario (Finnveden and Sterner, 2007). In the Supplementary Report requested in 2008 by the Government Offices, a consideration of congestion charging is one of the specified requirements. This is now part of the CBA, but congestion charging is still not included when accessibility is evaluated. This
is problematic because accessibility is one of the primary arguments for the choice of Bypass Stockholm (Swedish Road Administration, 2009).

A number of conclusions can be drawn from this discussion:

- In the Road Analysis, the goal was to find a road corridor, not to find a good solution for Stockholm's traffic and transport problems. There is still a need therefore to analyse what, taken together, would be a good solution for Stockholm's traffic problem.
- The Combination Alternative is rejected with reference to its not meeting the project goals. The choice of project goals is therefore central.
- None of the project goals in the Road Analysis is focused on environment, climate or sustainable development. If it had been so, then Bypass Stockholm could have been rejected with reference to its not meeting the project goals.
- Had the transport goals been guiding for the choice of alternatives, then Bypass Stockholm would hardly have been able to be recommended.
- Bypass Stockholm does not lead, according to the Road Analysis (2005), to shorter travel times than the Combination Alternative.
- It is not shown that Bypass Stockholm leads to increased accessibility.

### 3.2 Traffic volumes

New roads do not only lead to traffic moving from one road to another. New roads also generate new traffic (e.g. The Standard Advisory Committee on Trunk Road Assessment, 1994; Goodwin, 1996; European Conference of Ministers of Transports, 1998; Noland and Lem, 2002). London is an example often cited in this context. After the ring road M25 was constructed, it became evident that it generated new traffic and that planners had underestimated the traffic volumes both on it and on the roads that it had been thought traffic would move away from.

There are several mechanisms for why new roads generate new traffic, and one can distinguish between effects in the short and long term. In the short term, new roads can lead to car-use being more attractive relative to other transport forms, and to travel itself becoming more attractive relative to alternative activities. In the long term, new roads can additionally lead to new localisations. It can for example be attractive to develop new areas if there are better road connections, which then leads to increased traffic volumes. Such newly developed areas can often be harder to service with public transport, which leads to the share of public transport travellers decreasing.

The Swedish Road Administration's prognosis gives some consideration to the increased traffic volumes. The traffic prognoses show that Bypass Stockholm leads to increased traffic volumes. Consideration is made that passenger vehicle traffic increases in the short term. Increased traffic because of new localisation patterns is not included, however. For freight traffic, no consideration is made that new roads generate new traffic.

Thus, conclusions from this section are that:

- Bypass Stockholm leads to increased traffic volumes
- the Road Administration has likely underestimated these increases. This in turn leads to that:
  - congestion is underestimated
  - travel times are underestimated
  - accessibility is overestimated
  - environment impact, including CO₂ emissions, is underestimated
  - effects are missed of development of new areas on, for example, natural environments and emissions.
In section 2.3, we pointed out that more fuel-efficient vehicles and a larger share of renewable energy are not sufficient for meeting the climate goals, if car traffic continues to increase. Therefore it is important how large the traffic volumes are that result from different investment strategies and instruments. In this context it can be worth noting that the car will be the dominating transport form in rural areas and smaller urban areas in the future. If for climate motivations one wishes to reduce car travel, then it is in larger urban areas that the opportunity exists, because it is there that walking, cycling, and public transport, with the right measures, can be attractive alternatives.

3.3 Emissions of greenhouse gases

3.3.1 Introduction

According to the Swedish Road Administration (2009), the emissions of greenhouse gases are increased with Bypass Stockholm. In our estimation this increase is underestimated. An important reason is that Bypass Stockholm likely leads to higher traffic volumes than what the Road Administration has supposed (see section 3.2). Some additional reasons are discussed in the following section.

3.3.2 Emissions from construction of the road

A key failure of earlier analyses of Bypass Stockholm is that these did not include emissions from the construction of the road itself (Finnveden and Sterner, 2007). This was also one of the points that the Government Offices wanted to have supplementary information on.

The Road Administration has in the Supplementary Report (Swedish Road Administration, 2009) analysed energy consumption and emissions from construction of the road, but unfortunately in an incomplete way. The analysis that the Road Administration permitted to be conducted (Stripple, 2009) includes energy consumption and greenhouse gas emissions for the road's construction, but not for the production of the materials. The construction of tunnels requires concrete and steel that are not included. An initial analysis indicates that the energy consumption for the production of these materials can be at least as large as the energy consumption that is already included in the analysis. The effect on the calculations of emissions of CO$_2$ can thereby be large.

In connection with analyses of environmental impacts, it is sometimes discussed how one should assess energy use and its consequences. An example relates to emissions from electricity production. The different emissions from for example hydropower, nuclear power, wind power, and coal power vary tremendously of course. Thus a discussion often arises about what electricity production should be used in the analyses (e.g. Swedish Energy Agency, 2008; Sköldberg and Unger, 2008; Stripple, 2009). There are two types of data that can be chosen: average data and marginal data. Average data are data for the average electricity production during a certain time period in a certain area, for example average production in Sweden in 2008. Marginal data are for those production methods that are changed if electricity consumption increases or decreases.

The choice of average data or marginal data depends to a large extent on the type of analysis and question one poses (e.g. Ekvall and Weidema, 2004; Swedish Energy Agency, 2008; Finnveden and Moberg, 2005; Tillman, 2000). If the analysis is to perform an environmental accounting of a system, then the average data for the system being studied are the most suitable. If instead the analysis is for assessing impacts of changes and measures that affect energy consumption, then marginal data are the most suitable choice.
What then is relevant in this context? Environmental impact assessment, as the name implies, focuses on analysing the consequences of a decision. If a decision entails that energy consumption changes, data for the production that changes, not the average production, should be used. That is, marginal data should be used in environmental impact assessments. CBAs also focus on analysing effects of changes. The theoretical basis for analyses is differential equations, of course. That is, even in this case, marginal data should be used rather than average data.

However, in the analysis that Stripple makes (2009), average data are used as the primary alternative. This is erroneous according to the above. Instead, marginal data should be used. That is also done by Stripple in a sensitivity analysis. There he uses coal condensation power as an example of marginal electricity production. The result then becomes radically different and the emissions of carbon dioxide from the construction of the road become significantly higher. With average data the emissions are 0.248 million tons CO\textsubscript{2} compared with 5.83 million tons when the figures for marginal electricity production are used according to Stripple (2009).

### 3.3.3. Assumptions about new vehicles

In the Swedish Road Administration's Supplementary Report, a prognosis is used about future vehicles and their emissions of CO\textsubscript{2} (WSP Analys, 2008). In the prognosis, it is assumed that the share of vehicles driven with renewable fuels will be circa 20% in 2020. Furthermore, it is assumed that the share of plug-in hybrids among new car sales will be 45% in 2020, and that the total share of plug-in hybrids in the car-fleet will be about 10% that year.

We have already criticised these assumptions as being too optimistic (Åkerman and Finnveden, 2009). The prognosis that the share of vehicles driven with renewable energy will be 20% in 2020 can be compared with the Swedish Government's target of 10%. Furthermore, the prognosis for plug-in hybrids (circa 10% in 2020) can be compared with the Swedish Energy Agency's prognosis of 85 000 vehicles, which corresponds to circa 1.5%.

In the calculations of CO\textsubscript{2} emissions, two simplifications are then made that produce underestimations. One is that all vehicles with alternative fuels are driven exclusively with these (WSP Analys, 2008). The other simplification is that consideration is only made of emissions during the operation of the vehicle. Excluded, therefore, are the emissions during:

- production of renewable fuel (which can be significant, see above)
- production of electricity (which can be significant)
- production of the vehicle itself (which is larger for electric cars and plug-in hybrids than for conventional vehicles)

This leads to clear underestimations of the CO\textsubscript{2}-emissions.

### 3.3.4 Conclusions on CO\textsubscript{2}-emissions

By the Swedish Road Administration's own assessment, Bypass Stockholm leads to increased emissions of the greenhouse gas CO\textsubscript{2}. This increase is hugely underestimated, however, for the following reasons:

- the increase of traffic volume is likely underestimated (section 3.2).
- the production of materials for the roads has not been included.
- marginal data for the emissions should have been used.
- the introduction of vehicles fuelled with electricity and renewables has been overestimated.
- it has been assumed that vehicles with alternative fuels will be driven exclusively with these.
• emissions from the production of fuels and electricity for the operation of vehicles, have been excluded.
• emissions from the production of vehicles have been excluded.

3.4 Can the climate targets be met?

According to section 2, it is necessary for greenhouse gas emissions to decrease hugely in order to meet climate goals. According to the Swedish Road Administration (2009), Bypass Stockholm leads to increased emissions of greenhouse gases. One can then ask if it is still possible to meet the climate goals. The Road Administration claims that it is possible, and refers to an analysis from RTK. The Road Administration states: “RTK's analysis shows that it is possible to meet the climate goals with Bypass Stockholm, if, however, only with powerful economic instruments.”

The analysis referred to is not publicly available, however. Nor is it clear what the “powerful economic instruments” referred to are. There is therefore no possibility to make an assessment of the possibilities to meet the climate goals. It is possible, however, to draw the conclusion that because Bypass Stockholm leads to increased emissions of CO$_2$, even more powerful instruments will be needed if Bypass Stockholm is built than otherwise, if the climate targets are to be met.

3.5 Cost-benefit analyses

In an earlier report (Finnveden and Sterner, 2007), we have discussed the use of CBAs both in general and in previous analyses of Bypass Stockholm in particular. The reflection built on earlier CBAs (Transek, 2006). In the Swedish Road Administration's Supplementary Report (2009), a new CBA is made. The conclusion is reached that the CBA of Bypass Stockholm yields a positive result. There are, however, a number of deficiencies and uncertainties in the calculation. Some of these are discussed below.

1. According to the Swedish Government, powerful economic instruments are required to reach the long-term climate policy goals (Sweden Government Offices, 2009). Even the Road Administration (2009) notes this when it refers to RTK's analysis (see section 3.4). These “powerful economic instruments” will likely affect the CBA. But in the CBA it is not counted on that the long-term climate policy goals will be met. No reference is made to the “powerful economic instruments” that are necessary in the long term.

2. Bypass Stockholm leads to encroachment onto natural and cultural environments, some with national importance. However, these encroachments are not included in the CBA.

3. According to section 3.3, there is a clear underestimation of CO$_2$ emissions. This underestimation can be significant for the CBA.

4. According to section 3.2, there is a likely underestimation of the congestion generated by Bypass Stockholm. This can affect the results of the CBA.

5. From prior analyses, it is known that the oil price can affect the CBA (Transek, 2006). In the current analysis, it is assumed that the product price is unchanged through 2020 and thereafter increases by 0.3% per year (WSP, 2008). As there is a genuine uncertainty around the development of the oil price, it would have been interesting to see a sensitivity analysis with different oil price developments. In the absence of such, the result of the socio-economic calculation becomes more uncertain.
6. From earlier analyses, it is known that congestion charges and their design can affect results substantially (Transek, 2006). In the current analysis (Swedish Road Administration, 2009), it is assumed that if Bypass Stockholm were built, the present congestion charging system would be retained and congestion charging implemented on the Essinge Highway. In the Reference Alternative, which is used for comparison, the current congestion charging system is retained without change and congestion charging is not implemented on the Essinge Highway. We do not know today how future politicians will design the congestion charges, with or without Bypass Stockholm. It would therefore have been interesting to perform a sensitivity analysis with various designs of the system. In the absence of such, the result of the CBA becomes more uncertain.

7. The single largest cost for Bypass Stockholm is the construction of the road. According to the Swedish Road Administration's Supplementary Report (2009), the cost is “assessed” to be 25 billion SEK. No background to this amount is given, nor any references. It is reasonable to say that this figure suffers from a number of uncertainties. From prior road and tunnel projects there are experiences that cost calculations require revision, and nearly always upward. Because the cost must be judged to be uncertain, then the result of the CBA also becomes more uncertain.

Our conclusion is that it is impossible to draw the conclusion that Bypass Stockholm would have a positive net utility. There are all too many uncertainties and deficiencies in the calculation for it to be reasonable to draw such a conclusion.

It should be noted also that a CBA has been made only for Bypass Stockholm, not for any alternatives. It would have been interesting to see the results of other conceivable proposals for improving Stockholm's traffic situation.

4. Conclusions

4.1 Bypass Stockholm

Based on the discussion above, it is possible to draw several conclusions about Bypass Stockholm:

- Bypass Stockholm leads to increased emissions of greenhouse gases.
- The Swedish Road Administration has substantially underestimated the increase in emissions of greenhouse gases from Bypass Stockholm.
- The official road analysis recommended the option that was worst in terms of several of the transport policy goals including environment and climate.
- Based on the transport goals, it is difficult to understand why Bypass Stockholm was chosen.
- Bypass Stockholm leads to increased transport volumes. These increases are probably underestimated by the Road Administration, and that leads to the congestion being underestimated also.
- Bypass Stockholm leads to an urban structure that is more ineffective in terms of energy and climate.
- Bypass Stockholm does not lead to decreased travel times.
- It is not shown that Bypass Stockholm leads to increased accessibility.
- Bypass Stockholm leads to encroachment into natural and cultural environments.
- The CBA contains large uncertainties and holes. With the existing materials it is not possible to draw the conclusion that Bypass Stockholm would have a positive net utility.
- There is no comparison made with alternatives on the basis of CBA.
• Bypass Stockholm is estimated to cost 25 billion SEK. It may be possible to use that investment in a more effective way.

4.2 Planning of infrastructure projects.

One of the pillars of the Swedish environmental policy is that environmental factors must be integrated into all operational areas (Nilsson and Eckerberg, 2007). An expression for this is the sector responsibility for environmental issues that among other things entails that a number of agencies have responsibility to follow the environmental development within their sectors. In that way, the Swedish Road Administration has a sector responsibility for road transport.

This study can be seen as a case study in how integration of environmental factors works in practice. One can then point out that neither environment, nor climate, nor sustainable development is among the project goals that the Road Administration formulated. This turns out to be essential because the project goals are later used in order to choose alternatives.

The transport goals are formulated by the Swedish Parliament and can be seen as an expression that several different aspects, among them environmental issues, must be integrated into transport policies. It is unclear, however, what significance the transport policy goals have had in the process, because the option chosen is the worst in terms of several of the goals.

In this project, therefore, the integration of environmental issues is seen to work poorly.

The project goal formulated by the Road Administration was to find a road corridor. That is, the target was not to find a solution that from a comprehensive perspective would be a good solution for Stockholm's transport problems. It is interesting to note that there does not appear to be any actor with the responsibility to develop such proposals. In the absence of such an actor, it is essential that different actors work together. In this case one may note that several Swedish state authorities have been critical in their referral commentaries of the Swedish Road Administration's proposal and analysis.

4.3 Methods for assessment of environmental impacts

There are many tools developed for assessing the environmental impacts and the socio-economic effects of various systems, e.g. environmental impact assessment, strategic environmental assessments, life cycle assessments, socio-economic assessments, CBAs and life cycle cost assessments (e.g. Ahlroth et al, 2004; Finnveden and Moberg, 2005; Ness et al, 2007). With regard to several of these there is an ongoing discussion about the use of marginal data versus average data (e.g. Ekvall and Weidema, 2004; Tillman, 2000).

According to the discussion above, marginal data rather than average data should be used in environmental impact assessments and CBAs.

One may also note that the Swedish Road Administration's analysis confirms that the construction of roads can be associated with energy consumption and greenhouse gas emissions which can be significant. It is thus important that these be included in environmental impact assessments, strategic environmental assessments, and CBAs in a correct manner.
References


