ARE CBA RESULTS ROBUST? EXPERIENCES FROM THE SWEDISH TRANSPORT INVESTMENT PLAN, 2010-2021

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Abstract

The use of Cost-benefit analysis (CBA) as a tool for choosing between suggested transport investments is often questioned. Many argue that the results completely rest on what assumptions are made. This paper studies whether this is true for two sorts of assumptions; climate policy assumptions and benefit valuations. First, we study how much the CBA ranking is affected by varying the relative weight of different types of benefits. The valuation of travel time, traffic safety, emissions and freight benefits are systematically varied for 480 suggested road and rail investments in the latest Swedish transport investment plan. The conclusion is that the ranking is surprisingly stable. The balance between road and rail is also robust. Second, we vary the relative weights within a benefit type by differentiating the value of time. This exercise has an even smaller effect on ranking. Last, scenario assumptions relating to future climate policy options are altered. Even rather drastic assumptions, such as a doubled oil price, change the benefits with only a few percent and the rankings are hardly affected at all. The exception seems to be car ownership. In conclusion, our study suggests that decision makers can feel secure that following the CBA methodology will lead to sound investments being prioritized. The top-ranked investments stay more or less the same in all sensitivity tests.

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1. INTRODUCTION

The use of Cost-benefit analysis (CBA) as a tool for choosing between suggested transport investments is often questioned. Many argue that the results completely rest on what assumptions are made, a popular example being that increasing oil prices means we should invest a lot more in rail. But, is this true? In this paper we focus on two controversial uncertainties; climate policy assumptions and benefit valuations. These are issues much debated; but seldom researched.

CBA has been an important tool for transport planners for several decades, in particular for evaluating and ranking transport investments. While CBA is useful and enlightening for evaluating a single investment, CBA really comes into its own when it becomes necessary to compare the relative merits of many alternative investments against each other. An extreme example is the construction of a national transport investment plan. During such a process, planners need to quickly sift through several hundreds of proposed investments, evaluating and ranking them relative to each other. The sheer number of investments makes standardized and semi-automatic evaluation tools such as CBA virtually indispensable. It has recently been showed that the CBA outcome influenced the transport investment decisions in the latest Swedish transport investment plan (Eliasson and Lundberg, 2010). This finding is contrary to previous international studies and emphasizes that reliable CBA results are of practical importance.

However, using the CBA result as a tool for prioritization is often questioned. Common views among decision makers in Sweden are that:

1. The CBA results are very sensitive to the choice of assumptions and valuations,
2. Assumptions are often chosen by the analyst in order to get wanted results and
3. When results are not as expected, the forecast assumptions are wrong.

Even among planners and other professionals a widespread belief is that certain assumptions and valuations are very important for the optimal mix of investments. Some examples often mentioned are future oil price and technological development of cars, GDP growth rate, and valuation of time or carbon dioxide emissions (Swedish Rail Administration and Swedish Road Administration, 2009). The discussions on which figures to use in forecasts and CBAs tend to be long and animated.

Uncertainties exist in all phases of a transport CBA – transport forecasting, effect modelling, valuation and discounting. In this paper we chose to study scenario assumptions that are affected by the future climate policy. The obvious reason is that these are currently both very controversial and uncertain. We also study the importance of the benefit valuations, since they are also controversial and since much research is carried out to improve them.

We use data from the Swedish multi-modal National Transport Investment plan for the period 2010-2021. The study is limited to transport investments, for which close to 500 complete

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CBAs were carried out. A lot of effort was devoted to testing the robustness of the CBA outcomes. For all investments, alternate cost-benefit ratios with higher investment costs, lower and higher traffic growth and higher valuation of carbon dioxide were calculated. For a sample of investments, additional sensitivity analyses were carried out by building new scenarios and carrying out new traffic forecasts etc. In this study we have carried out further calculations for all investments by varying the valuation of different effects.

The scenario assumptions studied are oil price, technological development of cars, car ownership, and a package of policy measures to reduce green-house gases. Valuations that are altered include value of private trip time differentiated after length of trip, mode of transport and purpose, emissions, and traffic safety.

The paper is organized as follows. Section 2 describes how CBAs are used in Swedish investment planning and what types of uncertainties exist. A brief account of Swedish transport modelling and CBA methodology is also given. In section 3 the results on altering the relative benefit valuations are presented. Section 4 presents results on the impact of climate policy assumptions, while section 5 concludes.

2. USE OF CBA FOR PRIORITIZATION

Uncertainties in CBAs

In the literature, more general criticism against the CBA method as such is common. The criticism includes causes such as omitted impacts, errors in assumptions and valuations or missing interpersonal compensability (Mackie and Preston, 1998; Hansson, 2007). However, the literature about uncertainties in CBAs is rather limited, even if there are some studies on the robustness of the CBAs where sensitivity tests are done for a specific investment project (Boyce and Bright (2003), Rodier and Johnston (2002) and de Jong et al. (2007)).

Uncertainties exist in all phases of the process of making a CBA. Figure 1 illustrates the process, with the phases in solid lines and the results in dashed lines. Obviously it is impossible to predict correctly the future which means *scenario assumptions* will always be uncertain. We focus on assumptions that are affected by the future climate policy. Other assumptions, not studied here, that are either controversial or important when ranking transport investments include land use, road pricing, and supply of public transport. Almström et al (2011) find the ranking (based on CBAs for six rail and road investments) to be robust for different land use assumptions. It is difficult to generalize the effects of road pricing, but it can have a large impact on benefits and thus ranking of investments (Swedish Rail Administration and Swedish Road Administration, 2009a). Börjesson and Eliasson (2011a) find that different timetable assumptions (headway and travel times) can make the appraisal outcome virtually arbitrary. Timetable assumptions can thus have a large impact on the ranking.

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Transport forecasts can also turn out wrong because of sampling errors when gathering *data for estimation* of the transport model. There may also be model deficiencies in the *transport model* itself or in the *models used to calculate effects*. Most studies of uncertainties of CBAs focuses on the uncertainty due to modelling errors (Zhao and Kockelman (2002), Beser Hugosson (2005) and Brundell-Freij (2000)). A general finding in the studies is that uncertainty induced by modelling errors is smaller than the uncertainty induced by future scenario assumptions (Widlert (2002) and de Jong et al (2007)). There are also studies where multiple model runs have been made of future scenario assumptions with Monte Carlo approaches (Matstoms and Björketun (2003)). However, they do not study how the ranking of different alternative investments is affected.

There are many methodological and practical problems in *valuation* of non-market goods such as travel time, emissions or life. Simplified or erroneous valuations are thus likely and this is a research field in its own. However, studies on how valuations affect the ranking between projects in an investment plan are rare indeed, one study being Scheiner and Holz-Rau (2010). They alter valuations of traffic fatalities and travel time for more than 400 road projects and find that the evaluation results are fairly stable against variations in unit values of travel time and fatalities.

Another uncertainty is the simple fact that some *effects or valuations are omitted*, because the effects are not possible to model or valuations are missing. A few examples are intrusions, improved urban environment and wider economic benefits. Methods where efforts are made to consider such effects are multi-criteria analyses. There is a vast literature on these, where often sensitivity tests have been carried out. Typically, however, they are used in order to test variables that are not traditionally valued in CBAs and thus do not help us to understand how rankings based on CBAs are affected.

General parameters such as discount rate, cost of public funds or calculation period are also uncertain. While they can have a big impact on the net present value in absolute terms they tend to affect the benefit-cost ratio similarly for most investments. These uncertainties are therefore not all that interesting when ranking different investments. Last, uncertainties in *investment costs and future maintenance costs* can have a large impact on the benefit-cost ratios, and thus the validity of the CBA as a decision base. Cost calculation is a research field in its own that will not be discussed further here.

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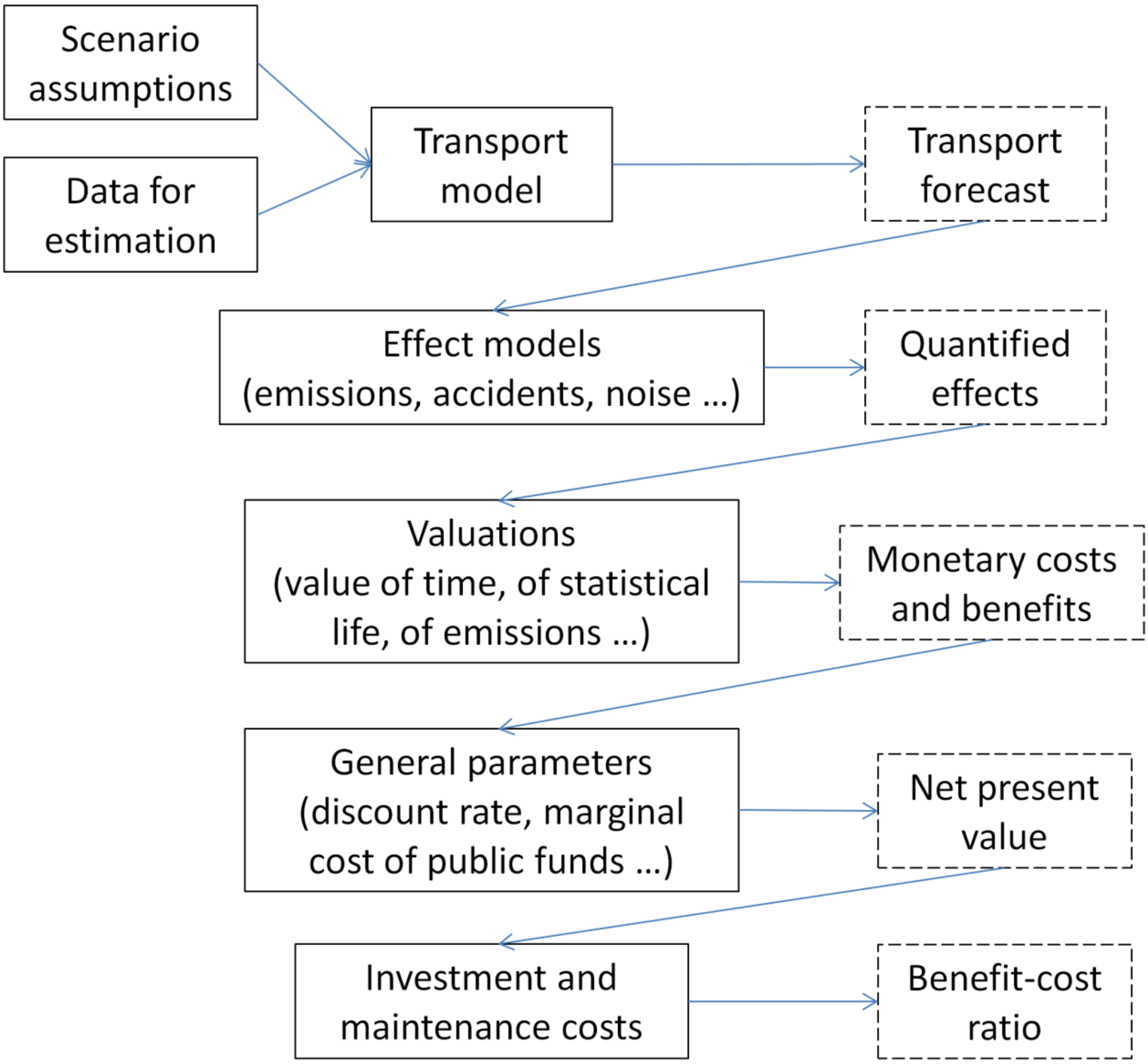

Figure 1: The process of making a CBA

Construction of the transport investment plan

The proposal for the new National Transport Investment Plan was delivered to the Government in December 2009 for possible amendments and eventual decision, after a preparation process of more than two years. The National Plan comprised one part with national road and rail investments and one part with 21 regional plans, one for each county[1]. The Rail and Road Administrations are responsible for making the decision support, including CBAs, for both national and regional investments. However, organizations at the county level are responsible for the selection of investments in the regional plans.

[1] The plans also contain investments for other purposes as well as funding for maintenance.

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Swedish investment plans are typically revised every five years and cover a period of around ten years. CBA has been used as a tool for Swedish transport planning in general and investment planning in particular for decades. However, in the most recent investment plan the Government had declared that CBA results should carry more weight, and would also affect the allocation of funds between road and rail investments. Earlier, each mode of transport had had pre-specified total budgets, so CBA results could in principle only affect the ranking of investments within each mode. This made the Road and Rail Administrations, who were responsible for delivering the investment plan proposal to the Government[2], devote considerable effort to ensuring that the CBA process and methodology were developed further and, above all, were comparable between modes. This was not only limited to parameters such as values of time or emissions, but also scenario assumptions (future population, fuel prices etc.), methods for calculating investment costs, presentation of results etc[3]. A large number of stakeholders were involved in various ways in the process of selecting which investments should be included in the plan, ranging from counties and regions to different interest groups, although it was the Rail and Road Administrations that had the final decision of which investments were included in the national plan proposal, and the county organizations had the final decisions regarding the regional plan proposals. The entire plan proposal was then eventually handed over to the Government for decision.

Out of a total of 600-700 suggested investments, 480 made it as far as having complete CBAs carried out.

Swedish transport modelling and CBA methodology

SAMPERS is the national transport model for person trips, covering all types of domestic person trips. First developed around 2000, SAMPERS is the official Swedish transport model used by virtually all public authorities. This has the benefit that virtually all analyses of transport investments or transport policy measures are comparable with each other, even if the analyses are carried out by different authorities or interest groups. SAMPERS consists of five different regional sub-models for short-distance trips and one national sub-model for long-distance trip. The demand models are nested logit models, while the assignment to the road and transit networks is carried out with EMME/2.

Car ownership and the composition of the car fleet are fundamental factors for the development of traffic. This is modelled by separate models connected to SAMPERS. The car ownership model calculates probabilities based on different socio-economic characteristics, and the price of gasoline, and writes up car ownership from year to year based on population trends, income and gasoline price development. The car fleet model describes the development of the car fleet as a result of scrapping and new vehicle sales.

[2] Previously, the Road Administration and the Rail Administration had carried out their planning more or less independently. This time, however, they carried out the entire planning process jointly. The Road and Rail Administrations will be merged into a Transport Administration in April 2010.
[3] The Rail and Road Administrations were already using the same transport models (SAMPERS for person traffic and SAMGODS for freight traffic, described below).

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New car sales will depend on the car models available in the market and their properties. The calculation results in a breakdown on different car models from different years, with various fuels and fuel consumption. Average consumption, average vehicle cost per km and average carbon dioxide emissions can then be calculated.

SAMGODS is the official national freight model. It operates on a much coarser geographical scale than SAMPERS (288 Swedish zones and ca 160 zones abroad), and has a rather simplistic model structure. Freight volumes per origin-destination (O-D) pair are calculated by adjusting a prior O-D matrix with the change per economic sector using an external multiregional input-output model. The resulting freight volumes per O-D pair are hence not sensitive to changes in transport costs. O-D volumes are then assigned to transport chains (combinations of modes and routes) with a deterministic assignment model (STAN).

Effects for a studied investment are quantified, monetized and discounted in the model SAMKALK. This model is integrated with SAMPERS. Most road investments (the ones that are less complex) are however analyzed in the easier to use model EVA. EVA is fed with traffic growth figures from forecasts made in SAMPERS. There are also easier to use models for less complex rail investments.

The CBA parameters – benefit valuations, discount rate etc. – are decided by representatives from a number of public authorities, using advice and results from commissioned researchers. The CBA guidelines are summarized in the so-called “ASEK report”, and are supposed to be used for all transport-related CBA in Sweden. For the latest ASEK report (2008), efforts were made to harmonize Swedish values and practices with the recommendations of HEATCO (2006). Below is a table presenting some of the more important parameters.

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Table 1: Some of the parameters used in Swedish transport-related CBAs. Source: SIKA (2008). 1 SEK is roughly € 0.1.

Value of time	Private trips <10 km	51 SEK/h
	Private trips >10 km	102 SEK/h
	Business trips	275 SEK/h
Value of lives and injuries	Life	22.3 MSEK
	Severe injury	4.15 MSEK
	Light injury	0.2 MSEK
Emissions[4]	Carbon dioxide	1.50 SEK/kg
	Particles	11 494 SEK/kg
	VOC	68 SEK/kg
	SO2	333 SEK/kg
	NOx	36 SEK/kg
General parameters	Discount rate	4%
	Producer/consumer price conversion factor	1.21
	Appraisal period	40 years

3. THE IMPACT OF RELATIVE VALUATIONS

Considerable research efforts are spent on measuring monetary valuations of time, safety, emissions etc. Nevertheless, the relative weight of these benefits will always be a controversial issue. The assumption in the CBA methodology that there is an explicit and fixed trade-off between saved lives, travel time gains and carbon emissions is admittedly somewhat baffling, and is often mentioned as one of the main criticisms of the CBA approach as such. Baffling as it may seem, most planners would agree that at some level, such trade-offs still have to be made (and are made, implicitly or explicitly) whenever decisions are made. Many have argued that one of the virtues of CBAs is that the trade-offs are explicit and hence can be challenged.

This debate is not the issue in this paper. Rather, we want to shed some light on the issue by asking: How much is the CBA ranking affected by the relative weight of different types of benefits? We focus on valuation of travel time, traffic safety, emissions and freight benefits since these effects are the dominant posts of most CBAs and many are difficult and/or controversial to value. Consequently, these valuations vary a lot between countries (HEATCO 2006).

[4] Values depend on geographical area (except for carbon dioxide), among other things on exposure rates. The values relate to the inner city of Stockholm.

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Method

A database was collected for all the 480 suggested investments in the latest Swedish investment plan process for which complete CBAs had been carried out. It comprised of 417 road investments (32 made with SAMKALK and the rest with EVA or similar models) and 63 rail investments. Each investment had information on calculated total costs and on benefits subdivided into different types.

Varying weights for types of benefits was a straightforward task, done by multiplying the corresponding benefits with 50 or 100 percent. In order to differentiate within a benefit type the share of traffic for business/private, long/short distance and work/other purpose needed to be imputed for each investment. For all road investments the shares used for business/private and for long/short distance were the default recommendations for EVA. For the rail investments these shares were gathered from the national travel forecast for the rail lines closest to the investment in question. The share of work/other trip purposes were the mean shares for car and rail, respectively, according to the Swedish national travel survey.

Results – relative weights for types of benefits

We will change the relative weights on four types of benefits: freight benefits (saved transport times, transport costs and delays), traffic safety benefits (saved statistical lives and injuries), emissions (reduced emissions of carbon dioxide, NO_x, SO_2, particles etc.) and person travel times (all trip purposes). As a background, the different effects share of the total benefits of the national investments in the latest Swedish investment plan is shown in the table below.

Table 2: Share, for different groups of effects, of the total benefits of the national investments in the latest Swedish investment plan.

	Road	**Rail**
Accessibility	90%	103%
Traffic Safety	14%	5%
Emissions	0%	14%
Producer surplus and budget effects	3%	-26%
Noise	N/A	5%
Maintenance	-6%	0%
Sum	**100%**	**100%**

Accessibility consists of both benefits for freight and personal travel. It is the dominant effect, accounting for about 90 percent of total benefits. For road investments, traffic safety effects are the second most important effect. For railway investments reduced emissions is the second most important benefit. The negative figure under budget effects is due to reduced tax revenues when lorry transport and car journeys move over to rail. Roughly, it is equivalent to the corresponding benefits in terms of road safety, noise and emissions, the

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reason being that these effects are to a high degree internalized by taxes (including fuel taxes).

In varying the relative weights, the value of a particular type of benefit is increased by 50% and 100%, while all other valuations are held constant, hence changing the relative weight of that particular benefit (or rather, group of benefits). The original ranking is then compared to the ranking where the valuation of a particular type of benefit has been increased, and we check how large fraction of the top-ranked investments differ between the two rankings (we check the top-ranked 50, 150 and 250 investments), and similarly for the lowest-ranked investments. Finally, Spearman's rho is used to simultaneously compare the rankings in their entirety. Spearman's rho, while a more complete and powerful test than merely checking "top lists", has the disadvantage of being hard to interpret. Results are found in the table below.

Table 3: Number of investments for which the ranking differ and Spearman's rho when valuations are increased by 50 and 100 percent respectively.

	Freight benefits +50%	Freight benefits +100%	Traffic safety benefits +50%	Traffic safety benefits +100%	Emission benefits +50%	Emission benefits +100%	Person travel time benefits +50%	Person travel time benefits +100%
Changes in Top 50	7	10	5	11	3	4	7	9
Changes in Top 150	8	14	15	22	1	5	7	11
Changes in Top 250	8	13	15	27	3	5	12	21
Changes in bottom 150	4	9	12	18	2	4	7	15
Spearman's rho	0.99	0.98	0.98	0.95	1.00	1.00	0.99	0.97
Median NBIR[5]	0.20	0.29	0.30	0.50	0.13	0.12	0.45	0.76

From the table, we can conclude that the CBA ranking is surprisingly stable. A very large majority (in most cases around 90%) stays in the top-ranked segment even if any particular valuation is doubled. Even if the valuations in a CBA are uncertain by nature, a doubling is a very large change – well beyond the typical difference between different valuation studies (although this obviously varies). The impact of changing relative valuations is different for different benefits, though: varying the value of traffic safety affects the ranking the most, while varying the value of emissions affect it the least.

Though the focus here is on rankings it is also interesting to study how the absolute benefit-cost ratios are affected. One reason is that CBA results sometimes seem to play a

[5] NBIR means Net Benefit/Investment cost Ratio and is the measure used in Swedish CBA practice. The NBIR differs from the benefit-cost ratio (BCR) in that the BCR includes maintenance costs in the denominator, and (less importantly) in that an investment increases welfare if BCR>1, while it suffice that the NBIR>0.

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particularly important role as a screening tool, helping planners to avoid investments with negative net benefits (see Eliasson and Lundberg, 2010). The median NBIR for all investments in the original list was 0.14, when doubling the value of benefit types it increases up to 0.76 (for personal travel time). This is not surprising since person travel time benefits is the dominant benefit for most investments. The reason why increased emission values decreases median NBIR is that a majority of the projects leads to (slightly) increased emissions (note that the shares in Table 2 only relates to the investments entering the final plan proposal). Thus, CBA outcomes in absolute levels are less robust than rankings.

The balance between investments in different transport modes often attracts political interest. Table 4 shows that the balance is rather robust for changes in valuations. In the original list 21 of the top ranked 100 investments are rail. This share increases to 24 or 23 when freight or emissions values are doubled. The reason is that a few freight rail investments enter the list, since they reduce freight costs or transport times and shifts transports from lorry to rail (thereby reducing emissions). When traffic safety or person travel time is doubled the share of rail decreases to 17 since road investments with either high traffic safety or travel time benefits enter the list. Thus, even when the value of different benefit types is doubled the balance between modes only changes slightly.

Table 4: Number of rail investments among top 100 when valuations are doubled.

	Original list	Freight benefits +100%	Traffic safety benefits +100%	Emission benefits +100%	Person travel time benefits +100%
Rail investments among top 100	21	24	17	23	17

Results – relative weights within benefit type

So far only the relative valuation of *types* of benefits has been varied. There are also uncertainties as to the valuations *within* each benefit type – for example, how travel time savings for work trips should be valued relative to business trips or leisure trips. As stated above, trading different types of benefits against each other seems to be more philosophically controversial (see Hansson, 2007) than assuming that valuations within a benefit type, such as different types of travel time, have relative weights. Further, we are inclined to believe that there are methodological arguments for being a little bit skeptical against the certainty of relative valuations; valuations of different types of benefits are typically obtained using different methods and in different choice contexts, and it is not unreasonable to think that this may introduce a certain bias (in any direction) between relative valuations. Hence, it is a rather comforting conclusion that CBA rankings do indeed seem fairly stable as to changes in relative valuations – at least in the context of investment ranking.

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HEATCO (2006) states that it is ideal to disaggregate value of time by journey purpose, income, distance, and modal comfort. This has been done in a new Swedish value of time study (Börjesson and Eliasson, 2011b). The currently used values and suggested new disaggregate values are shown in Table 5. Note that there is no differentiation for income since the new study found that income differences have a relatively small effect in the value of time differences between the relevant travel segments.

Table 5: Currently recommended values of time in Sweden (in SEK) and values according to new study. Only private trips, long distance > 10 km.

	Current VoT	New VoT study
Long distance, road	102	109
Long distance, rail	102	75
Short distance, road, work	51	97
Short distance, rail, work	51	65
Short distance, road, other	51	67
Short distance, rail, other	51	53

Table 6 shows how rankings are affected by varying the values of time. The overall impression is that differentiating the value of time hardly affects ranking. Increasing the value for long and short distance trips respectively affect ranking similarly, even though the value of time for long distance is twice as high. The largest effect is found when increasing the value for “other” private trips (i.e. not commuting or school trips). The simple explanation is that these purposes constitute the majority of the trips. One might expect that increasing the value for business trips would have a large effect since the value of time is much higher than for private trips. However, since the share of business trips is low, ranking is hardly affected.

Nor do the new value of time study change rankings much. Since values of time for road trips increases more than for rail (the value for long distance rail even decreases) one might expect the share of rail investments among the top ranked 100 to decrease. Somewhat surprisingly however the share is unchanged, one rail and two road investments are replaced by other investments in the same modes.

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Table 6: Number of investments for which the ranking differ and Spearman's rho when valuations are increased by 50 percent respectively.

	Long distance +50%	Short distance +50%	Work trips +50%	Other private trips +50%	Business trips +50%	New VoT study
Changes in Top 50	1	2	1	3	1	1
Changes in Top 150	3	3	2	4	3	5
Changes in Top 250	7	7	4	9	5	5
Changes in bottom 150	5	3	3	4	2	4
Spearman's rho	1.00	1.00	1.00	1.00	1.00	1.00
Median NBIR	0.27	0.24	0.19	0.32	0.22	0.23

The valuation of carbon dioxide emissions is very complex and controversial and the recommended valuations vary a lot (see HEATCO 2006, pp 116-117, for a discussion). Therefore all investment suggestions in the latest Swedish transport investment plan were analyzed with two carbon dioxide valuations (the standard value of 1.5 SEK/kg[6] and an alternative value of 3.5 SEK/kg, i.e. more than twice as high). In summary, the impact on the benefits of road investments was small and did not change more than a few percent. How the benefits of rail investments changed depends on how much freight moves from road to rail. For some rail investments this constitutes a large share of the overall benefits, and then the alternative valuation makes a big difference[7]. All in all however, the rankings are robust when altering the value of carbon dioxide. This conclusion is in line with findings from Timms et al (2002) stating that the choice of optimal transport strategies for cities is relatively insensitive to the costs of externalities.

4. THE IMPACT OF CLIMATE POLICY ASSUMPTIONS

Future taxes on vehicles and fuels and other climate policy assumptions are very uncertain indeed and are intensively debated in Europe and elsewhere. In the work with the latest Swedish National Transport Investment plan several such scenario assumptions were tested[8]:

- higher oil price

[6] Note that the valuation used in Swedish transport CBA is a lot higher than in most other European countries.
[7] Note however that the method used for evaluating increased track capacity for freight traffic in Sweden is more uncertain than most other types of benefit calculations (Swedish Rail Administration and Swedish Road Administration, 2009a).
[8] See Swedish Rail Administration and Swedish Road Administration (2009b) for a more comprehensive discussion.

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- slower technological development of cars
- higher car ownership
- a package of policy measures to reduce green-house gases (GHG).

Method

What *oil price* assumption should be made was subject to a lot of debate in the plan process. For the baseline scenario, it was assumed that the crude oil price would remain unchanged between 2006 and 2020, at around $62 (2006 price level), following the then-current forecast from the International Energy Agency (November 2007). In an alternative scenario, the oil price was assumed to roughly double, to $120 in 2020 and to $150 in 2040.

Another controversial assumption in the baseline scenario was that the *technological development of cars* would be rather rapid. By the year 2020 the share of plug-in hybrids (i.e. cars running largely on electricity) in the total car fleet was expected to be roughly 10 percent and the share of ethanol driven cars 23 percent. In an alternative scenario this development was slowed down – through assumptions on higher prices for ethanol (+38 %) and no plug-ins at the market.

Policy measures aimed at holding back a trend towards increasing *car ownership* are often discussed. In the base-line scenario the car ownership increased slowly compared with current trends[9]. In an alternative scenario car ownership increased with approx. 7 percent more.

In the baseline scenario, a package of rather strong *policy measures* leading towards a reduction of emissions of green-house gases (GHG) was assumed. The reason was that the Transport Administrations anticipated such a political will in the future. Included in this package were measures such as a distance-based tax on lorries (approx. 1 SEK/km), increased fuel taxes and increased vehicle taxes, differentiated with respect to fuel consumption. The increased taxes resulted in an increase in real petrol price of 38 percent from 2006 to 2020 and a corresponding rise of diesel price of 64 percent. Since these policy measures was very controversial and not decided upon politically, an alternative scenario with no new policy measures towards reduced GHG was constructed.

Results

The table below summarizes the effects of the alternative scenarios for typical road and rail investments with 100 percent of their benefits for personal and freight transport respectively.

[9] This was the unintentional result of unrealistic input data to the simulation model for car ownership. In an alternative scenario, in order to give a more realistic forecast on car ownership, this input data was adjusted.

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Table 7: Change in benefits from four alternative scenarios for typical road and rail investments with 100 % of their benefits for personal and freight transport respectively.

	Road, person	**Road, freight**	**Rail, Person**	**Rail, freight**
Higher oil price	-5%	-5%	2%	4%
Slower technological development	-3%	-	1%	-
Higher car ownership	5%	-	-1%	-
No policy measures on GHG	7%	2%	-2%	-4%

The result is that the benefits for a typical road investment decreases with approx. 5 percent and increases with approx. 4 percent for a typical rail investment in the scenario with higher oil prices. The main reason why the effect is not bigger is that the underlying oil price constitutes a rather small share of vehicle cost per km (fuel taxes and cost of wear were assumed unchanged). Another reason is a rebound effect; when petrol gets more expensive people tend to buy cars that consume less (or use alternate fuel sources).

The scenario with slower technological development for cars gives only a small change in benefits for road and rail investments. Benefits decrease with almost 3 percent for a typical road investment and increase with 1 percent for rail.

With increasing car ownership the benefits for road investments increases with approx. 5 percent while the benefits of rail investments decreases marginally (approx. 1 %). This effect is comparatively big since the change in car ownership was rather modest. Note that the impact on benefit can be several times higher for investments that reduce severe congestion in the road network. This is since small changes in traffic flows often have a high impact on travel times when traffic is close to road capacity.

In the scenario without policy measures to reduce GHG emissions the benefits increased with approx. 7 percent for most of the road investments, and decreased with approx. 2 percent for rail investments. This is true for personal traffic, for freight oriented investments the benefits increase with approx. 2 percent for road and decrease with approx. 4 percent for rail. Like in the previous scenario the impact is higher for investments that reduced severe congestion in the road network.

Table 8 shows how rankings are affected in the different scenarios. Almost no changes appear in the lists. This is not surprising since changes in total benefits were rather small.

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Table 8: Number of investments for which the ranking differ and Spearman's rho in four alternative climate policy scenarios.

	Higher oil price	Slower technological development	Higher car ownership	No policy measures on GHG
Changes in Top 50	1	0	0	0
Changes in Top 150	2	1	2	3
Changes in Top 250	2	1	1	2
Changes in bottom 150	1	0	2	3
Spearman's rho	1,00	1,00	1,00	1,00

The conclusion from all of these tests is that CBA results are fairly robust with respect to these scenario assumptions. Even rather drastic assumptions, such as a doubled oil price, change the benefits with only a few percent. The exception seems to be car ownership where the change of scenario assumption was relatively modest.

5. CONCLUSIONS

The question for this paper is if ranking is sensitive to alternative climate policy assumptions and valuations and thus if decision makers can feel secure that CBA results are robust. We find that CBA rankings are surprisingly robust, even for the rather drastic changes we have tried such as doubling the relative weight for one benefit type. There is little evidence to suggest that any valuations ought to change that much. The alternative scenario assumptions tested are probably not beyond what is realistic, but a measure such as increasing the fuel taxes with roughly 50 percent would come at a high political price.

As a rule of thumb, doubling the weight of a certain type of benefit only changes around a tenth of a given top ranking list. Some explanations are that existing demand constitutes a large share of future demand, that changes often have a rebound effect (one example being that increased fuel price results in increased demand for more fuel efficient cars) and that most investments are used by many different categories of traffic.

A few of the sensitivity tests gave results that deserve more discussion. Varying the valuation of traffic safety had a surprisingly big effect on ranking considering its small share of total benefits. The simple explanation is that traffic safety constitutes the dominant benefit type for some investments on the list. Differentiating the value of time (which lies behind the dominant benefits) does not alter rankings much, not even the balance between rail and road. The explanation is that most investments serve a mix of purposes (such as improving commuting and interregional travels as well as distribution traffic and long-distance freight).

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When the value of time is varied, it is the value for other trip purposes (i.e. not work or school) that has the biggest impact. This undermines something that is often neglected in the public debate – that other travel purposes than commuting dominate the use of, and thus benefits from, a road or rail investment.

Overall, our conclusion is that decision makers can indeed feel secure that following the CBA methodology will lead to sound investments being prioritized. The top-ranked investments are more or less the same in all sensitivity tests. This is a rather comforting finding. As long as budget constraints are strong, so that the very worst suggestions are avoided, the CBA method will sort out sound investments. In other words, even if decision makers pick second best solutions these are likely to be good ones. However, the CBA results should not be the sole decision criteria. One reason is that some types of benefits are systematically underestimated; another is that the method, per definition, does not take effects on equity into consideration.

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