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Finding transport projects with high value for money – what are the socio-geographic determinants?

VTI Working Paper 2021:4

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Abstract

We use cost-benefit data from 1052 projects in Norway and Sweden to analyse ex ante factors that can explain which characteristics of transport infrastructure projects explain high value for money. The aim is to identify characteristics that can be used in assessments of projects before a cost-benefit analysis is feasible. We find that in Norway, road toll financing is a good indicator of high value projects, especially in the poorer municipalities. In Sweden, co-financing serves to raise investment volumes, but tends to lead to worse value for money. In Sweden, congestion seems to be the biggest problem in medium-income municipalities, while there are traffic safety benefits to be obtained in the rural areas. A higher initial capacity on a link raises both benefits and costs, and costs are higher in more densely populated areas in both countries. We find diminishing economies of scale in Norway and increasing economies of scale in Sweden.

Keywords
CBA, Transport infrastructure planning, value for money

JEL Codes
R40, R42

Finding transport projects with high value for money – what are the socio-geographic determinants?

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Long abstract: Cost-benefit analysis (CBA) is an important part of the appraisal of transport projects in most countries, and ideally, from an economic perspective the discounted sum of social benefits in projects selected for implementation should be higher than the social costs of implementation and operation. However, studies from several countries have shown that many projects are selected for implementation despite negative net benefit-cost ratios.

One reason inefficient projects are not filtered out in the planning process may be that CBA is not carried out until some time into the appraisal process, when it is possible to produce cost estimates and traffic forecasts with an acceptable degree of accuracy. By then, stakeholder expectations may have grown to a point where project approval becomes inevitable, and thus, decision-makers are locked into a process where final project approval is the only acceptable option.

There may therefore be a need for an early screening tool to identify potentially good projects and weed out bad ones before a full CBA can be carried out. The purpose of this study is to identify characteristics of projects and their environments that are discernible at an early point (before the project even exists) and that may indicate whether the project will deliver good value for money.

This paper uses data from CBAs of 1052 road projects in Norway and Sweden that were considered for inclusion in various national transport plans from 2010 to 2033. The aim of the paper is to identify factors that can explain why projects yield a high value for money, or whether projects with a high value for money have special characteristics. We estimate a model that is based on indicators that do not require modelling or estimation of the explanatory variables. The testing of our four

hypotheses will help transport planners to identify project alternatives that should be developed further and ones that should be rejected.
The empirical results lend some support to the hypotheses. We find that in Norway, benefits are highest in poorer municipalities that agree to road toll financing of projects. In Sweden, the benefits from a project are highest in municipalities with intermediate levels of median net income. Moreover, there are traffic safety-related benefits to be found in the rural areas in Sweden. A higher initial traffic volume or capacity also increases the benefits from an investment.
Costs, in turn, are highest on the busiest links or where the already existing capacity is highest, and in more densely populated areas in both countries. For Norway, we find diminishing returns to scale, while there may be increasing returns to scale in Sweden, except with respect to the *ex ante* busiest links, where there seem to be decreasing returns to further increases in capacity. Regarding road toll and co-financing of projects, we find that in Norway, road toll financing is used to signal projects with high value for money, while in Sweden, co-financing is used merely to raise the investment value, thus creating space for projects with less value for money. In general, we note that it is surprisingly difficult to find general features or characteristics of projects that produce high value for money.

Short abstract (max 150 words): We use cost-benefit data from 1052 projects in Norway and Sweden to analyse *ex ante* factors that can explain which characteristics of transport infrastructure projects explain high value for money. The aim is to identify characteristics that can be used in assessments of projects before a cost-benefit analysis is feasible. We find that in Norway, road toll financing is a good indicator of high value projects, especially in the poorer municipalities. In Sweden, co-financing serves to raise investment volumes, but tends to lead to worse value for money. In Sweden, congestion seems to be the biggest problem in medium-income municipalities, while there are traffic safety benefits to be obtained in the rural areas. A higher initial capacity on a link raises both benefits and costs, and costs are higher in more densely populated areas in both countries. We find diminishing economies of scale in Norway and increasing economies of scale in Sweden.

Keywords: CBA, Transport infrastructure planning, value for money
JEL codes:
Declarations of interest: none
Acknowledgements: The authors thank Gunnar Lindberg and the participants at a VTI seminar on 17 February 2021 for comments on an earlier draft of the paper. Börjesson and Hammes have been financed by Transportföretagen.

1 INTRODUCTION

Most countries spend significant resources on the construction and maintenance of roads, railways and other transport infrastructure. The economic merits of proposed projects are usually estimated through social cost-benefit analysis (CBA) where costs and benefits are aggregated into a single measure in monetary terms, e.g. the net benefit-cost ratio (NBCR). CBA is useful because it allows for the comparison and ranking of a large number of projects based on an objective methodology. However, the final investment decision is a political one, which may explain why many projects with negative value for money are implemented annually. This results in inefficient allocation of economic resources, both because many projects with low value for money are built and some investments with high value for money are not implemented (Eliasson et al., 2015). Decision-makers in both Norway and Sweden claim that CBA is given weight, but empirical evidence indicates that this is at best a partial truth. The aggregate net present values in both the Swedish and Norwegian national transport plans for 2018–2029 were strongly negative (Welde & Nyhus, 2019; Swedish Transport Administration, 2018), nor have earlier studies found much evidence of practical use of CBA results in decision-making (Odeck, 1996; 2010; Fridstrøm & Elvik, 1997; Nilsson, 1991; Eliasson et al., 2015).

Eliasson et al. (2015) find that in Sweden, CBA has an impact on the selection of projects to the shortlist of candidates presented to decision-makers. However, once a project has made it to the shortlist, the CBA outcome has no impact. They find that in Norway, more projects with low value for money make it into the candidate list than in Sweden. And because the CBA outcome has such low impact on how decision-makers select projects from the shortlist, the results is low value from money of the transport plan. The Norwegian candidate projects have much lower average NBCR (-0,18) than the Swedish ones (0,36), and, furthermore, the selected Swedish projects have higher average NBCR (0.5 – 0.83) than the non-selected ones. This is not the case for the Norwegian projects where the NBCR for both the selected and the non-selected projects is equal. At the same time, Hammes and Nilsson (2016) show that while political factors have a large impact on the choice of projects in Sweden, it is also wrong to totally exclude the CBA outcome as an explanatory factor. These results imply that to increase the value for money of the transport plan, CBA must be carried out early in the decision process, preferably at the project generation stage. To be able to do this, there is a need for indicators of which transport investments generate high value for money. We stress that decision-makers of course must take other factors than value for money into account as well. However, this makes it even more important that the generated projects deliver high value for money, so that decision-makers can trust that all shortlisted projects deliver a reasonable value for money (Börjesson & Eliasson, 2015). Moreover, weeding out bad projects is just as important as identifying good projects, as otherwise bad projects may push out good ones due to budget constraints.

Thus, one possible explanation for poor selection efficiency is that comprehensive CBAs are carried out late in the project planning process, when the political cost of rejecting the project has grown too high. Cantarelli et al. (2012) use the term *lock-in* to describe the situation in which decision-makers are de facto committed long before any formal decision to build has been made. Early CBAs are rare, inaccurate and often produced by local promoters who may have an incentive to overstate benefits and underestimate costs. The identification of projects with high benefit-cost efficiency should be done before decision-makers are captured into an inefficient course of action. In such a process, insights into what characterizes a project with high value for money would be useful, but so far, such analyses have not yet been undertaken in the literature. The aim of the present paper is to explore what characterizes an infrastructure investment with high value for money. We analyse CBAs from a large number of Norwegian and Swedish transport projects from several stages of the planning processes.

There is a notion, often used as an argument against using CBA for project selection, that value for money will be higher in more densely populated areas such that more rural areas would miss out on infrastructure grants. We will test this notion. Comparing Swedish and Norwegian projects increases the generalizability of the results.

To our knowledge, early indicators that could support the project generation and early screening of project ideas have not been analysed in the previous research literature, with one possible exception. Halse and Fridstrøm (2019), through analyses of road projects included in the Norwegian national transport plans for the years 2010–2019 and 2014–2023, investigated why Norwegian road projects delivered poorer value for money than those in the neighbouring countries Denmark and Sweden. They suggested that the difference is a result of Norway's greater differences in altitude, longer coastline relative to its area, and lower temperatures. They also pointed to lower population density and a different settlement pattern as factors that may explain lower net benefit-cost ratios. On the other hand, Norway has higher traffic volumes (kilometres travelled) per inhabitant compared with its population and higher average income than Denmark and Sweden, which may increase the benefits of transport projects. Then again, higher income often also implies higher construction costs.

The evidence from Eliasson et al. (2015) from the 2010 planning processes showed that the value for money of the best Norwegian candidate projects was similar to that of the Swedish projects. However, the Norwegian list of candidate projects also included a long tail of projects with very low net benefit-cost ratios, which were not included in the Swedish list of candidate projects. Based on interviews with planners, Eliasson and Lundberg (2012) found indications that the projects with low value for money to some extent were eliminated in the project generation phase in Sweden, simply because the planners knew that benefit-cost ratios would be important for projects to be selected for the shortlist. In Norway planners probably knew that CBA outcome would not influence project selection, even when selecting projects for the agency-determined shortlist.

This study builds on the work of Halse and Fridstrøm (2019), but applies a different perspective. We investigate factors that can explain why projects are good in terms of value-for-money, or whether such projects have special characteristics. We estimate a model that can be used for early screening of project ideas so that transport authorities can identify project alternatives that should be developed further and those that should be rejected. The purpose is to establish early indicators of value for money so we can spend less resources on investigating unprofitable projects and increase the proportion of profitable projects selected for implementation.

The paper is organized as follows. Section 2 describes the CBA framework and the planning process in Norway and Sweden. Section 3 describes the method and Section 4 the data. Section 5 shows the results and Section 6 concludes.

2 THE ANALYTIC FRAMEWORK AND PLANNING PROCESS IN NORWAY AND SWEDEN

In this section, we first compare appraisal methodologies in the two countries and then discuss their planning and decision-making processes.

2.1 CBA models and calculation assumptions

The use of cost-benefit analysis (CBA) has a long tradition in both Norway and Sweden and is largely based on a similar methodology and principles.

Norway

In Norway, a CBA is required in the appraisal and planning of all major public projects, not only in the transport sector. The Ministry of Finance has issued a set of principles and requirements for such analyses (Ministry of Finance, 2014). The Norwegian Public Roads Administration (NPRA) has its own handbook, with accompanying software (NPRA, 2018). The handbook is also used by other transport agencies (the railway directorate, the coastal administration and Nye Veier Ltd.) and to some extent outside the transport sector.[1]

The transport agencies also manage a system of transport models. For passenger transport, the regional transport model (RTM) and the national transport model (NTM) are used for journeys shorter and longer than 70 km, respectively, and for the transport of goods the Norwegian freight model (NGM) is used. These are mathematical models that are based on empirical data, including national travel surveys.

[1] Nye Veier Ltd. is a government-owned limited company created in 2016. It is a construction company with the mission of prioritizing projects with high value for money.

The NPRA uses the EFFEKT software to calculate economic impacts. Costs and benefits are presented for four types of actors: 1) transport users, 2) operators, 3) government and 4) society at large (health and safety, environment etc.). The net present value and the net benefit/cost ratio are calculated. Table 1 presents some key prices and assumptions used in these calculations. The prices are found in Ulstein et al. (2020) and Ministry of Transport (2020) and will soon be included in the NPRA handbook (the handbook is being updated at the time of writing).

For non-monetized impacts, the NPRA handbook provides detailed guidance for how to assess impacts on landscape, outdoor/urban and rural life, natural diversity, cultural heritage and natural resources. Assessments are summarized using a scale from four minuses to four plusses.

So-called wider economic benefits are normally not included in the main calculation. Such impacts may be presented in a separate analysis when considered relevant.

Based on the estimated net present value, the non-monetized impacts and uncertainty, an overall assessment of the project's value for money is made. Additional information on distributional impacts, goal achievement and other considerations is provided when relevant.

Sweden

CBA has a long tradition in Sweden, too, and is mandatory in the planning of transport sector projects. The analyses are based on a similar theoretical framework as in Norway and other European countries.

The Swedish Transport Administration (STA) manages a set of transport models. For larger road investments, the SamPers forecasting model and the SamKalk impact model are used. For freight transport, there is a separate forecasting model, SamGods, with freight values for different product groups.

A set of common assumptions and parameter values to be used for all transport CBAs is published by ASEK (working group for CBAs in the transport sector). The current version is ASEK 7.0 (Swedish Transport Administration, 2020). Table 1 gives a summary of key assumptions.

In Sweden, too, there has been much debate about wider economic benefits. Such impacts may be included for certain types of projects. In some cases, the regional economic model SamLok is used to calculate the wider economic benefits that an investment can produce through labour market effects.

Non-monetized impacts should be presented and categorized as negative, insignificant or positive. Monetized and non-monetized impacts are weighted together in an overall assessment of the project's value for money. Furthermore, distributional impacts and an assessment of goal achievement are included as part of a broader appraisal framework called total impact assessment (TIA). TIA resembles a multi-criteria analysis, but without explicit weighting of the three parts. It is left to decision-makers to determine their relative importance.

Comparison: Norway vs. Sweden

The theoretical framework and CBA methodology is very similar in Norway and Sweden. There are, however, some differences in calculation prices and other key assumptions as shown below. Norway has traditionally used somewhat higher time values than Sweden, although the Norwegian values have been reduced in the most recent update (especially for short and medium journeys). The value of a statistical life (VSL) used to be higher in Norway but was recently adjusted upwards in Sweden and is now higher in Sweden. The social cost of carbon (SCC) (and several other environmental impacts) is also valued higher in Sweden than in Norway. The discount rate is slightly higher in Norway, and the cost of public funds is higher in Sweden.

Table 1 Calculation prices for Norwegian and Swedish road projects, expressed in euros, 2017 price level

Type of impact	Norwegian values, based on NPRA (2018), with some updates in Ulstein (2020) and Ministry of Transport (2020)	Swedish values, based on ASEK 7.0
Value of time, euros per hour	Business travel (based on valuation study) • 45.1/44.7/52.5 for short/medium/long journeys by car, all values are lower for train and bus, higher for walking / cycling To/from work (based on valuation study) • 7.1/15.4/21.5 for short/medium/long journeys by car, similar values for train and bus, higher for walking / cycling Leisure (based on valuation study) • 5.5/9.6/14.1 for short/medium/long journeys by car, similar values for train and bus, higher for walking / cycling	Business travel (based on gross wages) • 32.8 for car, bus and air, slightly lower for train All private travel (based on valuation study) • 6.7/12.2 for journeys by car below/above 100 km, 9.8 for travel to/from work <100 km. Lower for public transport, higher for walking / cycling Freight • Value per tonne-hour (varying between 0–1.92 depending on product group) or value per means of transport per hour

	Freight • As business travel, plus time-dependent operating cost 64.5 for heavy vehicles (separate freight values may be introduced in the future, which will give a higher valuation of freight transport than today.)	(0.21-2.46 depending on means of transport). These values are added to the vehicle's time value (i.e. driver's wage)
Accidents/value of a statistical life (VSL), euros	2.9 million	4.3 million
Social cost of carbon (SCC), euros per tonne CO2 equivalent	• Price path starting at 140 in 2020 • Increasing in line with GDP growth per capita	• Fixed SCC (no real price adjustment) 700 in main calculation • 1500 in sensitivity analysis
Real price adjustment	Yes, several impacts (including SCC) are adjusted by expected GDP growth per capita.	Yes, several impacts (including those based on willingness to pay) are adjusted by GDP growth per capita, or by specific indices
Uncertainty	• Stochastic estimation used for investment cost • Sensitivity analysis recommended for investment cost and annual traffic growth	• Stochastic estimation used for investment cost • Sensitivity analysis mandatory for investment cost, carbon price and traffic growth
Discount rate	Risk-adjusted discount rate, 4% (first 40 years), then 3% (years 40-75) and 2% (after 75 years)	Risk-adjusted discount rate 3.5%
Project lifetime, period of analysis and residual value	• Lifetime 75 years for motorway projects, 40 years for others • Period of analysis 40 years • Residual value captures the last 35 years. Calculated on the basis that benefits and cost flows continue during the residual value period	• Lifetime normally 60 years for new roads (lower for specific components) • Period of analysis normally equals economic lifetime • In cases when a residual value is needed, this should be calculated on the basis that benefits and cost flows continue during the residual value period
Cost of public funds	1.2	1.3

As shown in the table, some valuations are higher in Norway and others in Sweden. The total effect on net present value will depend on the specific project. When time savings is a key element (which is often the case), benefits will usually be higher with the Norwegian values. This is primarily due to GDP and income levels being higher in Norway. The flip side of the coin, however, is that construction costs are also generally higher in Norway, thus the effect on NPV evens out. The higher construction cost level is explained partly by higher income levels and partly by natural conditions (topography, terrain and soil conditions, climate etc.). Productivity differences in road construction has also been mentioned, for example the fact that Sweden typically uses larger contracts (NPRA, 2017). Large contracts in turn can be expected to lead to economies of scale, as demonstrated e.g. by Link (2006) for highway renewal in Germany and Wheat (2017) for road maintenance in the UK.

Overall, the differences in prices and assumptions are relatively small and should not significantly affect the prioritization of projects.

2.2 The planning and decision-making process

The planning and decision-making processes for transport projects in Norway and Sweden also have common features, but at the same time some significant differences.

Norway

Transport planning is closely linked to the National Transport Plan (NTP), which is a 12-year plan for road, rail, sea and air transport that is renewed every four years. The plan is presented to the Parliament as a white paper, based on a proposal from the transport agencies. The current transport plan covers the period 2018–2029 (Ministry of Transport, 2017).

Large projects are mentioned explicitly in NTP, and projects with construction costs exceeding NOK 1 billion (EUR 92.2 million) must include a *conceptual appraisal* (CA) with external quality assurance (QA1). This is part of a formal governance scheme managed by the Ministry of Finance (Ministry of Finance, 2019). Both CA and QA1 should include a CBA. However, the final decision to include a project in the plan is political, and the scheme cannot stop an unprofitable project from being selected.

Road projects are often a result of local initiatives and most of them have a long history before entering the NTP. The CA/QA1 scheme was established to ensure a more systematic approach to front-end planning and to give the national government more control. This has been achieved to some extent, but there is still a tendency to focus more on specific projects than on problems and needs at this stage (Samset & Welde, 2019).

In the pre-project phase, the detailed design of the road is clarified through a zoning plan. This is done in accordance with the Planning and Building Act, which gives the local government decision-making authority. Norwegian municipalities thus have considerable influence on the final solution, although the NPRA usually develops the plan. At this stage, a new CBA of the more detailed project is also performed.

The NTP is not a binding budget document. Each project must receive funding in the annual state budget. This only happens after an external quality review of the cost assessments and the steering document (QA2) as well as, if necessary, a local government approval of the road toll-funding scheme. Figure 1 shows the Norwegian planning process in conceptual form.

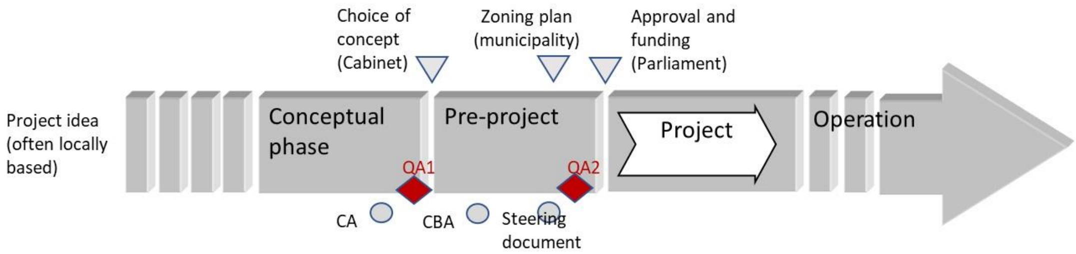

Figure 1 The planning process for major road projects in Norway (source: the authors).

Sweden

Road project planning in Sweden is also based on a 12-year investment programme that rotates every four years, the National Plan for the Transport System (NPTS). The current plan covers the period 2018–2029 (Swedish Transport Administration, 2017; Government of Sweden, 2018). The planning system was revised in 2014 due to legislative changes taking effect 1 January 2013 (Swedish Transport Administration, 2014).

Unlike in Norway, one agency (the STA) covers all modes of transport. It is usually the STA that initiates projects at an early stage, based on stated transport policy goals and guidelines. The exception is projects that are pre-selected by the government.

Since 2013, the process has started with the Parliament setting the financial framework for the plan. Subsequently, the STA investigates problems and solutions. For larger projects, this is done in the form of a so-called measure choice study (*åtgärdsvalsstudie*). The measure choice study has similarities with the Norwegian CA and is intended to ensure that a wide perspective is taken on possible ways to solve a problem. If the ÅVS concludes that there is a need for investment, a TIA (as defined in Section 2.1) is performed.

In the NPTS, large projects are subjected to three types of analyses that constitute the TIA: the CBA, a distribution analysis and a transport policy achievement analysis. There is no external quality assurance of each project, but the plan as a whole is reviewed by another government agency, Transport Analysis.

When a project is prioritized in the NPTS, an environmental impact assessment (EIA) is carried out and must then be approved by the county governor (i.e. the government's representative in each county). It must also be ensured that a new road is not built in contravention of municipal plans, yet the role of the municipalities is nevertheless less formalized in Sweden, and the Transport Administration is not dependent on having to adapt to local needs to the same extent as in Norway.

In the same way as in Norway, the NPTS is not a binding budget document. Traditionally, the Transport Administration has had considerable freedom in relation to the time of start-up and implementation of specific projects. Since 2013, this process has become somewhat more politicized as the government now makes annual decisions on the implementation and financing of individual projects for the next three-year period.

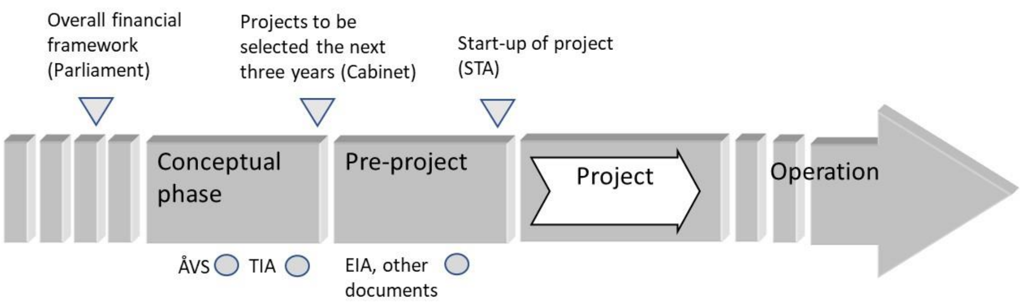

Figure 2 The planning process for major road projects in Sweden

Comparison

Both countries have long-term transport plans that are politically rooted, while the planning is largely delegated to the professional agencies.

Both Norway and Sweden have formal processes with clearly defined project phases and decisions, the Norwegian process including external reviews of analyses, with the Ministry of Finance in a gatekeeper role. As pointed out by Olsson et al. (2019), however, politicians may manoeuvre projects around these processes in both countries and use them only as a ritual exercise. The Norwegian QA scheme requires that CBAs be conducted but states no requirement to reject unprofitable projects.

A key difference between the countries is that in Sweden, there is a much clearer distinction, both formally and in practice, between the professional and political levels. The NPRA in Norway is closely linked to the Ministry of Transport and must follow political signals. In addition, local governments have had a very strong role in the planning process in Norway. Projects are often initiated locally, and NPRA depends on local policy decisions for route alignment and also for road toll financing when used. In comparison, the STA has greater degrees of freedom in relation to the political level, national as well as local (Welde, et al., 2013).

Transport planning is characterized by both analytical and political processes and it is important to try to understand the relationship between the two. Seen from the outside, both countries' planning and decision-making processes appear as rationally constructed and with considerable attention to analytical tools and models. But parallel to this is a communicative process characterized by multi-level political involvement, implying a risk that politically and often locally based logics dominate the rational-instrumental logic. This is especially true in Norway, but the trend is for more political involvement in Sweden as well.

There may be some contradictions between value for money and other considerations such as regional development policy. But if this explains the lack of adherence to CBA, we should expect a thorough and systematic investigation of a project's impact in those perspectives. Welde and Nyhus (2019) found, however, that goal achievement and distributional effects were hardly discussed in NTPs. It is therefore often unclear why a certain project has been selected, although political considerations clearly play a role (Hammes & Nilsson, 2016; Helland & Sørensen, 2009). According to Welde et al. (2013), there is no indication that high-valued projects are systematically better than low-valued projects in terms of goal achievement or distributional effects.

There is therefore reason to believe that an earlier indication of projects' value for money, before politicians have been locked into a certain choice, would contribute to a more rational planning and decision-making process where value for money can play a real role as a decision criterion.

3 METHOD

In this section, we discuss which specific characteristics of transport infrastructure investments may have any systematic impact on the value for money. We are searching for determinants that can be observed in an early phase so that they can support planners in finding investments with high value for money. Moreover, we want to investigate whether there are systematic differences in the value for money of projects in regions with higher or lower population densities. Such systematic differences would be important to acknowledge from a policy perspective, since they would imply that some regions would be favoured over others if CBA would gain a bigger impact on decision-making. In the following text, variables used to test hypotheses are written in italics.

Value for money can be defined as the total benefits of an investment exceeding the social costs of building the infrastructure. In optimum, marginal benefits would equal marginal costs for all projects. Benefits (*B*) are usually estimated using consumer surplus (CS) as a measure. In the cost-benefit analyses (CBAs) underlying our data, consumer surplus is approximated by the rule of a half. This approximation is appropriate as long as the change in generalized cost is reasonably small so that the demand function is approximately linear. Assuming that the generalized cost of modes other than car/truck remains constant, the change in CS due to an investment can be written as

$$\Delta CS = \sum_{od} V_{od}^{0}(c_{od}^{0} - c_{od}^{1}) + ½ \sum_{od} (V_{od}^{1} - V_{od}^{0})(c_{od}^{0} - c_{od}^{1}),$$

where initial and final demands for car trips are V_{od}^{0} and V_{od}^{1}, respectively, and c_{od}^{0} and c_{od}^{1} are the initial and final generalized costs for car trips, respectively, in both cases from zone *o* to zone *d*. Δ denotes change. The first term represents the gain of existing users (the rectangle) and the second term the gain accruing to new users (the triangle).

The traffic volume on the link, k, where the investment is made, V_k, is the sum of the demand over all origin-destination OD *(o,d*) pairs (assuming that there is only one route choice for each OD pair) in the network,

$$V_k = \sum_{od} V_{od} \delta_{od}^{k},$$

where δ_{od}^{k} is 1 if link k is part of the route from o to d and zero otherwise. If the route choices in the network are not impacted by the investment, the change in CS will be:

$$\Delta CS = V_k^{0}(c_{od}^{0} - c_{od}^{1}) + ½(V_k^{1} - V_k^{0})(c_{od}^{0} - c_{od}^{1}).$$

Hence, we expect that the CS increases roughly proportionally to the initial volume V_k^0 (the number of beneficiaries) since the rectangle is usually much larger than the tringle given that the reduction in the generalized travel cost is constant across investments and if there are no changes in route choices in the network. Hence, under restrictive assumptions, the benefits are roughly proportional to the initial volume of the link. These assumptions will seldom hold, and the benefits will therefore not be proportional to the link volume, even if we expect the benefit to increase with the link volume. The proxy used for initial traffic volume, alternatively initial capacity on a link (see below), is average annual daily traffic, *AADT*.

The CS will also be roughly proportional to the size of the benefit per beneficiary, i.e. the reduction in the generalized cost for any given traffic volume. The reduction in the generalized cost will vary across investments. For projects primarily improving city environments by introducing e.g. a *bypass* or a bicycle lane, the reduction in the generalized cost might be small; this means that the benefits might be smaller, since benefits in terms of improved city environment are not included among the priced effects in the CBA. This impact is tested by including the variable *city environment* in the regression model. It takes the value 1 if the object contains a bypass or bicycle lane and zero otherwise. For investments in establishing shorter routes or shortcuts, the reductions in generalized costs might be large due to the value of time savings; this can be the case for investments such as a *tunnel* or a *bridge*. Other types of investments leading to time savings include *highways*, *expressways*, *flyovers*, *roundabouts* and *additional lanes*. The impacts of these variables are captured by two dummy variables, *time road* taking the value of 1 for highways and expressways and *time crossing* taking the value 1 for flyovers and roundabouts, and zero otherwise. Travel times using public transport (PT) are reduced by *PT lanes*, while *bus stops* increase accessibility, thus reducing the generalized cost. This is captured by including a dummy variable, *public transport*, which takes the value 1 for PT lanes and bus stops, and zero otherwise. There is however a problem of severe multicollinearity in the Norwegian data, with the correlation coefficient between *highway* on one hand and *expressway* on the other being 1. For this reason, only highways are included in the model for Norway. In the Swedish data there are no such problems, the highest correlation coefficients being 0.46 between *tunnel* and *noise* barriers and 0.60 between *noise* barriers and *bus stops*.

The size of the reduction in the generalized costs due to traffic safety improvements, such as meeting-free country roads (*MFCRs*, denoted 2+1 roads in Sweden), *additional lanes*, game fences and flyovers for game (*game*) is unclear but probably small. Nevertheless, these improvements reduce the generalized cost, thus increasing benefits. We lack data on these variables for Norway. For Sweden, they are captured in the dummy variable *safety*, which takes the value 1 if the object contains MFCRs, additional lanes, or game-related measures, and zero otherwise.

A final impact of great importance arises because of congestion. This is depicted in Figure 3: On a congested link (in black), travel time savings resulting from a capacity increase are usually larger than on a less congested link (in blue). The capacity increase on the road depicted in blue produces smaller travel time savings because the capacity constraint is lower in the first place. Unfortunately, we lack data on the levels of congestion, which is a function of the amount of traffic (*AADT*) and the capacity on each link. The capacity influences the maximum possible AADT. Instead, we have some proxies such as *population density*, with a denser population generating more traffic on any given link, *median net income*, vehicle kilometres driven increasing in higher incomes, and a *centrality index*, assuming that congestion is higher in municipalities with a higher level of service, e.g., those with a better access to banks, post offices, shops etc. The *centrality index* is obtained from Statistics Norway and the Swedish Agency for Economic and Regional Growth, respectively, and ranges from 0 to 1. The value 0 represents the most rural municipalities and the value 1 represents the highest level of centrality in terms of functions such as the size of the population and the presence of banks, post offices and other public services (in essence, the metropolitan areas). Note however that more central or dense locations are characterized not only by more congestion but also by other factors such as more pedestrians, cyclists or PT passengers who might benefit from reduced generalized costs, a safer traffic environment and reduced emissions. Hence, if we find larger benefits for more central or dense investments, we cannot tell what factors drive these impacts.

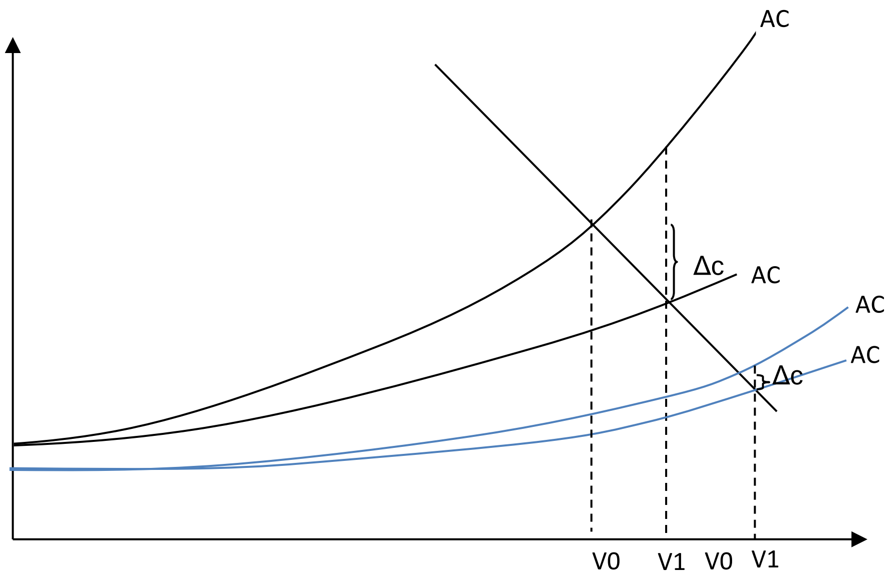

Figure 3. All else equal, higher congestion levels usually imply larger reductions in generalized cost of a capacity extension.

Costs comprise the other part of a CBA. Investment costs (*IC*) are affected by e.g. type of project (*bridge*, *tunnel*, *bike* project, *highway*, *MFCRs*, *regular road*, *expressway*, *additional lane*, *flyover*, *level crossing*, *interchange*, *bypass*, *thoroughfare*, *approach road*, *PT lane*, *game* measures, or *rest area*), its length and geographical factors such as *height difference* within a municipality, the presence of *mountains*, *length of coastline*, and *annual average temperature* and *rainfall* (mm) (Halse & Fridstrøm, 2019). Moreover, it may be that it is more costly to build where there is already a lot of traffic (high *AADT*) and in more densely populated (*population density*), more central (*centrality index*) and richer (*median net income*) municipalities, where land values tend to be high and buying land for a road is more expensive. It is also more costly to build if tunnels are required. The impact of tunnels and population density is controlled for by including an interaction for this effect in the regression models, the expectation being that tunnels in more densely populated areas may reduce costs. However, we only have data on tunnels for Sweden.

In the Norwegian data, multicollinearity may be a problem, however. The correlation coefficient between *population density* and *centrality index* is -0.63, and between *population density* and *AADT* it is 0.69. The correlation between the *centrality index* and *AADT* is -0.56. Multicollinearity should not be a problem for the Swedish data, as the highest correlation coefficients are 0.57 between *AADT* and *median net income* and 0.50 between *centrality index* and *median net income*.

The CS is also influenced by negative externalities arising from transport, such as noise and emissions of non-externalized pollutants like nitrous oxides and sulphur oxides. While the emissions remain non-internalized, there are attempts to reduce noise by building *noise* barriers. These raise the cost of an object.

It is also possible that there are economies of scale in building transport infrastructure projects. We attempt to capture these by including a proxy variable for the size of the project, *IC > median*, which takes the value 1 for projects with investment costs greater than the median and zero otherwise. A negative coefficient on this variable, i.e. that larger projects have lower costs, *ceteris paribus*, would lend support to the hypothesis of increasing economies of scale, whereas a positive coefficient indicates decreasing economies of scale.

Finally, we include a proxy for the political-economic context of infrastructure planning, i.e. whether projects that are co-financed by the region or municipalities have a systematically higher or lower value for money. For example, Flyvbjerg (2009) argues that to ensure the building of objects with high value for money, private financiers should participate without a sovereign guarantee. Public-private partnerships are not common in Norway or Sweden, however, even though some examples exist. Hammes and Mandell (2019) study two possible impacts of co-financing. First, they note that it is possible that co-financing even by municipalities or regions could be used to signal profitable investments. At the same time, their model also indicates that municipalities may use central government co-financing to increase investment volumes beyond what would be socially optimal. Börjesson and Kristofferson (2014) suggest that co-financing encourages the launching of projects with low value for money because all contributors take all benefits into account but only their own share of the costs. Finally, including road toll financing is necessary to deal with a peculiarity in the Norwegian data, with the fall in traffic volumes influencing both the benefit and the cost of projects.[2] We introduce the indicator variable *co-financing*, which takes the value 1 for projects that are co-financed by municipalities or regions or with road toll revenue, and zero otherwise.

It is important to estimate the impact of benefits and costs separately since some variables enter into the matrices of dependent variables for both and may, in aggregate, cancel each other out. For instance, we expect investments on links with larger traffic volumes to produce larger benefits because of a larger number of beneficiaries. On the other hand, we also expect such investments to be more costly because building to accommodate a larger traffic volume often requires the building of a larger and therefore more expensive road, such as *highways* or *expressways* with *flyovers*. To investigate this in more detail, we set up regression models with benefits and costs as dependent variables. To make objects of different sizes more comparable, we normalize the benefits and social cost with respect to the length of the object,

[2] When calculating benefits for projects with road toll financing in Norway, the benefits are reduced by the reduced traffic volume that higher driving prices lead to. At the same time, the social cost of an investment is reduced by the amount of road toll revenues since the government only considers investment cost and not marginal cost of public funds when calculating the social cost and thereby the NBCR of the project.

(1) $$B_i/km_i = \alpha_0 + X_i^j\alpha_k + \epsilon_B$$

(2) $$SC_i/km_i = \beta_0 + X_i^j\beta_k + \epsilon_C,$$

such that benefits per kilometre and social cost per kilometre are the dependent variables. In order to study the aggregate effect of benefits and costs on value for money, we examine which variables impact the net present value (*NPV*) in million EUR of a project Finally, we also study the relative measure, the net benefit to social cost ratio NBCR.

(3) $$NPV_i = \delta_0 + X_i^j\delta_k + \epsilon_{NPV}$$

(4) $$NBCR_i = \gamma_0 + X_i^j\gamma_k + \epsilon_{NBCR}.$$

Regarding the NBCR, the size of the project cancels out completely, since this measure is the net benefit per invested euro. The size of the project plays a role in the NPV measure, and the same holds for benefits and costs per kilometre even if division by the length of the project reduces the impact of the project size. The matrixes X_i^j are the variable j for object *i* and ϵ_l, $l \in \{B, C, NPV, NBCR\}$ is the error term.

4 DATA

The Norwegian data used in this paper comes from the NPRA's basis documentation of benefit-cost analyses for NTPS (2018–2029). For Sweden, the data originates from the STA and is for three consecutive NPTSs for the periods 2010–2021, 2014–2025 and 2018–2029. The Norwegian dataset consists of 286 observations, while for Sweden the dataset consists of 833 observations. For both countries, some observations with respect to variables of interest are missing. Therefore, the final estimation will have a smaller number of observations. For Sweden, this is especially so for observations in 2010. Both datasets have been complemented with information about population, municipality area and median net income from Statistics Norway and Statistics Sweden.

Table 2 shows the social costs and benefits of different object types in Norway and the three NPTSs in Sweden. The way in which the STA has summed up the different components changed between 2010 and 2014. Most of the benefits from the projects are gains for travellers and freight (travel time and vehicle cost). The benefits from traffic safety represent the second largest gains. Benefits in terms of health, climate and reduced health-damaging emissions are moderate.

Table 2. Mean values of the components of the benefits from an object, million EUR in 2019 price terms. Standard deviation in parentheses. Number of observations varies for the averages of total benefits, costs and socio-economic costs (NNO = 286, N2010 = 452, N2014 = 66, N2018 = 64) and the NBCR (NNO = 258, N2010 = 450, N2014 = 64, N2018 = 59).

	Norway 2019: N = 284	Sweden 2010: N = 448	2014: N = 66	2018: N =63

Travel time	65 (265)[3]	13.5 (28)		
Vehicle cost		0.20 (5.15)		
Travellers			165 (800)	119 (197)
Freight	0.02 (0.04)	0.55 (1.96)	63 (260)	30 (124)
Traffic safety	4.95 (13)	6.43 (13.2)	13.2 (16)	26.3 (38)
Exhaust emissions[4]	0.73 (25)	-0.40 (2.91)		
Climate			-5.54 (39)	-2.92 (7.06)
Health			1.62 (8.03)	1.34 (8.2)
Person transport companies			-1.57 (12)	-0.92 (5.02)
Other (mainly O&M)	-20 (60)	-2.41 (17.4)	-4.12 (19)	-3.08 (18)
Average total benefit	82 (335)	20.5 (42)	232 (1093)	169 (306)
Average investment cost	242 (529)	15.2 (29)	97 (431)	60 (133)
Average social cost (incl. MCPF)	314 (691)	34.3 (147)	106 (452)	84 (195)
Average NBCR	-0.39 (1.89)	0.42 (1.45)	1.54 (3.3)	1.32 (1.49)

The average sizes of the benefits and costs differ considerably across years in the Swedish data, and the projects were strikingly low cost in 2010 relative to those in the later years. One explanation for this is that in the 2010 planning process, the government decided that the CBA would play a larger role in the decision process (Eliasson & Lundberg, 2012; Eliasson, et al. 2015). To be able to use the CBA as a selection tool, many more projects must be evaluated than what the budget can accommodate. Here, the pool of possible projects probably contained more small projects than large ones. For this reason, many more projects were evaluated with a CBA in 2010 than were included in the plan, and the 2010 data therefore contains a large number of, often low cost, objects (725). Moreover, after 2010 the values of time were increased considerably, and the discount rate was reduced, which could be one reason the average NBCR is higher in 2014 and 2018 than in 2010.

Figure 4 shows the prevalence of different features in the projects in Sweden; a corresponding figure is not shown for Norway due to the low number of features reported for Norwegian projects, and because the Norwegian data lacks a time dimension. One project may contain many features, e.g. both tunnels and bridges, a roundabout or two and an interchange, the main type in Norway being regular roads and in Sweden a meeting-free country road (a 2+1 road with a separation of the meeting lanes and frequent possibilities for taking over other vehicles). In Sweden, projects including cycling lanes or pedestrian walks (the first group of staples) increased from 8 per cent to 41 per cent in the eight years from 2010 to 2018. The share of expressways (2+2 roads, not highways) has also increased from 2010 to 2018, as have projects that include game-related measures (either fencing or flyovers for animals). The share

[3] N_{NO} = 286.

[4] Includes climate emissions for Norway.

of bridges has also increased, as have projects including new bus stops. In contrast, new constructions of approach roads and rest areas have disappeared.

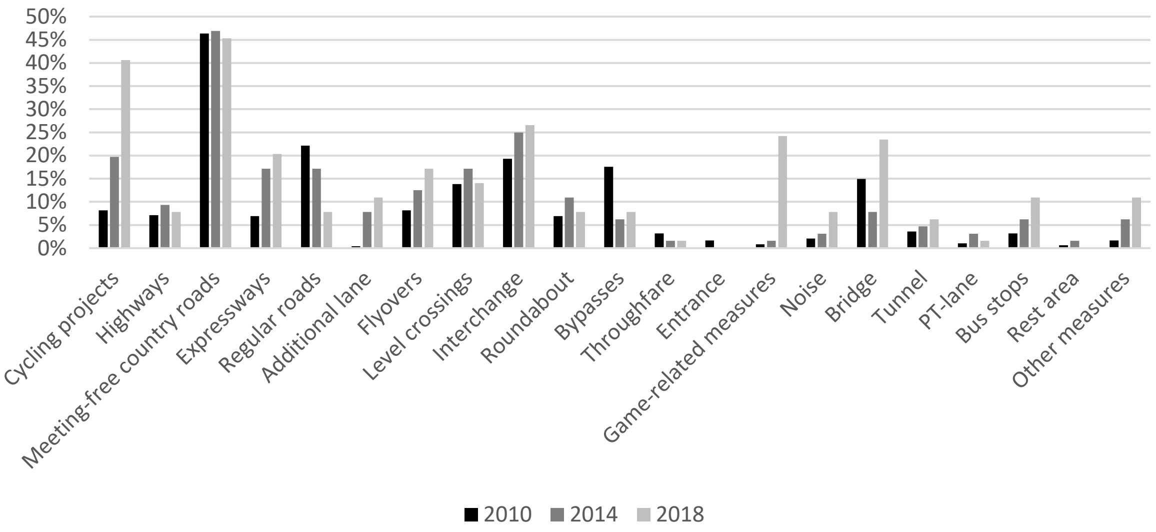

Figure 4. Percentage of Swedish projects in the respective years having a given feature. As one project can have several features, the sums exceed 100 per cent.

Figure 5 shows the planning status of the Swedish projects. As noted in Section 2, the planning process was modified in Sweden in 2014 (Swedish Transport Administration, 2014). Thus, for the plans from 2010 and 2014, the planning process is divided into four categories: a pre study, a road investigation (*vägutredning*), a work plan (*arbetsplan*) and a building phase. We also include the category 'other' for a low number of projects that do not fit this categorization (8 per cent in 2010 and 1.5 per cent in 2014). The plan from 2018 is divided into five stages: problem analysis, choice of measure (*åtgärdsval*), planning, a finished road plan (*vägplan*), and finally construction. Due to a lack of data for Norway, a corresponding figure is not shown.

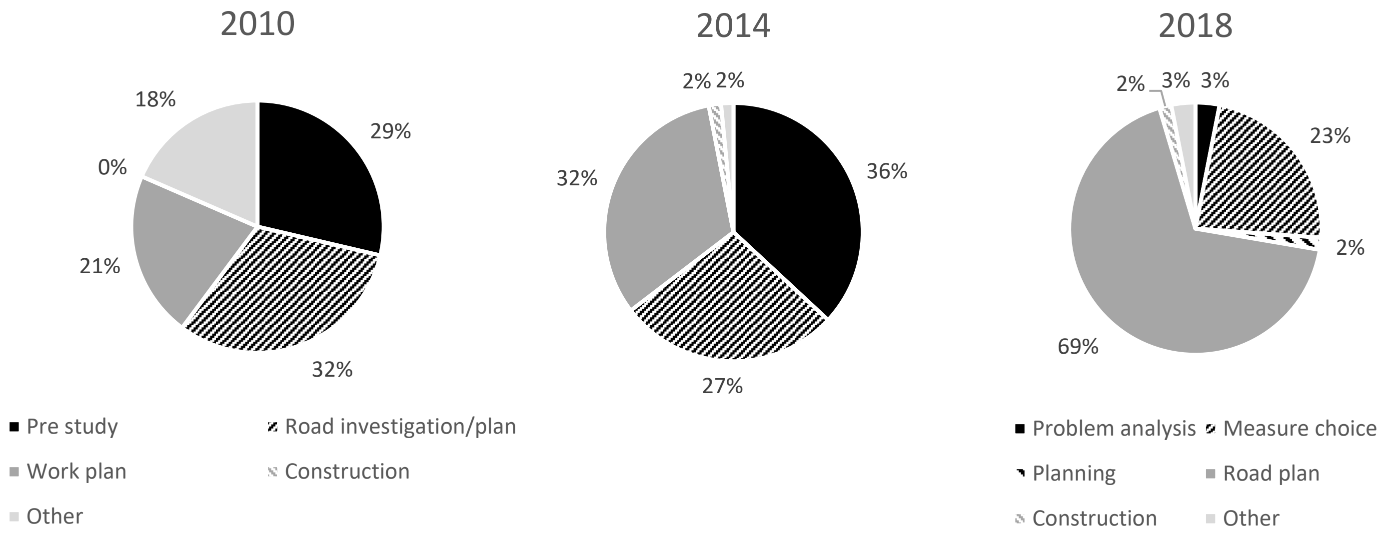

Figure 5. Share of projects in each planning stage for the three national plans in Sweden.

The share of projects in the different planning stages varies quite a bit across the years. In 2010, 57 per cent of the 725 objects in the database lack information about the planning status and are therefore not included in the figure. Of the projects for which information about the planning status is available, 29 per cent were in the earliest pre-study phase. In 2014 the share was 36 per cent. In 2018, 26 per cent of the projects were in the two earliest planning stages, *problem analysis* and *measure choice*. The share of projects in the first two planning stages (pre-study and road investigation/plan) in 2010 and 2014 amounted to 61 and 63 per cent, respectively. In 2018, only 28 per cent of the objects were in these earlier stages of planning, while 69 per cent were almost ready for building to start, i.e. they were in the road plan stage. It seems that the STA may have been working up old projects that in 2010 were in the earlier stages, and that are now nearing the construction start, but that few new projects have been added over the time. Finally, the shares of projects under construction are small for all years.

Table 3 shows the summary statistics for the variables used in the analysis, selected using the method outlined in Section 3.

Table 3. Summary statistics. Currency EUR, in 2019 price level.

	Norway					Sweden				
Variable	Obs.	Mean	Std.	Min	Max	Obs.	Mean	Std. Dev.	Min	Max
Dependent variables										
Benefit	286	82	335	-113	4239	582	61	389	-363	8896
Social cost	286	314	691	0	7736	582	48	211	0	3659
Social cost excl. SC = 0	284	316	693	1.22	7736	576	48.4	212	1.75	3659
Length of road [km]	286	7	14	0	82	768	10	10	0	100
B/km	160	20	90	-34	893	533	11	51	-17	737
IC/km	160	40	118	1	1400	533	5	23	0	473
SC/km	160	51	143	1	1680	533	7	30	0	527
NBCR	258	-0.39	1.89	-2.65	28	573	0.64	1.81	-2.56	23.24
Population density	283	77	210	0.57	1426	643	241	709	0.84	5075
Centrality index (0 = lowest, 1 =	283	0.61	0.25	0	0.99	641	0.67	0.25	0	1
Median net income, kEUR	283	48	4.71	38	65	647	18.8	2.12	15.3	31
AADT (V)	286	5656	11 026	0	90 000	425	5.817	13 963	0	132 830
Bridge	0	-	-	-	-	603	0.15	0.88	0	17
Tunnel	0	-	-	-	-	603	0.04	0.19	0	1
Height difference	283	10.84	4.98	0.60	19.40	0	-	-	-	-
Mountains	283	0.22	0.29	0	0.93	0	-	-	-	-
Length of coast	283	0.69	0.47	0	1	0	-	-	-	-
Annual average temperature	283	3.78	2.39	-3.1	7.6	0	-	-	-	-
Annual average rainfall (mm)	283	1.06	0.46	0.29	3.18	0	-	-	-	-
Cycling project	286	0.10	0.30	0	1	832	0.12	0.32	0	1
Highway	286	0.12	0.33	0	1	602	0.07	0.26	0	1
Meeting-free country road	0	-	-	-	-	606	0.47	0.5	0	1
Regular road	285	0.88	0.33	0	1	602	0.2	0.4	0	1
Expressway	285	0.12	0.33	0	1	603	0.09	0.29	0	1
Flyover	0	-	-	-	-	605	0.1	0.29	0	1
Level crossing	0	-	-	-	-	603	0.14	0.35	0	1
Additional lane	0	-	-	-	-	606	0.02	0.15	0	1
Interchange	0	-	-	-	-	603	0.21	0.41	0	1

Roundabout	0	-	-	-	-	604	0.07	0.26	0	1
Bypass	0	-	-	-	-	604	0.15	0.36	0	1
Thoroughfare	0	-	-	-	-	603	0.03	0.17	0	1
Approach road	0	-	-	-	-	603	0.01	0.11	0	1
PT lane	0	-	-	-	-	605	0.01	0.11	0	1
Bus stops	0	-	-	-	-	603	0.04	0.2	0	1
Game measures	0	-	-	-	-	601	0.03	0.18	0	1
Noise	286	0.29	0.45	0	1	603	0.03	0.17	0	1
Rest area	0	-	-	-	-	607	0.01	0.08	0	1
Other measures	0	-	-	-by	-	603	0.03	0.17	0	1
Co-financing	286	0.23	0.42	0	1	832	0.09	0.28	0	1
Co-financing share	286	0.11	0.24	0	1	0	-	-	-	-

5 RESULTS

Tables 4 and 5 show the results from the estimations. We have used generalized linear methods (GLM) to estimate the impact on benefits per kilometre. As shown in Table 3, the present value of benefits ranges from a negative to a high positive value, in millions of EUR. To estimate the factors impacting the social cost per kilometre, we have used a Tobit estimator. This is because the Swedish data is truncated since projects smaller than 50 mSEK (about 5 mEUR) are not included in the national plan. In Tables 4 and 5, we have excluded variables with insignificant coefficients.

Starting from the estimates of benefits per kilometre in Table 4, columns 2 and 4 for Norway and Sweden, respectively, we note that in both countries, AADT has a positive and significant impact on the benefits. That is, benefits increase in the initial amount of traffic. The impact is of a similar order of magnitude, with a one-unit increase raising benefits per kilometre by about 3,700 EUR in Norway and by about 1,400 EUR in Sweden. We thus conclude that benefits, indeed, are proportional to the initial volume/capacity of traffic on a link.

The second significant impact on benefits per kilometre in Norway arises from the interaction between road toll financing and median net income. Co-financing serves to raise the benefits from an investment. However, the total effect is negative. Thus, the impact of income on benefits per kilometre is -143 mEUR in the poorest municipality without road toll financing, but -139 mEUR with road toll financing. In the municipality with the mean median net income, the impact of income on benefits per kilometre is -182 mEUR without road toll financing and -177 mEUR with road toll financing. Finally, in the richest municipality, income impacts benefits per kilometre by -245 mEUR without road toll financing and by -238 mEUR with road toll financing. We included median net income in the model as a proxy for congestion with the expectation of benefits being higher in the presumably more congested, richer municipalities. These results do not support the hypothesis that congestion is a bigger problem in richer municipalities in Norway, quite the contrary. An explanation to the results could be that poorer municipalities are keener to invest in projects with larger benefits or have a less efficient transport system in the first place, making larger improvements easier to accomplish. Moreover, the results lend support to the hypothesis that co-financing may be used to signal profitable investments, since the fall in benefits is lower for projects with road toll co-financing.

Even in Sweden, the median net income influences benefits per kilometre (column 4 in Table 4). The impact is non-linear, positive and concave. Thus, benefits per kilometre are about 325 mEUR in the poorest municipalities, 342 mEUR in the municipality with the mean median net income and 220 mEUR in the richest municipality. If the results are interpreted in terms of congestion, they indicate greatest congestion in municipalities with an intermediate level of median net income. This in turn indicates that to reduce congestion, more investments should be directed to these municipalities than to the richest or the poorest ones.

In Sweden, even the centrality index gets a significant coefficient. Moreover, the variable's interaction with traffic safety is significant. The marginal impact of the centrality index on benefits per kilometre in the most rural municipalities (centrality index = 0) is -110 mEUR. In a municipality with the mean centrality index of 0.67, benefits per kilometre are about -14 mEUR if the project does not include traffic safety enhancing features, and -39 mEUR if it does contain traffic safety enhancing features. In the most central municipalities (centrality index = 1), benefits per kilometre are about 24 mEUR without traffic safety improvements, and about -15 mEUR if the project contains traffic safety improvements. Interpreting the centrality index as a proxy for congestion then lends support to a hypothesis formulated in Section 3, i.e. if there is more congestion in more centrally located municipalities, benefits per kilometre from building new infrastructure will be higher there. The negative impact of traffic safety could be interpreted as traffic safety measures reducing the congestion-mitigating impact of investments.

Traffic safety as such has a positive marginal impact on benefits of about 18 mEUR per kilometre in the most rural municipalities, however. The total impact is about -8 mEUR in the municipalities with mean centrality (0.67). Finally, in the most central municipalities, traffic safety improvements included in a project reduce benefits per kilometre by about 20 mEUR. These results indicate that opportunities to enhance traffic safety still exist in the rural areas, whereas they have already been largely realized in more urban areas.

Turning to the third and the last columns of Table 4, where the social cost per kilometre (investment cost including the marginal cost of public funds) for Norway and Sweden, respectively, is the dependent variable. In both countries, the social cost per kilometre of investment increases with initial link volume: It is more expensive to build on busier roads or where capacity to begin with is high. The social cost per kilometre also increases with population density in both countries; this is expected since it is more expensive to build in dense areas for instance due to higher land prices.

In Norway, social cost per kilometre is higher for projects with above-median investment costs. This may indicate diminishing economies of scale; an effect that is absent in Sweden. Moreover, road toll financing also influences costs per kilometre in Norway. The lowest cost projects per kilometre are therefore small ones without road toll financing, and the highest cost ones (per kilometre) are large projects without road toll financing. These findings regarding co-financing lend some further support to road toll financing functioning as a devise signalling good projects in Norway, at least when it comes to large projects. Finally, as the average annual temperature rises in Norway, it becomes less costly to build a kilometre of road.

In Sweden, the social cost also increases with median net income, and more so for projects with co-financing. There are at least three possible explanations for this. First, there is possibly more congestion in more affluent areas. Second, it is possible that richer municipalities have more resources for lobbying and consequently are granted more projects. This may in turn make building costs higher, for example because the demand for construction workers rises, leading to higher labour costs. Moreover, land values are usually higher in richer municipalities. Third, lobbying could lead to 'too much' investment in a rich municipality, i.e. that costlier projects get built; see e.g. Oates (1972) and Hammes and Mandell (2019).

Some features of projects raise costs. In both countries, highways are expensive to build. In Norway, this is in relation to regular roads; in Sweden compared with an average project. Due to availability of data, we have not been able to test the impact of projects with other features in Norway, except for cycling projects. The coefficient on *cycling project* is insignificant. In Sweden, it is costlier per kilometre to build tunnels, expressways, flyovers, interchanges, and bypasses than an average project. The centrality of the municipality where the project is built also impacts costs per kilometre, with the costs being higher in municipalities with a higher *centrality index*. However, MFCRs (2+1 roads) are somewhat cheaper to build in all types of municipalities, and cheaper in more rural municipalities than in more urban ones. The latter effect may be due to lower land costs in more rural areas.

The impacts of additional lanes and level crossings on costs per kilometre of investments in Sweden depend on the population density in the municipality of the project. First, in municipalities with the mean and maximum population densities, projects with additional lanes but no level crossings are more expensive to build than the average project, the cost per kilometre increasing in population density, while projects with only a level crossing are cheaper, the cost falling in population density. Projects with both an additional lane and level crossings are cheaper than the average project but more expensive than projects with just level crossings. In the municipalities with the lowest population density, the tables are turned, however, and additional lanes are cheaper to build, and level crossings costlier to build per kilometre than the average project.

Table 4. Regression results for equations (1) and (2). B/km was estimated using generalized linear models, while ln(SC/km) was estimated using a Tobit estimator. SC means social cost, which consists of investment cost including marginal cost of public funds.

	Norway B/km	Norway ln(SC/km)	Sweden B/km	Sweden ln(SC/km)
Main_cost				
AADT	0.00368**	0.0000294**	0.00145*	0.0000114*
	(2.63)	(2.88)	(2.25)	(2.19)
Co-financing=0 # Net income, kEUR	-3.763*			
	(-2.01)			
Co-financing=1 # Net income, kEUR[1]	-3.648*			0.157*
	(-2.25)			(2.49)
Net income, kEUR[1]			35.24**	2.693***
			(2.74)	(4.37)
Net income, kEUR # Net income, kEUR			-0.908**	
			(-2.64)	
ln(Pop density)		0.201**		0.242***
		(2.93)		(4.90)
Co-financing=1		0.563***		
		(3.73)		
IC > median=1		1.177**		
		(3.34)		
Co-financing=1 # IC > median=1		-0.910*		
		(-2.31)		
Highway		0.421+		0.487**
		(1.82)		(3.14)
Annual average temperature		-0.0709+		
		(-1.78)		
Centrality index			-110.6**	
			(-2.67)	
Centrality index # Centrality index			134.2**	
			(2.65)	
Traffic safety=1			17.98+	
			(1.77)	
Traffic safety=1 # Centrality index			-38.13*	
			(-2.03)	
Tunnel				0.904**
				(2.74)
Meeting-free country road=0 # ln(Centrality index)				-0.560***
				(-4.39)
Meeting-free country road=1 # ln(Centrality index)				-0.258*
				(-2.18)
Additional lane=1 # ln(Pop density)				0.145+
				(1.90)
Expressway				0.243+
				(1.75)
Flyover				0.517***

				(3.35)
Level crossing				0.710*
				(2.43)
Level crossing=1 # ln(Pop density)				-0.213**
				(-2.74)
Interchange				0.647***
				(4.95)
Bypass				0.190*
				(2.07)
Constant	178.3*	2.432***	-323.8**	-8.523***
	(1.99)	(14.78)	(-2.74)	(-4.77)
sigma				
Constant		0.770***		0.809***
		(15.38)		(24.65)
Observations	159	159	411	390
AIC	1858.4	387.3	4216.8	975.8
BIC	1870.7	415.0	4248.9	1043.2

t statistics in parentheses
+ p<0.1, * p<0.05, ** p<0.01, *** p<0.001
[1] ln(Net income, kEUR) for ln(SC/km)

Turning now to the first two columns of Table 5, explaining the net present value (NPV), which depends on costs and benefits. Since this variable is not normalized with project cost, we expected NPV to be higher for larger investments, which is not the case for NBCR. In fact, this expectation turned out not to be true, and in Norway, the average NPV is 342 mEUR lower for larger-than-median projects than for smaller projects. This strengthens the earlier conclusion about diminishing returns to scale in Norway. In Sweden, however, the expectation holds, and large projects have a NPV greater than small ones, the marginal difference begin 72 mEUR. At the same time, in Sweden, the size of the project interacts with co-financing: Small projects without co-financing have the lowest predicted median NPV of about 20 mEUR, co-financed small projects have a predicted median NPV of about 55 mEUR, projects not co-financed but that are large have a predicted median NPV of 55 mEUR and, finally, the highest predicted median NPV, about 705 mEUR, is found among projects that both have been co-financed and that are large. These results indicate that even in Sweden, co-financing can be used by the co-financing municipalities to signal high value for money vis-à-vis STA.

Objects with large initial traffic volume (AADT) tend to have, to begin with, larger capacity than projects with a lower AADT. We find that the NPV falls in AADT in Norway, i.e. there are decreasing economies to scale to building ever more capacity. However, in Sweden, the NPV still increases with initial traffic volume for large enough volumes, possibly indicating congestion in these networks. For Sweden, NPV also increases with median income, although the marginal impact is highest in the poorest municipalities and falls with income.

In both countries, the NPV falls with larger population density. Moreover, other impacts, such as that of height difference, annual average temperature and rainfall in Norway and of project type (tunnel) in Sweden, also depend on population density. Thus, a given height difference has the smallest (positive) impact on NPV in Norway in the municipalities with the least dense population, the impact rising from a marginal effect of about 64 000 EUR to 160 mEUR in the most densely populated municipalities. The impact of annual average temperature is similar, with a given temperature raising NPV by 460 000 EUR in the least densely populated municipality but by 1.1 mEUR in the most densely populated municipality. Finally, the impact of average annual rainfall on NPV is negative, consisting of a reduction by 1.3 mEUR in the least densely populated municipality but falling to -3.2 mEUR in the most densely populated one. These results indicate that the investments in the dryer areas in the south of Norway have higher NPV. In Sweden, tunnels and higher population density raise the NPV. This indicates that tunnels, despite their high cost, may still be more cost efficient to build in more densely populated areas than purchasing very expensive land for building. At the same time, tunnels also probably contribute to a better city environment, including lowered noise levels and barrier effects. Finally, in Norway, highways have, *ceteris paribus*, a lower NPV.

We finally turn to the NBCR, which equals the NPV divided by social costs, i.e. the size of the investment is cancelled out. In Norway, initial traffic volume (AADT) has no effect, possibly because the costs increase with both volume and benefits. This is not the case in Sweden, where the impact is very small, however, raising NBCR by 0.000083 at the initial traffic volume of zero. This falls to 0.000079 for the mean investment and zero for the investment with maximum AADT. We take these results to indicate that there may be congestion in the parts of the road network with currently lower traffic volumes, or that there are possibilities to build new links to relieve congestion, but that these possibilities have been emptied for the parts of the network with the highest already existing capacity.

In Norway, the NBCR increases with population density, indicating higher congestion levels in the network or that more cyclists, pedestrians and bus users may benefit from the project. Moreover, the impact is influenced by road toll financing, so that objects with such financing have, on average, a higher NBCR than projects without, the impact of road toll financing increasing in population density. Thus, the marginal effect is negative for projects in the most sparsely populated areas and rises to a positive 0.85 in the most densely populated municipality. Again, this finding lends support to the contention that road toll financing in Norway can be used to signal projects with high value for money. In Sweden, however, a higher population density lowers the NBCR. The other proxy for urbanization, the centrality index in Sweden, has a non-linear impact, the effect on the most rural municipalities being -2.3, and on the most urban municipalities 0.62. This finding, too, lends support to the hypothesis of congestion being a problem in the most urban areas in Sweden, but as was noted above, probably not on the roads with the highest currently existing capacity.

In Norway, the impact of median net income on the NBCR is borderline insignificant at the 10 per cent level. The NBCR decreases with longer costal line in the municipality, probably due to higher investment costs in relation to the benefits in those areas.

Finally, unlike in Norway where the impact of road toll financing depends on population density, in Sweden, co-financing influences NBCR regardless of population and has a special impact on two types of investments, namely additional lanes and bypasses. First, projects with co-financing have a lower NBCR than the average project, the difference being -0.051. This supports the hypothesis that co-financing in Sweden is not used as a signalling devise but only serves to raise the volume of investments. Projects that include the construction of an additional lane without co-financing have an NBCR that is 0.038 higher, while those with co-financing have an NBCR that is 10.5 higher. Bypasses have a lower NBCR; without co-financing their NBCR is -0.39 lower than for the average project, while with co-financing this rises to 0.35. Finally, projects including both additional lanes and a bypass, and with co-financing, have an NBCR 10.9 higher than the average project. These findings in turn support the signalling hypothesis of co-financing.

Table 5. Regression results for equations (3) and (4). All models were estimated using generalized linear models.

	Norway NPV mEUR	Sweden NPV mEUR	Norway NBCR	Sweden NBCR
Main_cost				
AADT	-0.00710*	-0.00881***		0.0000826***
	(-2.49)	(-8.18)		(6.62)
AADT # AADT		0.000000244***		-5.91e-10***
		(19.55)		(-4.55)
Net income, kEUR		109.9***		
		(4.96)		
Net income, kEUR # Net income, kEUR		-2.660***		
		(-4.89)		
ln(Net income, kEUR)			-0.616	
			(-1.64)	
Co-financing=1		35.77*		-0.0508
		(1.96)		(-0.22)
IC > median=1	-362.2***	72.02		
	(-5.48)	(1.20)		
Co-financing=1 # IC > median=1		577.7***		
		(5.03)		
Co-financing=0 # Population density	-3.092*			
	(-2.37)			
Co-financing=1 # Population density	-2.195+			
	(-1.67)			
Co-financing=0 # ln(Pop density)			0.109***	
			(3.53)	

Co-financing=1 # ln(Pop density)			0.116***	
			(4.61)	
Tunnel=1		35.69		
		(1.11)		
Population density		-0.0186		-0.000535***
		(-1.51)		(-3.84)
Tunnel=1 # Population density		0.00335		
		(0.12)		
Length of coast			-0.159*	
			(-2.13)	
Height difference # Population density	0.112+			
	(1.87)			
Annual average temperature # Population density	0.809***			
	(3.38)			
Annual average rainfall (mm) # Population density	-2.266***			
	(-4.64)			
Centrality index				-2.333*
				(-2.11)
Centrality index # Centrality index				2.950**
				(2.95)
ln(Centrality index)				-0.198+
				(-1.91)
Additional lane=1 # Co-financing=0				0.0379
				(0.07)
Additional lane=1 # Co-financing=1				10.52***
				(8.69)
Bypass=1				-0.389*
				(-2.17)
Bypass=1 # Co-financing=1				0.399
				(0.73)
Highway	-312.3***			
	(-4.29)			
Constant	-15.81	-1090.9***	1.626	0.448
	(-0.68)	(-4.83)	(1.13)	(1.57)
Observations	282	417	212	410
AIC	4078.7	5048.3	272.3	1308.5
BIC	4111.5	5092.7	292.5	1348.7

6 CONCLUSIONS

Large resources are spent on the construction and maintenance of roads and other transport infrastructure. Several earlier studies show that in Norway and Sweden, few of these investments are guided by insights into which projects would yield most value for money, i.e. project prioritization does not follow the guidance obtained from a CBA. Since projects whose costs greatly exceed the benefits lead to a waste of public resources, it would be important to be able to weed out 'bad' projects from the portfolio at an early stage, before these projects have reached such political momentum that their cancellation has become impossible. The aim of this article has been to find such indicators of 'good' projects, indicators that could be used at an early stage to stop the planning of projects with a low probability of contributing to increased societal welfare. In order to increase the generalizability of our results, we use data from Norway and Sweden.

It has been quite difficult to find proxies for value for money in the data available from the Norwegian Public Roads Agency and the Swedish Transport Administration.

We set out to test whether any of six factors would have an impact on the benefits from an investment: initial traffic volume or initial capacity, a project's impact on city environment, the impact of time savings, the increased welfare from a better or faster provision of public transport, traffic safety benefits, and reduced congestion or benefits to pedestrians or cyclists. Of these factors, only initial volume/capacity, traffic safety benefits in more rural areas in Sweden, and possibly reduced congestion, alternatively benefits to pedestrians and cyclists, turned out to be significant. Thus, to increase benefits from an investment, our model indicates that in Norway, investments should be directed towards poorer municipalities that agree to road toll financing of the projects. In Sweden, the greatest benefits are to be found not in the poorest or the richest municipalities, but in those in between. Moreover, in the rural areas in Sweden, there seem to be traffic safety-related benefits to be found. There may also be possibilities for relieving congestion in the urban areas, thereby increasing the benefits from a project.

Costs are the second aspect of value for money. We hypothesized that costs are influenced by e.g. project type and geographical factors, and that it is more expensive to work on roads with a high initial flow of traffic and that are situated in more densely populated, urban and richer areas. Moreover, we assumed that building to internalize external effects such as noise would be costly. We also study which of two possible co-financing-related hypotheses holds: that co-financing can be used as a signalling devise by local authorities to indicate projects with high value for money, or that co-financing, by shifting the cost to a central actor while the benefits mostly are local, increases investment volumes beyond the socially optimal. Finally, we also test for economies of scale.

We find several factors that influence costs. Thus, in both countries, it is indeed more costly to build on busy links or where the existing capacity is large already, and in more densely populated areas. Highways are more expensive to build than other types of roads. Moreover, in Norway we find indications of diminishing returns to scale, i.e. that more expensive projects also tend to have a higher cost per kilometre of road, and that road toll financing is, indeed, used as a means to signal projects with higher value for money. The latter finding is intriguing, especially considering the results for Sweden, which indicate that co-financing just serves to raise the investment volume, thus creating more space for low-value-for-money projects. Finally, for Sweden, for which there is more data about project type available than for Norway, we find differences in costs for different types of investments compared with an average project.

We end by considering two aggregate measures for value for money, the NPV and the NBCR, the former of which is not normalized for project size but indicates actual welfare gains, and the latter being normalized for project cost and thus yielding a measure that is easily comparable for projects of different sizes. The consideration of aggregate measures partly yields new insights and partly strengthens findings from the disaggregated models.

Thus, we find further evidence for the diminishing returns to scale in Norway, while the results indicate that in Sweden, there may be increasing returns to scale – an impact that was missed in the previous models. The above-discussed results for road toll and co-financing hold for both measures, even though we find some indication that even in Sweden, co-financing may have an informational aspect, too, besides the impact of increasing the investment volume.

In Norway, geographical factors also turn out to influence the NPV. That is, a given height difference increases the NPV, and the impact is greatest in the most densely populated areas and for larger height differences. A similar impact is found for average annual temperature. On the other hand, high levels of annual average rainfall reduce the NPV. We lack geographical information for Sweden, but interacting a possible indicator of difficult geography, i.e. tunnels, with population density yields the finding that tunnels in densely populated areas raise the NPV. We hypothesize that the impact is due to the contribution of tunnels to better city environments in more densely built areas.

Finally, the results are poorest for the normalized measure of value for money, i.e. NBCR. Most effects seem to cancel out. What remains are the impacts of road toll- and co-financing, the results further strengthening the above findings. Moreover, we find further support for the hypothesis of congestion possibly being a problem in the urban areas of Sweden, while this does not seem to be the case in Norway.

Our general conclusion is that it is surprisingly difficult to find general features or characteristics of projects with high value for money. This indicates that the value for money for any type of project in any part of the country is mainly determined by specific features of the transport network and the detailed design of the projects. Hence, it is likely possible to generate and design investments with high as well as low value for money in many parts of both the studied countries. To be able to design projects with high value for money, local knowledge, good transport models (allowing deeper analyses of the consequences of many different project designs) and insight in transport economics and analysis are probably critical. A political-economic planning context, i.e. the institutional framework of planning, that favours design and selection of projects with high value for money is probably just as important.

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