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Dissimilarities between the national cost/benefit models of road projects: Comparing appraisals in Nordic countries

Thor-Erik Sandberg Hanssen [a,*], Petri Helo [b], Gisle Solvoll [a], Jonas Westin [c,d], Lars Westin [d]

[a] Nord University, Business School, Norway
[b] University of Vaasa, School of Technology and Innovations, Finland
[c] Umeå University, Department of Mathematics and Mathematical Statistics, Sweden
[d] Umeå University, Centre for Regional Science, Sweden

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ABSTRACT

The Nordic Council has a vision to create the most integrated region globally by 2030. Nevertheless, Nordic cross-border infrastructure projects are generally developed by each nation individually. Joint Nordic infrastructure planning is thus fragmented. An example of this, as reported herein, is how road projects are assessed by the infrastructure planning authorities in Norway, Sweden, and Finland, the latter to which is included in the comparison for the first time. In each country, cost/benefit analyses (CBAs) are used. In each nation, the monetary values of changes in travel time, accidents, and environmental externalities are estimated. We then apply those values to the three national CBA models to assess an illustrative hypothetical road project. Theoretically, the models should provide similar outcomes when using a common set of parameters. Instead, we show that the choice of national model is crucial to the outcome. The Swedish model, for example, generates a higher cost of travel time than the other models irrespective of the nation from which we choose the parameters. Consequently, CBA-based assessments in the Nordic area depend strongly on the model applied and peculiarities in its coding. Finally, we discuss the policy implications of our findings for appraising national and Nordic projects.

1. Introduction

The transport flows and trade between Nordic countries are substantial (Transport analysis, 2014). Given the highly integrated network this demands, infrastructure planning is expected to be well coordinated between Nordic countries. The vision of the Nordic Council is moreover to create 'the most integrated region in the world by 2030' (Nordisk samarbeid, 2019). It may thus be a surprise that common cross-border Nordic infrastructure planning is mainly managed by each nation individually. Each country has its own set of models, and coordination at the Nordic level is rudimentary. For instance, no common model to forecast transport flows and assess common projects in the Nordic area is developed. Instead, projects that aim to improve the efficiency of the transnational network between Nordic countries are assessed and managed in ad hoc fact-sharing meetings and negotiations between national bodies (Trafikverket, 2020; Transport analysis, 2014). This adds to the overall impression of fragmentation and inefficiency in Nordic transport policy generally, especially with regard to appraisals of common infrastructure projects.

A major obstacle to improved efficiency and a more concerted Nordic approach is the difference between the national models used for theoretically similar assessments, as the behavioural parameters vary between nations. To address this shortcoming, this study, for the first time, adds Finland into a country comparison of three Nordic nations. Focusing on the models used for assessment, we run three nationally developed models with parameters from one of the nations to assess the benefits of a road project. Theoretically, given the similar parameters, we would expect the models to provide similar results. We find that this is generally not the case.

Norway, Sweden, and Finland use transport network models and cost/benefit analyses (CBAs) to appraise planned investments. Thus, CBA is a part of the transport policy in those countries. Since the 1990s, each national transport authority has developed official assessment guidelines. These guidelines have received further input from the European Union (EU) project HEATCO (Bickel et al., 2006) to harmonise project assessment and measures of transport costs at the EU level. As decisions to invest in or maintain public infrastructure should be preceded by an assessment of the welfare impacts of a measure (Vickerman, 2017), decision-makers are encouraged to use CBAs to assess a project's viability in economic terms, especially in public transport policy where externalities and system-related impacts are common (Mackie et al., 2014). Nevertheless, Eliasson et al. (2015) find that the cost/benefit ratios of projects are not important for political priorities in the Swedish and Norwegian national transport investment plans.

Because of the similarities between Nordic countries, experiences and approaches have been exchanged. The guidelines in Norway, Sweden, and Finland have thus developed many similar features. They are roughly

* Corresponding author.
E-mail address: thor-erik.s.hanssen@nord.no. (T.-E.S. Hanssen).

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moving towards a common structure, although national characteristics remain. However, as aforementioned, neither a joint Nordic transport model with a common network for forecasting mutual flows nor common parameter values and other assumptions for the evaluation of costs and benefits at the Nordic level have been developed, negotiated, or agreed upon (Trafikverket, 2020).[1]

Hence, the CBAs for a hypothetical project evaluated within the framework of each Nordic country provide divergent results. Since the preferences of the average inhabitant, discount rates, budget constraints, political priorities, and models used vary by nation, the net benefit of a similar project can differ, even if the cost of the project is comparable between countries. This may hamper joint decision-making in cross-border and other infrastructure projects of common Nordic interest.

The justification for and setting of a priority between measures with impacts covering many nations require negotiations and an understanding of how CBAs should be used in international projects otherwise inferior projects may be favoured, impact analyses may miss some impacts, and the allocation of resources becomes biased at the national and Nordic levels. Hence, an increased understanding of the disparities in country-level model formulations is important.

Based on the foregoing, we measure how a hypothetical road improvement project is evaluated in the national CBA models used on road projects by the transport administrations in Norway, Sweden, and Finland. We apply the parameters from one nation to each of these three national models and present a 3 × 3 matrix of the changed benefits. The project evaluated is a speed limit reduction. In this case, the policy aims to reduce speed to improve safety and lower the environmental consequences of traffic.

As expected, the benefits differ in three main ways when we use the parameters from different nations. First, we can explain some of these differences by the different preferences of average road users in the three countries that reflect their individual social, economic, and historical experiences. Second, some differences may be due to the econometric techniques used to estimate the parameter values of the preferences in each country. Finally, some differences are related to the technical and programming-related peculiarities of the computer models used by each national transport administration. The optimal situation would be that the first category explains all the differences in the benefits among the three countries. Since the national CBA models for minor road projects have a common theoretical base, we would a priori assume that the outcome of a simulation using the same parameters (i.e. those from one country) would be independent of the national model used. However, our analysis shows that this is not generally the case. Hence, the programming-related peculiarities inherent in the models affect the outcomes.

This study is novel in that it identifies national disparities in model formulation as a source of the differences in the benefits obtained from CBAs. Other studies have not simultaneously addressed and separated the country-level differences in parameter values and modelling frameworks to understand the overall differences between nations in the outcomes of their CBAs. Our comparison of the models and parameters used to evaluate the road projects in these three countries, where Finland is included for the first time, adds to the interest of the present study.

The remainder of this paper is organised as follows. Section 2 presents the planning procedure for road projects in Norway, Sweden, and Finland. Section 3 introduces the principles behind the valuation of time, life, and environmental externalities. Examples of the range of such values in European countries are also provided. In Section 4, we present the parameter values used in our simulations and their ratios. In Section 5, we discuss how the benefits of a hypothetical road project depend on the programming peculiarities of the models developed in the three countries. In the last section, we provide conclusions and implications for transport policy.

2. Models for the CBAs of road projects in Norway, Sweden, and Finland

Although CBAs are not the only sources of information when transport infrastructure funds are allocated in Nordic countries (Hanssen and Jørgensen, 2015; Helland and Sørensen, 2009; Jussila Hammes and Nilsson, 2016), it is important to understand the similarities and differences between assessment tools when national transport policies are compared. For example, it is of interest to identify the geographical distribution of the impacts on both sides of the border and relate those to the financing necessary from each country, especially in negotiations related to a common Nordic network (i.e. cross-border investments). Examples of cross-border projects are the existing Øresund bridge (Knowles and Matthiessen, 2009) and the proposed Helsinki–Tallinn tunnel (Hilmola et al., 2015). In the negotiations on the allocation of the costs of such efforts between nations, the lack of common models and parameters may be a source of inefficiency.

In this case, the dissimilarities between the outcomes of national models may add risk and uncertainty to decision-making. Differences between national CBAs have previously been identified. Olsson et al. (2012) study railway projects in seven European countries and find that the same project may obtain a negative or positive net present value depending on the model used. Welde et al. (2013) compare decision-making processes in Norway and Sweden, while Eliasson et al. (2015) analyse the use of CBAs in Sweden and Norway and compare the decision-making processes in both countries. In their critical review, they conclude that electoral support is an important factor for successful projects and that the main function of CBAs is to filter out inefficient projects.

In Norway, Finland, and Sweden, national guidelines stipulate the standards for traffic forecasts, estimation of project impacts, and parameter values to apply in CBAs. The main impacts of most projects are changes in travel time, emissions, noise, accidents, and operation and maintenance costs. There is ongoing discussion on if and when wider effects in other markets (e.g. labour and housing markets, agglomeration effects) should be included without 'double accounting' (Hussain and Westin, 1997). However, in national planning, a traditional assumption is that a model of the transport system can measure all monetary impacts. Before we present our results, we summarise the central aspects of traditional models in Norway, Sweden, and Finland. Our focus is on the CBA models for minor road projects.

2.1. Norway

The impact assessments of the Norwegian Public Roads Administration include an economic appraisal and, when required, a supplementary investigation of the spatial and social effects. Norway divides the economic appraisal into a monetised CBA and an assessment of non-monetised impacts. The Norwegian EFFEKT model is the primary tool used to conduct CBAs of minor road projects. EFFEKT calculates the consequences of a measure on travel time, fuel consumption, accidents, maintenance, environmental impacts, and other monetised benefits and costs.

To describe and predict the system-wide network impacts of a project, national and regional transport models are used. For passengers, a national transport model and five regional transport models are developed. The national transport model is used for passenger journeys over 100 km, while regional transport models are applied for trips shorter than 100 km. Regional models are flexible, and can zoom in and analyse even smaller regions. Similarly, a national freight transport model for Norway exists comprising PINGO, the spatial computable equilibrium model for Norway, and a logistics model. In PINGO, analyses of how population growth and industrial development might affect future freight flows regionally are performed, while the logistics model simulates the network-level impacts of a measure.

[1] In 2018, the Nordic Council Committee for growth and development criticised the status of Nordic transport planning and suggested, in its decision A1755/tillväxt (https://www.norden.org/sv/node/1791), measures to improve infrastructure planning at the Nordic level. So far, the Nordic Council of Ministers has made decisions following those suggestions.

2.2. Sweden

The Swedish Transport Administration is responsible for all appraisals in the national transport system. It uses a broad impact assessment method to describe the effects and costs of a proposed transport measure from three perspectives. The CBA module provides the benefits and costs valued monetarily, a transport policy goal analysis describes how a measure adds to the goals of the transport policy, and an analysis of the distributional impacts describes how the net benefits are distributed among groups. The broad ASEK workgroup revises the values, parameters, and methods for the CBAs annually. The ASEK report thus recommends parameter value estimates and asks related methodological questions.

Several tools are used to estimate the impact of measures in the transport system. The EVA model is used to calculate the CBA-related effects of a minor road project with a given traffic volume. Thus, in principle, EVA has the same aim as the Norwegian EFFEKT model. If a measure is larger and expected to generate new traffic, system-oriented models at the national level forecast those, as in Norway. Of those, SAMPERS is used for passenger flows and SAMGODS for freight transportation. Both models are connected to STRAGO, a spatial equilibrium model of Sweden. The transport administration owns and manages all these tools.

2.3. Finland

In Finland, nine ELY centres (short for Economic Development, Transport, and Environment) conduct CBAs for transport measures. These centres are responsible for the regional implementation and development tasks of the central government in Finland. The Finnish Transport Administration conducts analyses of sea and rail projects at the national level. IVAR, the CBA model that most closely resembles EFFEKT in Norway and EVA in Sweden, is a web-based tool for performing economic appraisals of road networks. IVAR is owned and maintained by the Finnish Transport Administration. Emme, a network model developed by the consulting company INRO, is used to analyse multimodal traffic flows in major cities. The VTT Technical Research Centre of Finland maintains Emme. Private consulting firms have developed other models for forecasting freight and passenger transport flows nationally.

2.4. Nordic CBA models for minor road projects

In summary, the institutional and model structures in Norway and Sweden have developed in similar manners. For CBAs of minor road projects, EFFEKT in Norway and EVA in Sweden have a common theoretical background. The IVAR model in Finland is also theoretically akin to those and is used for a similar type of analysis but is not developed by the planning administration. Nevertheless, the three models have a common theoretical motivation and should thus provide the same results if parametrised in the same manner.

3. Valuation of time, accidents, and the environment in CBAs

The monetary values of important impacts of investments in road infrastructure are, with some exceptions, unavailable in the marketplace. Here, we discuss the valuation of time, life and accidents, and environmental impacts in general. Then, in Section 4, we address the national parameter values used in Norway, Sweden, and Finland.

3.1. Valuation of time

The value of travel time savings typically accounts for 60–80% of the quantified user benefits of transport projects (Hensher, 2001; Mackie et al., 2001). Hence, the value of travel time is critical for the profitability of investments (Gunn, 2008); fundamental for travel demand modelling, social cost analysis, and public policies (Small, 2012); and is the most important figure in transport economics (Fosgerau, 2006).

A recent meta-analysis of studies of the value of travel time in European countries (Wardman et al., 2016) shows that the national average valuation of reduced travel time varies by factors such as trip purpose, GDP, distance, transport mode, and the method used to estimate the values of travel time. The purchasing power parity-adjusted value of travel time per hour for an average car commuter varies from €2.10 in Macedonia to €18.06 in Luxembourg. As such, the average value of travel time in Luxemburg is more than eight times higher than that in Macedonia.

3.2. Valuation of life and impacts of accidents

The expected accident costs in CBAs are determined based on the risk of an accident and associated costs should an accident occur. Thus, the expected accident cost on a road is reduced if a project reduces accident risk or the cost should an accident occur. According to Bickel et al. (2006), a broadly accepted classification of accident impacts includes the following:

- Fatal (death arising from the accident).
- Serious (injuries require hospital treatment and are lasting, but the victim does not die within the fatality recording period).[2]
- Slight (either the injuries do not require hospital treatment or if they do, the effect of the injury subsides quickly).
- Damage-only accidents (accidents leading to no personal injuries).

The valuation of accident costs comprises the direct economic costs (e.g. medical costs, property damage, and administrative costs), indirect economic costs (e.g. lost productive capacity), and the value of safety per se. The latter represents people's willingness to pay to reduce accident risks (Elvik, 2018). Wijnen et al. (2019) review the official monetary valuations of the prevention of road crashes, road fatalities, and injuries in 31 European countries. The purchasing power parity-adjusted estimates of costs per fatality range from €0.7 million to €3.0 million. The variation in cost estimates is due to differences in the definition of a road fatality, cost components included, and methods used to estimate each cost component. An alternative perspective on the partial economic costs associated with vehicle collisions is given by Shannon et al. (2020). They use data from the United States for 2010–2015 to estimate the expected compensation costs to avoid an injury. This method can be seen as an alternative approach to the valuation of accidents.

3.3. Valuation of the environment

The environmental effects focused on in CBAs are air pollution, noise, and greenhouse gas emissions. The method recommended by the EU to manage environmental issues is the so-called impact pathway approach (Bickel et al., 2006), a bottom-up method designed to handle technology and site-specific parameters and variations in costs by time (e.g. daytime vs night-time noise).

The valuation of air pollution should be based on the damage it causes (Bickel et al., 2006). Market prices may be used for the valuation of material damage and crop losses. For health impacts, the cost of illness can also be estimated using market prices, and an individual's loss of welfare in CBAs must be valued using stated preference methods. As expected, we also find a variation between countries. Measured by 2002 values, the cost factors for road transport emissions emitted per tonne of nitrogen oxide (NO_X) vary from €500 in Cyprus to €5000 in Hungary.

Noise impacts are mainly related to annoyance and health problems. The purchasing power parity-adjusted factor costs per year per person exposed to a noise level of $\geq$70 Lden vary from €63 in Latvia to €241 in Luxembourg (Bickel et al., 2006). Istamto et al. (2014) show willingness to pay estimates to avoid road traffic noise of €90 per person per year for general health risks, €100 per person per year for a 13% decrease in severe

[2] A 30-day period restriction for fatalities, as given in Nellthorp et al. (1998), is a pragmatic simplification for accident reporting. Owing to evidence of underreporting arising from the period restriction of 30 days, Bickel et al. (2006) recommend using correction factors to manage underreporting.

annoyance, and €320 per person per year to avoid an increase in noise level from 50 to 65 dB.

The method used to calculate the cost of greenhouse gas emissions is to multiply the CO_2 equivalent emitted by a cost factor. Because of the global scale of the damage caused, the same values should be applied in all countries. According to Bickel et al. (2006), the factor price per tonne of CO_2 equivalent emitted in 2010–2019 should be set to €26, with an upper estimate of €63 and a lower estimate of €16, when conducting sensitivity analyses. By comparison, the price for one CO_2 equivalent in the EU Emissions Trading System in week 33 in 2020 was €25.90 (Energi og Klima, 2020). However, in practice, countries apply a wide spectrum of values because of internal political considerations. Despite this variability, the values used in each country may still be based on scientific considerations.

3.4. Individual, national, and international values

National CBA models in the national planning arena apply average values of travel time and so on to the national population. From a national transport policy perspective, this method avoids public discussion on, for example, the value of time and life for people with different incomes. The CBAs of cross-border infrastructure investments between two nations can then be intricate. The valuation of a measure on each side of the national border may differ. In Section 4, we compare the parameters in the three countries.

4. National CBA parameter values in Norway, Sweden, and Finland

4.1. Value of travel time, life, and the environment

Table 1 presents the parameter values for time, life and accidents, and environmental impacts used in Norway, Sweden, and Finland. The data were collected from the public sources listed in footnotes and confirmed in interviews with the local transport authorities in each country. However, the parameter values are subject to change in all three countries.

The value of travel time is significantly higher in Norway than in Sweden and Finland. For example, the valuation of a one-hour reduction in business travel time in Norway is 100% and 35% higher than in Finland and Sweden, respectively. The difference between Norway and the other countries is even greater for trips to/from work and leisure travel. For example, the travel time value of leisure travel is 164% higher in Norway than in Finland.

In the case of life and accidents, the categories are different. Norway operates with five categories, ranging in severity from death (i.e. the economic value used to quantify the benefit of avoiding a fatality) to material damage. Sweden has a similar classification but no value for 'very serious injury'. Finland differs from the other two countries in that it has no distinct category for material damage and labels injury levels using 'permanent injury', 'serious temporary injury', and 'minor temporary injury'. However, in the next update of the guidelines, Finland's categories will become more similar to those used in Norway and Sweden.

In Table 1, Norway values life and accidents higher than Sweden and Finland do. In Norway, the value of a life is 21% and 32% higher than in Sweden and Finland, respectively. The value of a serious injury is 108% and 212% higher. Because the costs of treatment and loss of productive capacity are central in the determination of the value of life and accidents, the differences in how these are valued reflect national differences in living costs.

For environmental impacts, Table 1 indicates that CO_2 emissions are valued the highest in Sweden, particle emissions (PM_{10}) are valued the highest in Finland, and NO_X emissions are valued the highest in Norway. These environmental impacts of road traffic have a different impact radius. PM_{10} has mostly local impacts (i.e. it affects individuals near the emission source), NO_X has more regional impacts than PM_{10} does because it can cause acid rain some distance away from the transport infrastructure, and CO_2 contributes to climate change.

Table 1
Parameter values for CBAs in Norway, Sweden, and Finland. Numbers in € (2017).

Parameter	Norway[a]	Sweden[b]	Finland[c]
Time			
Business travel	48.2 €/p/h	35.6 €/p/h	24.1 €/p/h
To/from work	23.3 €/p/h	10.6 €/p/h	10.9 €/p/h
Leisure travel	18.2 €/p/h	7.2 €/p/h	6.9 €/p/h
Heavy goods vehicle	72.9 €/v/h	3.9 €/v/h	23.8 €/v/h
Goods	–	0.12 €/t/h[d]	–
Life and accidents			
Life	3,242,996 €/p	2,676,766 €/p[e]	2,452,880 €/p
Very serious injury	2,910,105 €/p	–	1,375,782 €/p
Serious injury	1,030,886 €/p	495,363 €/p	330,591 €/p
Small injury	78,390 €/p	24,249 €/p	64,018 €/p
Material damages	4081 €/p	1541 €/p	–
Environment			
Carbon dioxide (CO_2)	28 €/t	153 €/t	41 €/t
Particles (PM_{10})	55,840 €/t[f]	1210 €/t	74,884 €/t
Nitrogen oxide (NO_X)	6443 €/t[g]	4004 €/t	886 €/t
Other parameters			
Discount rate	4%	3.5%	3.5%
Marginal cost of public funds	1.2	1.3	No
Time span of the analysis	40 years	15–60 years	30 years
Lifetime of investment	40 years	15–60 years	10–50 years
Real price adjustments	Yes	Yes	No

€/p = Euro per person. €/p/h = Euro per person per hour. €/v/h = Euro per vehicle per hour. €/t = Euro per tonne. €/t/h = Euro per tonne per hour.

[a] The parameter values are based on Statens vegvesen (2018). Travel time values are for trips longer than 70 km. The parameter values are adjusted to 2017 NOK based on the change in the consumer price index. €1 = 9.48 NOK.

[b] Parameter values for 2014. These values are adjusted to 2017 SEK based on the change in the consumer price index. €1 = 9.75 SEK.

[c] Source for Finnish data: Liikennevirasto (2015) and interviews with Trafi Finland economists.

[d] The valuation refers to the value of goods transported. In Norway and Finland, the corresponding parameter values are not taken into account in the CBAs.

[e] In the forthcoming version of ASEK, the valuation may be raised to the Norwegian level.

[f] The rate is for towns and smaller cities. The rates for Oslo and Trondheim are €172,888 and €368,327 per tonne, respectively.

[g] The rate is for emissions outside cities. The rate for emissions in the three largest cities is €25,772 per tonne.

Differences in national emissions values may be driven by national differences in the valuation of the societal cost of emissions. Emissions of greenhouse gases (e.g. CO_2) with their worldwide economic and societal consequences are a global externality (van den Bergh and Botzen, 2015). Therefore, the benefit of a one-unit reduction in CO_2 emissions should theoretically be equal irrespective of where a reduction occurs. The different values used in Norway, Sweden, and Finland instead reflect political considerations related to the inability to know what damage may ensue (Pezzey, 2019) or the different intertemporal valuations among politicians and voters of the cost of taking measures to combat climate change. However, the basis for valuing CO_2 emissions need not be damage costs; it could also be abatement costs (i.e. the costs of reaching a given climate target).

Regarding the other assumptions central to CBAs, the discount rate is 0.5 percentage points lower in Sweden and Finland than in Norway. The marginal costs of raising public funds are 20% in Norway and 30% in Sweden, whereas Finland has no mark-up for spending public money. Moreover, the timespan of the analysis and assumed lifetime of infrastructure differ somewhat. This phenomenon applies to how the residual value of the investment after the analysis period is treated and which year is set as the starting year of the analysis. In Norway and Sweden, the value of travel time and of life and accidents can be real price-adjusted. However, real price adjustment should only be considered where there is a firm theoretical and empirical basis for estimating how changes in the valuation of the relevant parameters deviate from general inflation. Finland instead assumes that the parameter values follow an index of consumer prices. Further, the value of CO_2 emissions might not only be real price-adjusted, but also be set higher in future years as the cost of reaching climate goals increases (Rødseth et al., 2019).

4.2. Ratios between the value of travel time, life, and carbon dioxide

Using the parameter values in Table 1, we can identify the relative influence of improvements in efficiency, safety, and environmental impacts in Norway, Sweden, and Finland. For example, we can calculate how much travel time must be reduced to offset the value of one additional road traffic fatality (i.e. the ratio between the value of life and the value of travel time). Table 2 presents the ratios between the economic valuation of leisure travel time, life, and CO_2 emissions.

The numbers in the first row show the reduction in leisure travel time (hours) that corresponds to one life saved in each country. These numbers imply that all else equal, the estimated welfare effect in Sweden (Finland) is the same irrespective of whether a road project reduces the number of fatalities by one or leisure travel time by approximately 372,000 (353,000) hours. Considering that the welfare effect of one life saved in Norway corresponds to approximately 179,000 h of reduced leisure travel time, life seems to be valued less than reduced leisure travel time in Norway than in both Sweden and Finland. Hence, a road project that reduces travel time but only provides a limited improvement in traffic safety is more favourable when the parameters from Norway are used than those from the other two countries.

The second row in Table 2 shows how many tonnes of CO_2 emissions must be reduced for its economic value to correspond to one life saved. These numbers illustrate the degree to which safety is valued over the global environment. The higher the values, the higher is life valued relative to the environment. Based on the ratios in Table 2, one life saved corresponds to almost seven times as many tonnes of CO_2 in Norway as in Sweden. To put this ratio for Norway into context, the average CO_2 emissions from a new passenger car registered in the EU in 2018 was 120 g of CO_2 per kilometre (European Environment Agency, 2019). Hence, one such vehicle would have to drive approximately 965 million km to emit an amount of CO_2 with the same economic value as that of one life saved. Furthermore, as passenger cars in Norway typically drive 12,000 km per year, the economic value of one life saved equals the economic value of the annual CO_2 emissions from 80,000 passenger cars. In Sweden (and Finland), the economic value of one life saved equals the economic value of the annual CO_2 emissions from approximately 12,000 (42,000) passenger cars when assuming an average annual driving distance per vehicle of 12,000 km and CO_2 emissions of 120 g per km.

The third row shows the reduction in leisure travel time required for its economic value to correspond to a reduction of CO_2 emissions by 1 tonne. Consequently, the welfare effect in Norway, Sweden, and Finland is assumed to be the same irrespective of reducing CO_2 emissions by 1 tonne or leisure travel time by 1.5, 21.3, and 5.9 h, respectively. In other words, a vehicle that emits 120 g of CO_2 per km has to drive 8333 km to release 1 tonne of CO_2. The economic value of the reduction in CO_2 emissions from not driving 8333 km in Norway, Sweden, and Finland is the same as a reduction in leisure travel time of 1.5, 21.3, and 5.9 h, respectively. Consequently, measured in reduced leisure travel time, CO_2 emissions are valued 14 times higher in Sweden than in Norway.

5. Applying the national parameter values to an illustrative road project

Thus far, we have documented the range of parameter values in the three countries that is crucial for CBAs. Here, we discuss how this range affects the outcome of the CBA of a hypothetical road project conducted in each country. To focus the evaluation on the models, we have chosen a simple project. In complex cases, the problem of moving parameter values with slightly different definitions from one nation to the model of another nation arises. This would add another source of errors, addressing which is outside of scope of this study in which only the benefits are calculated.

We apply the following null alternative. The road length is 10 km, road width is 6.6 m, and speed limit is 90 km/h. Average daily traffic is 719, counting only passenger cars (light vehicles). We assume that 9%, 15%, and 76% of trips are business trips, trips to/from work, and leisure trips, respectively, with trip lengths between 70 km and 200 km. Although it does not matter for the evaluation, these types of roads are common in the border regions between the countries. We compare the null alternative with a safety-oriented development alternative, namely, a reduced speed limit from 90 km/h to 80 km/h. As the cost of reducing speed is not considered, we assume it is minor and equal for each country. Moreover, we only estimate the economic consequences of time costs, accident costs, and environmental costs. Average daily traffic is held constant. All else equal, we assume that reduced speed increases average travel time, reduces accident frequency and severity, and decreases the negative impact of traffic on climate change.

First, we calculate the impact using each CBA model: EFFEKT (version 6.61) for Norway, EVA (version 3.5) for Sweden, and IVAR (version June 2018) for Finland. We use the parameter values for the national model in question (e.g. Norwegian values in the EFFEKT model) and replace the national values with the parameter values from the other countries (e.g. Swedish and Finnish parameter values in the EFFEKT model).

As expected, the results in Table 3 show that the speed reduction increases time costs for road users. The reductions in traffic safety and environmental costs do not offset the increased time costs in any of the models. The changes in costs are generally larger when we use the Norwegian EFFEKT model than the other two. Except for environmental costs, this is also the case when Norwegian parameter values are used in the Swedish EVA and Finnish IVAR models. In contrast to our assumption, the Norwegian EFFEKT model predicts increased costs of traffic safety, whereas the other two models return the expected cost reductions. It is unreasonable that accident costs increase when the speed limit is reduced. The reason for this peculiar result is that the EFFEKT model by default assumes that the road standard is worse when the speed limit is 80 km/h than when it is 90 km/h. This is a built-in premise that cannot be overruled by users.

Table 3 also shows the large differences in costs in the null alternative between the three models when the parameter values change. While this is expected, there are also large differences when we introduce the parameters from one nation into the other two models. When we compare the changes in the reduced speed limit between models and national parameters, the outcome varies because of the different national parameter values. However, in this case, we also observe differences when we use the parameter values from one nation in each model. The differences from the parameter changes are motivated by the behavioural, policy, or estimation differences between nations. However, the table provides clear evidence for our claim that the less explicit, often in-built programming or coding

Table 2
Ratios between the value of leisure time, life, and carbon dioxide in Norway, Sweden, and Finland.

	Norway	Sweden	Finland	Comment
Life/leisure time	178,698	372,157	352,929	Reduction in leisure time hours equal to one life saved
Life/CO_2	115,821	17,495	59,826	Reduction in CO_2 emissions (tonnes) equal to one life saved
CO_2/leisure time	1.5	21.3	5.9	Reduction in leisure time hours equal to 1 tonne reduced CO_2 emissions

Table 3
Current costs in the null alternative and changes in time costs, accident costs, and environmental costs of reducing the speed limit from 90 km/h to 80 km/h on a hypothetical road using the CBA models and parameter values from Norway, Sweden, and Finland. (Numbers in 2017€).

	Norwegian EFFEKT model Parameter values from:			Swedish EVA model Parameter values from:			Finnish IVAR model Parameter values from:		
	Norway	Sweden	Finland	Norway	Sweden	Finland	Norway	Sweden	Finland
Current costs in the null alternative									
Time costs	18,679	8838	7834	32,626	16,375	14,365	11,644	7294	8888
Traffic safety costs	5732	3296	3506	6249	3850	3786	4748	1753	2036
Environmental costs	331	1587	410	285	1047	283	268	1356	362
Total	24,741	13,721	11,750	39,160	21,272	18,434	16,660	10,403	11,286
Changes due to the development alternative									
Time costs	2536	1200	1064	1252	627	550	975	853	785
Traffic safety costs	362	366	326	−386	−230	−221	−730	−343	−383
Environmental costs	−23	−110	−28	−4	−24	−6	−5	−28	−7
Total	2875	1456	1361	862	373	323	240	482	395

peculiarities of each national model generate the different outcomes between models—even when using the same parameters. Such problems, which are generated within the black box character of the models, are difficult to observe when the models are only applied to the objects within each nation. Only inter-modal comparisons, as presented here, may reveal the biases in outcomes generated by such peculiarities.

6. Conclusions and implications

In this study, we compare how national parameters of the valuation of time, accidents, and environmental externalities as well as model construction in Norway, Sweden, and, for the first time, Finland affect the outcome of CBAs for a similar road project. Regarding the national parameter values, we draw the following conclusions:

- The value placed on time is significantly higher in Norway than in the two other Nordic countries. A one-hour reduction in business travel time in Norway is 100% and 35% higher than those in Finland and Sweden, respectively.
- The value placed on accidents is also the highest in Norway. The value of one life saved in Norway is 21% and 32% higher than in Sweden and Finland, respectively.
- The value placed on the environment (valuation of CO_2, PM_{10}, and NO_X emissions) also differs considerably. CO_2 emissions are valued the highest in Sweden, PM_{10} emissions are valued the highest in Finland, and NO_X emissions are valued the highest in Norway.
- The ratios of the values placed on time, life, and the environment in each country show that a road project that reduces travel time but provides little traffic safety improvement is relatively more favourable when the Norwegian EFFEKT model is used than when either the Swedish EVA model or the Finnish IVAR model is used.
- A reduction in CO_2 emissions by 1 tonne equals a reduction in leisure travel time by 1.5, 21.3, and 5.9 h in Norway, Sweden, and Finland, respectively. Consequently, measured in reduced leisure travel time, CO_2 emissions are valued 14 times higher in Sweden than in Norway.

Since wages influence time costs for business trips and trips to/from work strongly, it is not surprising that the travel time value for job-related trips is high in Norway. According to the OECD (2019), purchasing power parity-adjusted average wages are approximately 16% higher in Norway than in Sweden and Finland. However, the large differences in travel time values for leisure travel are difficult to explain. Surprisingly, in Norway, the travel time values for leisure travel are even higher than those for trips to/from work in the neighbouring countries. Hence, over time, priorities according to the current parameter values and models will provide a road network with a focus on improved accessibility in Norway, whereas the focus will be on traffic safety and environmental impacts in Sweden and Finland.

However, our most interesting finding is that using a case in which the speed limit on a hypothetical road is reduced from 90 km/h to 80 km/h, we also demonstrate how differences in the models used in the three countries with respect to the effect calculations and their monetary valuation provide diverging outcomes depending on which model is used. Generally, the Norwegian EFFEKT model returns the largest change in benefits, and this is not surprising. We show that some of those differences are caused by the above-discussed differences in the parameter values between nations. However, another cause is concealed in the design of each model. Owing to the black box character of each model, it is difficult to understand the extent to which errors, lapses, and mistakes in coding and programming influence those outcomes.

From a policy perspective, our results have two notable implications. First, cross-national comparisons of national parameter values and model approaches, as we have conducted in this study, may allow us to identify and separate less important differences (e.g. data shortages, estimation failures, and programming shortcuts) from fundamental changes that may be traced back to behavioural differences between the average road user and policy priorities in all three countries. Such less important anomalies may not be identified when models and estimations are made and developed by the often relatively small groups of analysts and experts within each country. Since the three models aim to solve the same problem and are based on the same theory, only fundamental behavioural differences should explain the disparities in outcomes.

Second, we may consider either a road project crossing a national border or two similar projects on each side of a border. If two CBAs are realised with a model from each nation, the results may show significant differences in benefits. This could be a starting point for the actors on both sides to negotiate financing and priorities. However, those negotiations could be sufficiently demanding with respect to how the parameter values reflect the differences in preferences and economic possibilities between nations. If mistakes and errors in the models as well as in the estimation of the parameter values exist, decision-making on such projects is further complicated.

Moreover, national CBAs only include the benefits for the country under consideration; thus, the funding of projects that have significant benefits in nearby countries will lose out against purely national projects, negatively affecting those actors working in a cross-border regional environment. A managerial implication of this phenomenon at the Nordic level is that a joint CBA model should be developed, namely, a model with a Nordic network and a common evaluation module that represents how the benefits and costs are distributed when national preferences are considered. As a minimum, data should be systematically gathered and models compared. The Nordic bodies or national transport administrations in Nordic countries should also make those open and public.

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Author contribution

All authors contributed equally to this article.

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