Nordic Council of Ministers

Transport infrastructure investment

– Climate and environmental effects in cost benefit analysis in the Nordic countries

Transport infrastructure investment

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Foreword

Transport is a core activity in our economies, essential to production and trade and important for human welfare. It is also an activity with substantial environmental impacts, such as greenhouse gas emissions, noise, local air pollution, and land use. Transforming the transport sector is key to creating a low-emission, and eventually a zero-emission society.

It is therefore very important that environmental impacts enter the basis of decisions on transport investments. The purpose of this project is to study how environmental effects are included in cost-benefit analyses leading up to transport infrastructure investments in Nordic countries. To which extent do analysts use monetized values? What approaches and methods are used to estimate these values? How are non-monetized effects presented and represented in the analyses?

The report has been prepared by the Institute of Transport Economics (TØI) in Norway. The report includes national chapters on Denmark, Finland, Norway and Sweden. NME members have provided comments on drafts. The authors of the report are responsible for the content, and any views presented do not necessarily reflect the views and the positions of the governments in the Nordic countries.

A major challenge for the consultants has been that monetary values in several of the countries have been changing during the project period. Such changes will appear also in the future. Readers should not read this report as a definitive list of monetary values, but as a snapshot. Yet we are sure that the report will be useful and offer readers a view of the variety of approaches and methods used, and hopefully provide policymakers with ideas and inspiration.

March 2021

Bent Arne Sæther

Chair of the Nordic working group for Environment and Economy

Preface

Assessments of environmental effects and greenhouse gas emissions are central in cost benefit analysis in projects related to transport. This has been even more important since all the Nordic countries have committed themselves to climate targets and European ambient air quality standards. The Nordic Council has funded a project with the aim of comparing the handling of climate and environmental effects in Cost Benefit Analysis in transport projects in the Nordic countries.

Abstract

This study funded by the Nordic Council, compares the handling of climate and environmental effects in CBA in transport projects in the Nordic countries. The main emphasis has been the comparison of recommended methods and assessments between the countries for noise, air pollution and climate effects.

Important findings:

- For **noise** Finland take nuisance in consideration while the other countries also include health effects.
- For **PM**, the values are related to $PM_{2.5}$ in Denmark and Finland, to PM_{10} in Norway and to both $PM_{2.5}$ and PM_{10} in Sweden.
- For **NO_X**, the values in Finland and Sweden are almost negligible compared to the values used in Denmark and Norway.
- The most extreme difference between values in the Nordic countries relate to **global** warming **emissions** where the values of emissions in 2020 vary from €24/ton CO_2 in Denmark (with an alternative calculation of €197/ton) to €665/ton in Sweden.

Summary

The issues considered in the report are:

- The methods used to assess monetary values of the effects.
- Recommended monetary values.
- Recommended adjustments of monetary values.
- The methods used to integrate effects without a monetary value.

The main emphasis has been the comparison of recommended methods and assessments between the countries based on country reports from all the Nordic countries with the exception of Iceland.

The assessed environmental effects with a monetary evaluation covered by the report are noise, air pollution and climate effects.

The Impact Pathway Approach for noise and air pollution

Noise and air pollution cause effects such as annoyance, health problems, death and (in the case of air pollution) damage to nature and buildings.

The Nordic countries (Denmark, Finland, Norway and Sweden) use the Impact Pathway Approach to assess the costs per additional unit of noise or pollution.

The short version of the Impact Pathway Approach consists of the following steps:

- modelling changes in noise and emissions of pollution;
- modelling the resulting exposure;
- modelling exposure-response functions between the levels of noise/pollution and annoyance/damage;
- evaluation of annoyance and damage; or
- calculation of the overall costs per unit of noise/pollution based on the size of the affected population.

This study mainly looks at the evaluation part of the Impact Pathway Approach.

Noise

Noise causes both annoyance and health effects. Annoyance from noise is covered by all the countries, but health effects are only considered in Denmark, Norway and Sweden.

The values of annoyance from noise are based on studies of the willingness to pay for avoiding noise. In Sweden and Denmark the values are based on hedonic models estimated on data on house prices while Norway bases annoyance values on stated preference studies. Finland bases its values on older Swedish estimates.

The health effects of noise in Denmark, Norway and Sweden are based on international studies related to health effects from noise and take into consideration factors such as increased risk of death, loss of productivity and healthcare costs.

Finland, Norway and Sweden use different values for noise from road and railway transport while Denmark uses the same values. Denmark also presents noise values per dwelling, while the other countries present values per person.

Table S1 states the current valuation of noise depending on the level of noise in each country. Denmark and Sweden also state the values to be used in 2040. Danish values per person are calculated from the value per dwelling using 2.15 persons per dwelling to make comparisons between the countries simpler.

Table S1: Recommended values of noise by country, dB-level and year. €2019 per person per year.

			Outdoor dB-level*					
Noise from road	**Unit**	**Year**	**50**	**55**	**60**	**65**	**70**	**75**
Finland	Person	2019	0	133	735	1879	3594	6158
Sweden	Person	2019	8	191	620	1420	2270	3499
	Person	2040	11	267	865	2066	3164	4877
Norway	Person	2019	0	144	772	1444	2288	3133
Denmark	Person**	2019	0	171	352	772	1483	3047
	Person**	2040	0	207	425	873	1793	3684
			Outdoor dB-level*					
Noise from rail	**Unit**	**Year**	**50**	**55**	**60**	**65**	**70**	**75**
Finland	Person	2019	0	51	286	766	1501	2614
Sweden	Person	2019	6	150	498	1083	1914	3000
	Person	2040	9	209	964	1510	2668	4181
Norway	Person	2019	0	57	778	1923	3226	4530
Denmark	Person**	2019	0	171	352	772	1483	3047
	Person**	2040	0	207	425	873	1793	3684

*For Finland: 50–54, 55–60, 60–65, 65–70, 70–75 and 75–.
**Calculated from the value per dwelling based on 2.15 persons/dwelling.

Air pollution

Air pollution causes damage to people, nature and buildings, but the actual effects vary across pollutants.

Table S2 shows emissions to air with a recommended value by pollutant and country.

Table S2: Emissions with a recommended value by country.

	PM	NO_x	SO_2	NH_3	HC	CH_4	N_2O
Denmark	X	X	X				
Finland	X	X	X		X	X	X
Norway	X	X	X				
Sweden	X	X		X			

Only two pollutants (PM and NO_x) have recommended values in all the countries.

In Norway the recommended value of PM relates to PM_{10} (including $PM_{2.5}$), in Denmark and Finland valuation is related to emissions of $PM_{2.5}$, while Sweden uses values of both. For road traffic, emissions of PM are mostly related to road dust as well as exhaust emissions.

In Finland, Norway and Sweden the relation between exposure and concentration levels is modelled based on the situation in 4–5 different areas. In Denmark, a detailed atmospheric modelling of concentrations in the air is based on emissions in the northern hemisphere with extra details for Denmark through a 1 x 1 km grid. Exposure is modelled at two levels: regional and local, where only a part of the regional effects is taken into consideration.

The evaluation of effects on the local level is based on many factors. Norwegian evaluations are directly or indirectly based on VSL (the Value of Statistical Life) from willingness to pay studies. In Denmark the cost is based on factors such as the cost of extra cases of bronchitis. These effects are also taken into consideration in Norway and Sweden, but in Sweden they are based on the actual harm and damage that emissions to air have on the human health and on the environment.

Regional values from rural areas in Norway are based on the cost of reaching politically set environmental goals and in Sweden on the damage to the natural environment.

The results per pollutant are shown in Table S3.

Table S3: Recommended values per kg of particulate matter (PM) for CBA in the Nordic countries. €2019/kg.

	Emissions		Road dust	
	$PM_{2.5}$	**PM_{10}**	**$PM_{2.5}$**	**PM_{10}**
Finland electric train*	0.5			
Finland diesel train urban area	87			
Finland diesel train other areas	6.0			
Finland urban area road	143		143	
Finland rural area road	9.1		9.1	
Denmark urban area	174		174	
Denmark rural area	115		115	
Norway large urban area		330		796
Norway small urban area		37		88
Norway rural area		2.3		2.3
Sweden urban area	689			172

Table S4: Recommended values per kg of emissions other than PM for CBA in the Nordic countries. €2019/kg.

	NO_x	HC	SO_x	CH_4	N_2O	NH_3
Finland electric train*	0.6	0.03	0.4	0.88	13.0	
Finland diesel train urban area	0.6	0.03		0.88	13.0	
Finland diesel train other areas	0.3	0.03		0.88	13.0	
Finland urban area road	1.5	0.03				
Finland rural area road	0.3	0.03				
Denmark urban area	34		2			
Denmark rural area	16		2			
Norway large urban area	40.5		22.3			
Norway small urban area	9.1		1.1			
Norway rural area	2.3					
Sweden	0.30					0.80

*Emissions related to generation of electricity.

Climate effects

The impacts of further increase in the concentration of climate gases are uncertain, and because the problem is global the emphasis has in later years been on the abatement costs. The most important climate gas is CO_2, while the impact of other gases such as CH_4, N_2O, HFK, PFK and SF_6 is calculated based on their climate effect compared to CO_2 and measured in CO_2-equivalents.

While Finland values emissions of CO_2-eq based on long-term damage costs, the three other countries base their values on abatement costs. Denmark links the 2019-evaluation to the price in the EU Emission Trading system (EU ETS), while Norway links its values to global abatement costs modelled in IPPC (2018) and Sweden to the penalty for not meeting fuel standards.

Future prices are estimated based on presumed European abatement costs outside ETS in Denmark, the enforcement fee of its low carbon fuel standard in Sweden and global abatement costs in Norway. Values are shown in table S5.

Table S5: Values of CO_2 for use in CBA in the Nordic countries. €2019/ton CO_2-eq.

Country		Based on	2020	2030	2050
Finland		Damage cost	79		
Sweden		Penalty for not meeting fuel standard	665	665	665
Denmark	ETS	ETS carbon price	24.2	35.8	
	Non-ETS	ETS carbon price	24.2		
	Non-ETS	Non-ETS abatement cost Europe		43.5	
		Alternative price	197.1	197.1	
Norway	Present	Abatement cost	152	225	493

Recommended adjustments of assessments

For environmental costs, all the countries recommend adjustments of unit values for future years based on the expected change in income. The proxy for income is expected real growth in GDP per capita. In Finland this means an adjustment of 1.5 percent annually. In Norway the result is an adjustment of 0.9 percent annually until 2060.

The methods used to integrate effects without a monetary value.

All the 4 countries have implemented the EU's Environmental Impact Assessment Directive.

In **Norway and Sweden**, the recommended treatment of non-monetary effects is based on a separate analysis of non-monetary environmental effects to avoid double-counting. The effects are then weighted against the monetary results of CBA in order to reach conclusions which take into consideration both the monetary effects and the non-monetary environmental effects of infrastructure projects.

In **Finland and Denmark,** infrastructure projects also require non-monetary assessments of environmental effects in addition to CBA based on effects with a value.

Considerations regarding the use of limited environmental goods

Considerations regarding limited environmental goods are to a large extent integrated in the described assessments of environmental effects without a specific recommended monetary value since all the countries require a description/ evaluation of either all the environmental effects caused by a transport project (Finland and Denmark) or just the effects without a monetary valuation (Sweden and Norway).

Intrusions to the visual landscape are limited goods mentioned in all the countries, whereas biodiversity and cultural heritage are specifically mentioned in Norway, Finland and Denmark. Denmark and Finland also specify impacts on soil and water.

Sammendrag

Nordisk ministerråd har finansiert et prosjekt der formålet er å kartlegge hvordan klima- og miljøeffekter håndteres i nytte-kostnadsanalyser i Norden. Temaene som belyses i rapporten er:

- Metodene som benyttes for å verdsette effektene
- Anbefalte verdier
- Anbefalte metoder for å justere verdiene over tid
- Anbefalte metoder for å ta hensyn til effekter som ikke måles i penger

Rapportens hovedfokus er knyttet til sammenligning av metoder for verdsetting og anbefalte verdier for støy, utslipp til luft og klimaeffekter basert på rapporter fra hvert land, unntatt Island, som ikke dekkes av rapporten.

Generelt om metodikk

Støy og utslipp medfører en rekke effekter, som helseproblemer, dødsfall og skader på natur og bygninger.

Som utgangspunkt for verdsetting av disse effektene benytter de nordiske landene (Danmark, Finland, Norge og Sverige) generelt en skadefunksjonstilnærming.

Det innebærer at man gjennomgår følgende trinn:

- Modellering/måling av støy og utslipp.
- Modellering av eksponering som følge av støy/utslipp.
- Modellering av dose-respons-sammenheng mellom støy/utslipp og ulemper/skader.
- Beregning av omfanget av skader og ulemper.
- Verdsetting av skader og ulemper.

Støy

Støy forårsaker både plager og negative helseeffekter. Verdier av støyplager benyttes i alle landene, mens bare Danmark, Norge og Sverige tar hensyn til helseeffekter. Verdien av støyplager er basert på studier av betalingsvillighet for å unngå støy. Mens Norge baserer verdiene på samvalgsundersøkelser av betalingsvillighet, benytter de øvrige landene studier av boligpriser som basis for verdsettingen. Finland benytter data fra studier av svenske boligpriser som grunnlag, men disse er av noe eldre dato enn de nyeste studiene i Sverige. Kostnadene knyttet til helseeffektene fra støy er basert på internasjonale studier og tar hensyn til faktorer som økt dødsrisiko, produktivitetstap og kostnader ved medisinsk behandling.

Finland, Norge og Sverige benytter forskjellige verdier for støy fra vei og jernbane, mens Danmark bruker samme verdier. Danmark presenterer også kostnadene per bolig, mens de andre landene presenterer kostnadene per person. Tabell S1 sammenligner dagens verdsetting av støy i hvert land i 2019 og for Danmark og Sverige i 2040. For at tabellen skal vise sammenlignbare tall er det lagt til grunn 2,15 personer per bolig i Danmark.

Tabell S1: Anbefalte verdier for støy i Norden fordelt etter støynivå, land og år. €2019 per person per år.

		Utendørs dB-nivå*					
Veistøy	**År**	**50**	**55**	**60**	**65**	**70**	**75**
Finland	2019	0	133	735	1879	3594	6158
Sverige	2019	8	191	620	1420	2270	3499
	2040	11	267	865	2066	3164	4877
Norge	2019	0	144	772	1444	2288	3133
Danmark**	2019	0	171	352	772	1483	3047
	2040	0	207	425	873	1793	3684
		Utendørs dB-nivå*					
Jernbanestøy	**År**	**50**	**55**	**60**	**65**	**70**	**75**
Finland	2019	0	51	286	766	1501	2614
Sverige	2019	6	150	498	1083	1914	3000
	2040	9	209	964	1510	2668	4181
Norge	2019	0	57	778	1923	3226	4530
Danmark**	2019	0	171	352	772	1483	3047
	2040	0	207	425	873	1793	3684

*For Finland: 50–54, 55–60, 60–65, 65–70, 70–75 and 75–.
**Beregnet basert på 2,15 personer/bolig.

Utslipp til luft

Utslipp til luft forårsaker skader for mennesker, natur og bygninger, men skadene varierer etter type utslipp.

Tabell S2 viser hvilke utslipp til luft (utenom CO_2) som det foreligger anbefalte verdier for i hvert land. Kun for to typer utslipp (PM and NO_x) foreligger det anbefalte verdier alle landene.

Tabell S2: Utsipp til luft med anbefalte verdier i Norden.

	PM	NO_x	SO_2	NH_3	HC	CH_4	N_2O
Danmark	X	X	X				
Finland	X	X	X		X	X	X
Norge	X	X	X				
Sverige	X	X		X			

I Norge knyttes den anbefalte verdsettingen av partikler (PM) til PM_{10} (som inkluderer $PM_{2.5}$), i Danmark og Finland til $PM_{2.5}$, mens Sverige anbefaler verdier for begge deler. For veitrafikk knytter verdsettingen seg til både eksos og veistøv.

I Finland, Norge og Sverige er forholdet mellom utslipp og konsentrasjonsnivåer modellert for 4–5 forskjellige områder. Danmark har modellert konsentrasjonsnivåer basert på utslipp på den nordlige halvkule, men på mer detaljert nivå for dansk område. Modelleringen er gjennomført på både lokalt og regionalt nivå. På regionalt nivå tas det bare hensyn til deler av utslippene.

Verdsettingen av effekter på lokalt nivå er basert på en rekke forhold. Norske verdier bygger direkte eller indirekte på VSL (Verdien av et Statistisk Liv) basert på studier av betalingsvillighet. I Danmark er verdsettingen basert på forhold som for eksempel kostnaden ved et ekstra tilfelle av bronkitt. Slike forhold tas det også hensyn til i Norge og Sverige. I Sverige er kostnadene utelukkende relatert til de faktiske skadene som utslipp påfører mennesker og natur, mens utslipp utenfor tettbygde strøk i Norge også er basert på kostnaden ved å oppnå konkrete mål om reduserte utslipp.

Anbefalte verdier er gjengitt i tabell S3 og S4.

Tabell S3: Anbefalte verdier for partikler (PM) i Norden. €2019/kg.

	Emissions		Road dust	
	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}
Finland elektrisk tog*	0,5			
Finland diesel tog i tettsted	87			
Finland diesel tog utenfor tettsted	6			
Finland vegtrafikk i tettsted	143		143	
Finland vegtrafikk utenfor tettsted	9,1		9,1	
Danmark tettsted	174		174	
Danmark utenfor tettsted	115		115	
Norge større tettsted		330		796
Norge mindre tettsted		37		88
Norge utenfor tettsted		2,3		2,3
Sverige I tettsted	689			172

*Utslipp fra elektrisitetsproduksjon.

Tabell S4: Anbefalte verdier for andre utslipp enn partikler i Norden. €2019/kg.

	NO_x	HC	SO_x	CH_4	N_2O	NH_3
Finland elektriske tog*	0.6	0.03	0.4	0.88	13.0	
Finland diesel tog i tettsted	0.6	0.03		0.88	13.0	
Finland diesel tog utenfor tettsted	0.3	0.03		0.88	13.0	
Finland vegtrafikk i tettsted	1.5	0.03				
Finland vegtrafikk utenfor tettsted	0.3	0.03				
Danmark tettsted	34		2			
Danmark utenfor tettsted	16		2			
Norge større tettsted	40.5		22.3			
Norge mindre tettsted	9.1		1.1			
Norge utenfor tettsted	2.3					
Sverige	0.30					0.80

*Utslipp fra elektrisitetsproduksjon.

Klimaeffekter

De faktiske kostnadene knyttet til økt konsentrasjon av klimagasser i atmosfæren er usikre, og siden problemet er globalt har hovedfokuset i senere år vært mest knyttet til tiltakskostnader for å redusere utslippene. Den viktigste klimagassen er CO_2, mens effekten fra klimagasser som CH_4, N_2O, HFK, PFK og SF_6 omregnes til CO_2-ekvivalenter basert på klimaeffekten sammenlignet med effekten av CO_2.

Mens Finland verdsetter CO_2-ekvivalenter basert på langsiktige skadekostnader, benytter de andre landene tiltakskostnader som utgangspunkt for verdsettingen. Danmark knytter verdien i 2020 til prisen på utslippskvoter i det europeiske kvotesystemet (EU ETS). Prisen for senere år knyttes EU ETS for utslipp innenfor kvotesystemet og til tiltakskostnader på europeisk nivå for klimagassutslipp utenfor kvotesystemet. Norges verdsetting i 2020 er relatert til globale tiltakskostnader anslått i IPPC (2018). Den norske verdien etter 2020 oppjusteres gradvis med diskonteringsraten slik at utslipp har tidsuavhengig nåverdi i nytte-kostnadsanalyser. Sveriges verdsetting er knyttet til avgiften på drivstoff med for høyt innslag av fossil opprinnelse.

Anbefalte verdier er gjengitt i tabell S5.

Tabell S5: Anbefalt verdsetting av CO_2-ekvivalenter i Norden. €2019/tonn CO_2-ekv.

Land		Basert på	2020	2030	2050
Finland		Skadekostnad	79		
Sverige		Skatt på fossilt drivstoff	665	665	665
Danmark	ETS	ETS kvotepris	24.2	35.8	
	Utenfor ETS	ETS kvotepris	24.2		
	Utenfor ETS	Europeiske tiltakskostnader		43.5	
		Alternativ pris	197.1	197.1	
Norge	Present	Tiltakskostnad	152	225	493

Anbefalt justering av verdier over tid

Alle land i Norden anbefaler realprisjustering der miljøkostnader justeres i takt med antatt inntektsutvikling definert som BNP per innbygger. I Finland innebærer dette 1.5 prosent oppjustering årlig. I Norge tilsvarer det 0,9 prosent årlig oppjustering.

Metodikk for å integrere miljøeffekter som ikke er prissatt.

Alle de 4 landene har implementert EUs direktiv for vurdering av miljøeffekter.

I **Norge og Sverige** anbefales det en separat analyse av ikke-prissatte miljøeffekter for å unngå dobbelt-telling. Resultatene fra analysen veies deretter opp mot prissatte effekter for å komme fram til en konklusjon som tar hensyn til både prissatte og ikke-prissatte effekter.

I **Finland og Denmark** kreves det vurderinger av ikke-prissatte effekter i tillegg til beregningene basert på prissatte effekter i NKA i prosjekter av en viss størrelse.

Vurderinger av begrensede miljøgoder

Vurderinger av begrensede miljøgoder er i høy grad integrert i analysene av miljøeffekter som ikke er prissatt. I Finland og Danmark kreves det en beskrivelse av alle miljøeffekter som følge av infrastrukturprosjekter, mens det i Norge og Sverige kreves beskrivelser av miljøffekter som ikke er prissatt.

Inngrep i det synlige landskapet er en type begrensede miljøgoder som nevnes av alle landene. Biologisk mangfold og kulturarv nevnes spesielt i Danmark, Finland og Norge, mens Danmark og Finland spesielt nevner effekter for jord og vann.

1 Introduction

Considerations regarding environmental and climate effects are increasingly important for decisions concerning infrastructure projects in transport.

As mentioned in Hanssen et al (2020), Cost Benefit Analysis (CBA or BCA) is a vital tool in this process, but although most of the procedures in CBA follow common rules in different countries, the exact assessments of environmental and climate effects used in CBA in transport projects vary from country to country.

In this report funded by the Nordic Council, we look at how environmental and climate effects are treated in CBA in transport projects in the Nordic countries. The issues considered in the report are:

- the methods used to assess monetary values of the effects;
- recommended monetary values;
- recommended adjustments of monetary values over time;
- the methods used to integrate effects without a monetary value; and
- considerations regarding the use of limited environmental goods.

The assessed environmental effects considered are:

- noise;
- air pollution; and
- climate effects.

Many non-monetary effects are also considered. The effects that are covered vary from country to country, as described in chapters 8 and 9.

DTU, VTI and TØI have provided reports regarding the recommended treatment of environmental effects in CBA in Finland and Sweden (VTI), Denmark (DTU) and Norway (TØI) based on updated knowledge in early 2020 including the latest revisions to the value of CO_2 in Sweden (June 2020) and Norway (July 2020). All these reports are enclosed as attachments.

TØI's final, updated values from Sweden and Finland, based on recent publications[1] from these countries, are provided in a separate attachment. The main report was finalized by March 2021.

The main emphasis has been the comparison of recommended methods and assessments between the countries based on the information in the country reports and possible differences in the treatment of non-monetary environmental goods.

1. Finnish Transport Infrastructure Agency (2020) for Finland and Swedish Transport Administration (2020) for Sweden

2 A short overview of evaluation procedures in the Nordics

2.1 Denmark

The Danish Ministry of Transport and Housing supplies a set of assumptions to be used for economic appraisal within the transport sector in Denmark. Specific parameter values and unit prices are presented in the "Transport Economic Unit Prices" and are collected and presented online by DTU on behalf of the ministry.

Some of the unit cost estimates are supplied by DTU, but most of them have been adopted from other sources. All costs are presented at market prices. This means that a tax component is added to the costs at firm or public sector level. This tax component reflects the average load of VAT and excise taxes on private consumption and is currently estimated to be 28% (Finansministeriet, 2019). The tax component is used to convert treatment costs, production loss and the price of CO_2 emission permits to market prices. Costs that are already expressed in market prices (as e.g. VSL) do not need this conversion. The unit prices are published as a spreadsheet that is updated every, or every second, year along with a spreadsheet-based model for conducting the CBA-calculations. The spreadsheet can be found online at:
http://www.cta.man.dtu.dk/modelbibliotek/teresa/transportoekonomiske-enhedspriser

2.2 Finland

The methods and the unit values to be used in transport sector project evaluation in Finland are recommended by the Finnish Transport Infrastructure Agency. The values are updated every five years with the latest update published in December 2020. The reason for the five-yearly updating cycle has been to make it possible to compare values between projects that have been evaluated at different times. In the future, the aim is to update the values at four-year intervals so that they are updated about a year before a new National Transport Infrastructure Plan is introduced.

Unit prices included in a CBA in Finland are construction and maintenance costs, the impact on travel time, accidents, noise, emissions and the cost of vehicle use. They are published in a series of reports for road, rail, and maritime transport, respectively.

2.3 Iceland

Iceland has not provided any information for this report. A report by Mannvit (2017) does, however, indicate that assessments of environmental effects of transport primarily rely on Transportministeriet (2010) as well as other Danish sources. A few actual assessments are also available in the report.

2.4 Norway

CBA is central in Norwegian infrastructure planning. Most transport projects undergo a thorough assessment of positive and negative impacts for transport users as well as for the wider economy, society and the environment.

CBA guidelines are embodied in an official government document, Rundskriv R-109/14 (Finansdepartementet 2014). All costs with a market price are calculated at full cost including VAT. For expenses without a market price, costs are calculated based on actual costs including social benefits and taxes aimed at correcting external effects, but excluding VAT and import duties.

Each transport agency has a user manual for CBA[2], and the basis for the assessments has been the values determined by the Institute of Transport Economics (TØI) and other contractors over the years.

An early report from TØI (Eriksen and Hovi 1995) calculated the marginal environmental cost per passenger- and ton-km related to emissions, including CO_2, road dust and noise, for road traffic, railways, waterborne transport and aviation. The values have later been entirely or partly revised several times. The two latest published revisions covered only parts of the transport sectors:

- Thune-Larsen et al. (2014, revised in 2016) for road traffic; and
- Magnussen et al. (2015) for freight transport by rail and sea

With the aim of updating all assessments and ensuring consistent values, the transport agencies asked TØI to update most monetary assessments of marginal external effects of transport in 2018. The results are published in Rødseth et al. (2019) and are used in this study, except in the case of CO_2-emissions.

On July 3rd 2020, the Ministry of Transport sent a letter to the transport agencies with a recommendation for the valuation of CO_2-emissions in CBA in the National Transport Plan (2022–2033).

2.5 Sweden

The methods and the values to be used in project evaluations in the transport sector in Sweden are recommended by the Swedish Transport Administration in the so-called ASEK report. While the report is revised every year, and a new version is published on April 1st, larger changes are only made every 3–4 years. The latest version was published in 2020 (ASEK 7.0).

The Swedish Transport Administration's aim when producing the ASEK report is to recommend both the *methods* to be used, both with regard to economic analyses and the principles of calculation for transport projects, and the *values* to be used in economic analyses (CBA) and traffic prognoses. The work on ASEK also involves other agencies. Moreover, ASEK contributes towards the coordination of research and development within the area.

2. Håndbok V712 Konsekvensanalyser (Vegdirektoratet 2018), Veileder i samfunnsøkonomiske analyser i jernbanesektoren (Jernbanedirektoratet 2018) and Metodenotat: beregning av prissatte virkninger (Kystverket 2016)

3 Exchange rates, latest update of values and recommended adjustments of values

3.1 Exchange rates used in this report

All the recommended pricing in this report are given in euros at the 2019 price level, $€_{2019}$. To convert the values to $€_{2019}$, the following exchange rates have been used:

- Denmark 1 € = 7.46 DKK
- Island 1 € = 137.4
- Norway 1 € = ISK 9.72
- Sweden 1 € = NOK 10.52 SEK

During the lifetime of a transport project the values will have to be adjusted year by year, normally according to either increasing price levels or income growth.

3.2 Recommended adjustments of values and latest update

All the countries recommend adjusting the evaluated values for expected environmental damages based on the expected changes in real income levels for costs involving income, production loss and the value of life. The proxy for change in real income is expected growth in GDP per capita.

Denmark

A consultancy report contained a general update of the external costs for the Danish unit prices in 2010 (Transportministeriet, 2010), and many of the cost estimates are basically the same today apart from income and price level updating. Since 2010, VSL (Value of Statistical Life) has been revised and the Danish Centre for Environment and Energy (DCE, 2019) has made a revision of the air pollution costs, and these are incorporated in the present unit prices. These changes are included in the present version of the unit prices. The version (1.91) of the **Danish** unit prices used in this report was published in August 2019 with numbers for 2019 in 2019-prices.Also, the climate costs have been changed continuously, as the emission reduction costs estimates have changed, with the latest update (by March 2021) in January 8th 2021[3].

The 2010-figures are projected for 2019 using the consumer price index and, as described above, GDP per capita growth for the components related to income and VSL. In addition, most numbers are projected for each year up until 2090. Costs involving income, production loss, and value of statistical life (VSL) for future years are adjusted based on projected real GDP growth per capita published by the Danish Ministry of Finance (Finansministeriet, 2019) with an elasticity of 1. The other values are kept constant in the future.

3. Oppdatert nøgletalskatalog i notat fra Finansministeriet 8.januar 2021

Finland

The most recent revision of the unit values used for doing project evaluations of transport infrastructure investments in **Finland** was published in Finnish Transport Infrastructure Agency (2020). The values are presented in 2018-terms and updated to 2019 terms based on a CPI-increase of 1.1% and a real GDP per capita increase of 1.0% (OECD, 2020).

The general guide to project evaluation (Metsæranta et al 2020) recommends that unit values in real terms are increased by a factor of 1.5 percent per year. This is based on an expected average real GDP growth of 1.5 percent per year, combined with an average elasticity of the valuation with respect to income, of 1.

Iceland

The only information available is the actual values used in Mannvit (2017). The report refers to the work the consultancy COWI did in 2010 on Danish unit prices (Transportministeriet, 2010).

Norway

In **Norway,** the most recent revision of the values is from 2019 (Rødseth et al. 2019).

The revision of environmental costs is sanctioned by the Government in Rundskriv R-109/14. Future adjustments must follow the expected growth in real GDP per capita in the latest Perspektivmelding as well as updated information about environmental effects. Based on the latest available Perspektivmelding, the adjustment (without changes in dose-response ratios) will be 0.9 percent per year. For the value of a statistical life (VSL) and values derived from VSL, the original unit value is 30 million NOK (2012).

The present recommended valuation of emissions of greenhouse gas for 2020 is described in chapter 4 and relates to a letter from the Ministry of Transport to the Norwegian transport agencies dated July 3rd 2020. For future years, the recommendation is an adjustment using the change in CPI and the general discount rate of 4% per year. As a result, emissions will have the same discounted value in CBA in all future years.

Sweden

The base year for the values used in this report for **Sweden** is 2017 (ASEK 7.0). In this report, all the values have been adjusted to 2019 prices based on an increase in CPI of 3.8% between 2017 and 2019 (Statistikmyndigheten SCB, 2020). The ASEK 7.0 report (Swedish Transport Administration, 2020) recommends updating the values both with respect to CPI and GDP per capita. The GDP per capita increase was 1.1% in Sweden between 2017 and 2019 (OECD, 2020). Combining CPI and GDP per capita increase results in a total increase of 5%, which is used to update all the 2017-values in the tables in this report. In some tables a prognosis value for 2040 is also presented. All the values in this chapter are given in Euro, converted from Swedish kroner using a conversion rate of 1 € = 10,52 kr.

4 Methods and assessments of noise

4.1 Methods

Noise emissions from traffic pose an environmental problem that affects many people. Noise exposure not only disturbs people, it can also result in health impairments, lost productivity and an increased risk of death.

According to the Handbook on the External Costs of Transport (2019), two major impacts are usually considered when assessing the noise impacts of traffic:

- Annoyance, reflecting the disturbance which individuals experience when exposed to traffic noise.
- Health impacts related to the long-term exposure to noise, mainly stress-related health effects such as hypertension and myocardial infarction.

It is assumed that the two effects are independent.

The most accurate methodology available for the estimation of marginal noise costs follows the Impact Pathway Approach. Based on the Handbook on the External Costs of Transport we define the following steps of the IPA for noise in table 4.1.

Table 4.1: The Impact Pathway Approach for Noise. Source: Navrud (2002).

Step	Description
Noise Emissions	The change in levels of noise are measured in terms of change in time, location, frequency, level and source of noise.
Noise dispersion	Differences in exposure are estimated according to location and measured in dB and noise level indicators like L_{den} .[4]
Exposure-Response Functions	The overall change in noise impact is calculated based on the relation between decibel levels and negative impacts of noise. Each impact has one or more endpoints.
Economic assessment	An economic value for a unit of each endpoint of the exposure-response functions is calculated.
Overall assessment	The economic value of each unit of endpoint is multiplied by the corresponding impact and aggregated over all endpoints.

4

Emissions and dispersion are measured by model calculations and will not be further commented on in this study.

The economic assessment in Sweden, Denmark and Norway currently takes into consideration both annoyance and health impacts from noise based on the Impact Pathway method. Finland only considers annoyance costs from noise.

4. **L_{den}** is a 2002 European standard to express noise level over an entire day.

4.1.1 The value of annoyance/disturbance

The Nordic countries base the value of annoyance on studies of the willingness to pay for avoiding noise. Hence, the exposure-response function and the economic assessment is made in one step. In Sweden, Finland and Denmark values are based on hedonic models calculated from data on house prices. However, it must be noted that Finland uses older Swedish estimates. Norway bases annoyance values on stated preference studies.

Denmark

The costs of annoyance in **Denmark** are estimated using a hedonic study of house and apartment prices in Miljøstyrelsen (2003b) and Bjørner et al. (2003). Each dwelling is then given the weight of a factor SBT, defined by:

$$SBT\ weight\ for\ each\ dwelling = 4.22^{0.1 \times (dB - 73)}$$

The estimated cost per SBT is estimated based on the statistical relationship between prices of traded real estate and their calculated SBT while correcting for other attributes. The results are presented in Table 4.2:

Table 4.2: Noise annoyance cost.

2019 – € per SBT per year	2019	2040	Weight
Apartments	688	832	55%
Houses	3165	3827	45%
Average	1803	2180	100%

Finland

Like in Denmark, Finnish values are based on house prices, using the results of a Swedish study that estimated the impact of road noise on house prices (SIKA, 2009). The valuation of noise from rail transport is based on the valuation from road transport. Consequently, the cost of noise both road and railroad are based on the societal cost of road noise. The value of noise from road/railroad noise in Finland rises from $€_{2019}$ 133/51 at 55–60 dB to $€_{2019}$ 6157/2614 at noise levels exceeding 75 dB.

Norway

The **Norwegian** values of noise for roads and railways were on the other hand estimated using a contingent valuation (CV) study in Magnussen et al. (2010). In the study, people were asked to choose between levels of noise from railways and road traffic combined with monetary transactions. The estimated value of annoyance per person bothered by noise per year was NOK_{2009} 2750. The equivalent value in 2019, based on the present exchange rate and increase in BNP, is €$_{2019}$ 408.3.

Based on effect curves from Miedema & Oudshoorn (2001), the recommended value of noise annoyance per dB per person has been updated in Rødseth et al. (2019). The cost of outdoor noise levels under 50/53 dB for road/railroad noise has been set at zero. Above this level, the cost of increased road/railroad noise per person is valued at €$_{2019}$ 5.15/6.8 per dB respectively.

Sweden

The cost of annoyance in **Sweden** is, like in Denmark and Finland, based on house prices. The values have been estimated based on a hedonic model using data from (small) house sales in seven different municipalities in different parts of Sweden. Based on a hedonic demand curve, Andersson et al. (2013) calculated the willingness to pay for non-marginal changes in noise from road traffic. Swärdh (2012) estimated the willingness to pay for avoiding railway noise. The values have later been revised in Swärdh (2015). The value of noise outdoors is set to zero below 50 dB.

The value of disturbance from road/railroad traffic noise in **Sweden** starts at €$_{2019}$ 8/7 per year per person affected by 50 dB of outside noise in 2019, increasing to €$_{2019}$ 3273/2547 at 75 dB. For noise in 2040, values are increased by 39 percent.

4.1.2 The value of health impacts.

Apart from Finland, the Nordic countries base values of exposure-response effects in terms of health effects from noise on international studies related to health effects from noise, and take into consideration increased risk of death, loss of productivity and healthcare costs.

Denmark

The health costs in **Denmark** are estimated in a study from 2003 (Miljøstyrelsen, 2003a). The cost estimate is based on an international meta-study from 2002 (van Kempen et al., 2002) that reports a risk increase for heart disease of 9% for each 5dB increase in the daytime for levels of noise between 51 and 70 dB. The two diseases included are cardiovascular disease and hypertension.

The components of the health costs in Denmark are stated in table 4.3.

Table 4.3: Noise health cost components for Denmark.

	2019 – € per SBT per year
Health treatment	83
Production loss	7
Death	3019
Total health costs	3109

Norway

In Rødseth et al. (2019), the recommended values of health cost related to traffic noise in **Norway** are related to the value of DALY (Disability Adjusted Life Year).

Recommended values of health effects related to noise are difficult to compare directly with the Danish values. The Norwegian values are stated in Table 4.4.

Table 4.4: Recommended values for health effects in Norway.

Health effect	DALY per case	€2019
Health effects of severe annoyance[5]	0.02	3315
Health effects caused by disturbed sleep	0.07	11 602
Increased risk of ischemic heart disease	11.376	1 885 470

5

Effect curves from Basner et al. (2018) predict the likelihood of disturbed sleep according to the level of noise during the period of sleep.

The value of the increased risk of ischemic heart disease has been calculated based on the increased risk of death because of ischemic heart disease related to increased noise as stated in van Kempen et al. (2018).

The resulting total values per person per dB are summed up in table 4.5 and 4.6.

Tabell 4.5: Recommended total unit prices for noise related to road traffic (€2019/ dB/person/year).

Health effects related to	52	53–55	56–64	65–
Annoyance	5.1	5.1	5.1	5.1
Cardiovascular		12.4	12.4	12.4
Disturbance of sleep			73.8	73.8
Severe annoyance	34.4	34.4	34.4	77.6
Total cost due to road traffic noise	39.5	52.0	125.7	168.9

5. Annoyance of sufficient severity to cause health effects not covered by the contingent valuation (CV) study in Magnussen et al. (2010).

Tabell 4.6: Recommended total unit prices for noise related to train traffic ($€_{2019}$/dB/person/year).

	53–56	57–64	64–
Annoyance	6.8	6.8	6.8
Disturbance of sleep		192.3	192.3
Severe annoyance	21.9	21.9	61.6
Total cost due to rail traffic noise	28.7	221.0	260.7

Sweden

Health effects of noise in **Sweden** are based on studies by the World Health Organization (WHO, 2011; 2012). The health effects covered in the studies have then been combined with the base risk of heart infarct in the Swedish population in 2013. Measures for the consequences of heart-related illnesses have been obtained from the ExternE (Bickel & Friedrich, 2005). The factors taken into consideration are presented in table 4.7. It is difficult to compare these values with those in Denmark and Norway

Table 4.7: Values of health symptoms related to noise in Sweden.

Cause	Unit	Value (€2019)
Early death	VOLY	110 255
Symptoms of hearth infarct	Case	23 058
Symptoms of angina pectoris	Sick day	1 671
Loss of productivity – absence from work	Day	136
Healthcare costs	Hospital day	292

The value of health effects from road/railroad traffic noise in **Sweden** starts at $€_{2019}$ 4/7 per year per person affected by 58 dB of outside noise in 2019, increasing to $€_{2019}$ 226/452 at 75 dB. For noise in 2040, values are increased by 39 percent.

4.2 Recommended total values of noise

Total values of noise are summed up differently in each Nordic country.

- Finland, Sweden and Denmark recommend total values of noise at different noise levels, while Norway recommends a price for each additional dB-level.
- Sweden recommends one value for each level of dB and Denmark one value per SBT, while the other countries recommend values for intervals of noise levels (50–55 dB etc.). Sweden also recommends a value for aviation and maritime transport of 1.4 times the value of noise from road traffic.
- Denmark recommends values per dwelling while the other countries recommend values per person.
- Only Sweden and Denmark recommend future values (for 2040).

A summary of values for comparison between the countries is presented in table 4.8 and figures 4.1–4.2. The values for Norway in table 4.8 are marginal values for each additional dB while the values for the other countries are total values for a certain noise level. At the same time, values for Denmark are calculated per dwelling, while the other countries calculate values per person.

In figures 4.1–4.2, the values have been converted to total value per person per year.

Surprisingly, Finland has the highest values for road noise by far, despite health costs not being included. The other countries have relatively similar values at the 75 dB-level, while Denmark has significantly lower values for dB-levels 60–70. Norway has the second highest levels in the 60–70 interval, followed by Sweden.

For rail noise, Norway recommends far higher values at every noise level than the other countries, followed by Sweden.

Table 4.8: Recommended values of noise costs by country, dB-level and year. €$_{2019}$ per person (home) per year.

Noise from road	Unit	Year	Outdoor dB-level* 50	55	60	65	70	75
Finland	Person/year	2019	0	133	735	1879	3594	6158
Sweden	Person/year	2019	8	191	620	1482	2270	3499
	Person/year	2040	11	267	865	2066	3164	4877
Norway	Person/dB/year	2019	0	52	126	170	170	170
Denmark	Dwelling/year**	2019	0	368	756	1552	3189	6551
	Dwelling/year**	2040	0	445	914	1877	3856	7921
Noise from rail	**Unit**	**Year**	**Outdoor dB-level* 50**	**55**	**60**	**65**	**70**	**75**
Finland	Person/year	2019	0	51	286	766	1501	2614
Sweden	Person/year	2019	7	150	498	1083	1914	3000
	Person/year	2040	9	209	964	1510	2668	4181
Norway	Person/dB/year	2019	0	30	221	261	261	261
Denmark	Dwelling/year**	2019	0	368	756	1552	3189	6551
	Dwelling/year**	2040	0	445	914	1877	3856	7921

*For Finland: 50–54, 55–60, 60–65, 65–70, 70–75 and 75–.
**An average dwelling in Denmark includes 2.15 persons.

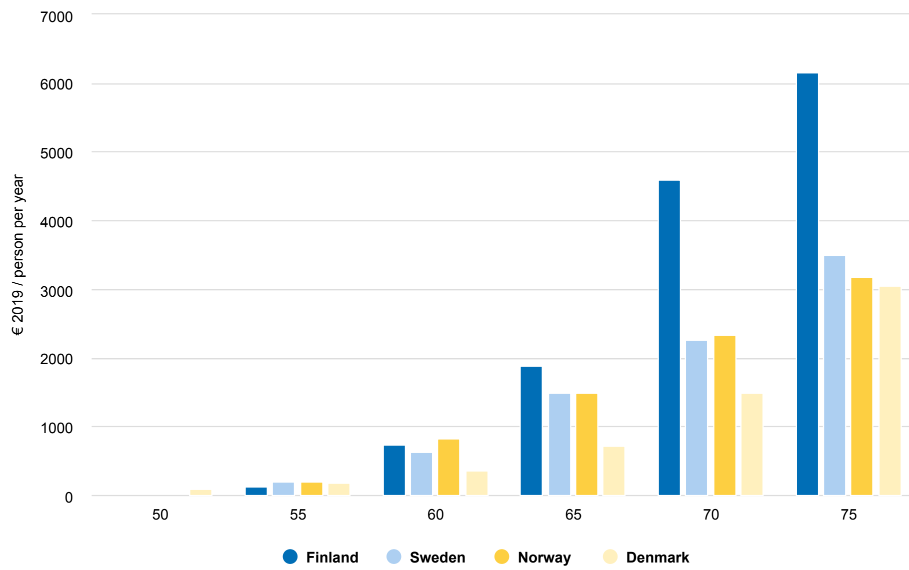

Figure 4.1: Recommended noise values for road increase with the noise level, with the highest levels for Finland.

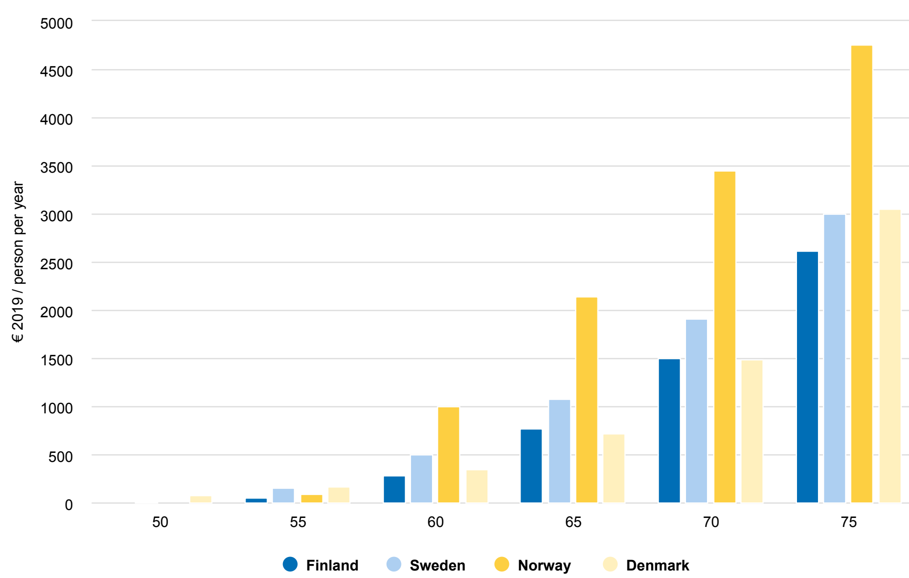

Figure 4.2: Recommended noise values for railroad increase with the noise level, with the highest levels for Norway.

4.3 Recommended values of noise per vehicle km

It is challenging to compare the Nordic countries directly in terms of values per vehicle km because of different segmentation with respect to vehicle type, time of day and urbanization.

Swedish recommendations for road noise are also more detailed than those in Denmark and Norway in some respects, with 5 different values for urban areas depending on population density. Norway differentiates between urban areas with less than and more than 100 000 inhabitants, and (for trains) make a distinction between day and night. No values of noise per vehicle have been available for Finland.

The noise values for road noise in Denmark, Norway and Sweden are presented in table 4.9 and illustrated in figures 4.3–4.7. We observe that the values in rural areas are very low except for heavy vehicles in Norway. The values for heavy vehicles such as buses and trucks are far higher than for cars, and far higher in urban areas than in rural areas. The values are also in most cases higher in Norway than in Sweden and Denmark for comparable combinations of area and vehicle.

Table 4.9: Recommended road noise values by country, vehicle type, degree of urbanization and year. Eurocents$_{2019}$/vehicle km.

Rural area	Year	Car	Bus	Truck
Sweden	2019	0	0	0
	2040	0	0	0
Norway	2019	0.4	2.5	2.5
Denmark	2019	0.1	0.4	0.7
	2040	0.1	0.5	0.9

Urban area	Year	Car	Bus	Truck
Sweden	2019	1.16	5.41	5.41/13.62*
	2040	1.64	7.63	7.63/19.21*
Norway	2019	3.1 – 3.4**	16.8 – 24.6**	16.8 – 24.6**
Denmark	2019	0.8 – 2.4***	7.8	13.9
	2040	1.0 – 2.9***	9.5	16.8

* Without/with trailer.
** Varies according to the size of urban area (less/more then 100 000 inhabitants).
*** Varies according to type of fuel (lowest cost for electric/plug-in-hybrid).

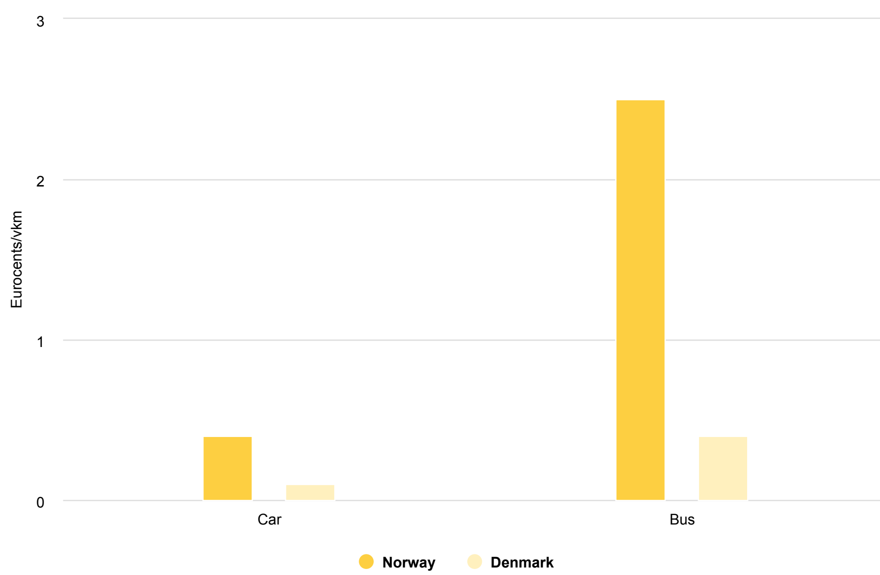

Figure 4.3: Recommended noise values in rural areas are far higher for buses than for cars, highest for Norway and zero for Sweden.

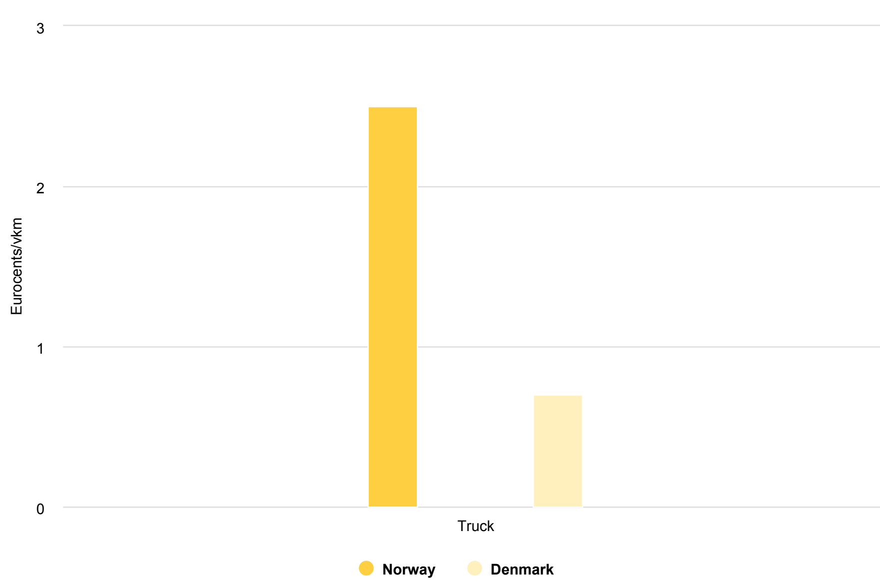

Figure 4.4: The noise values of noise from trucks in rural areas are highest in Norway and zero in Sweden.

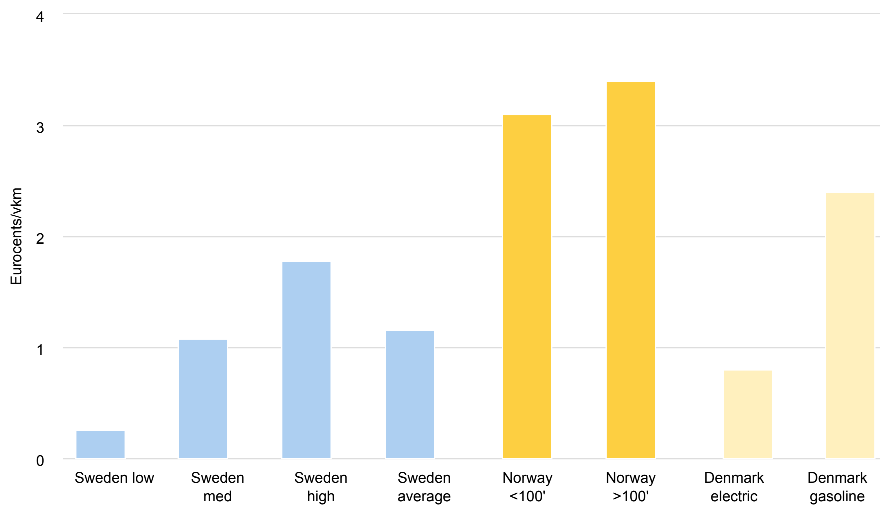

Figure 4.5: Recommended noise values from cars in urban areas are highest in Norway and generally higher in areas with the highest population density.

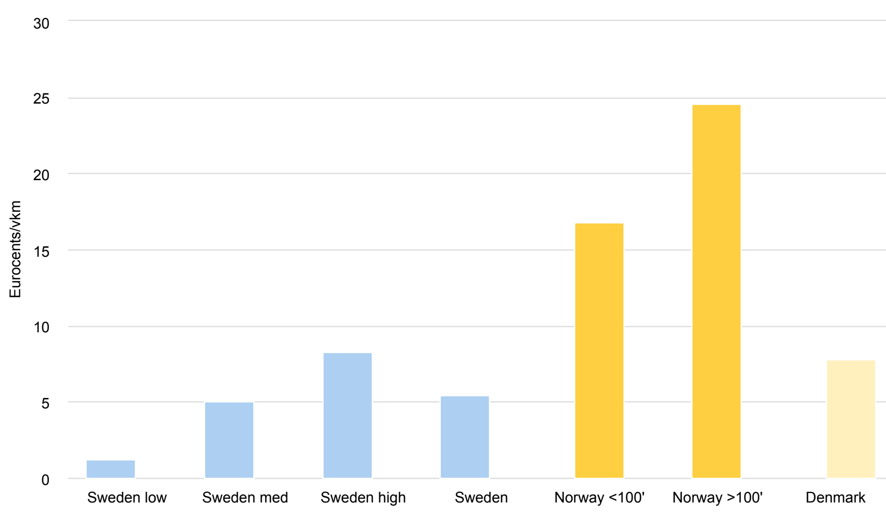

Figure 4.6: The noise values for buses in urban area are highest in Norway and highest in areas with the highest population density.

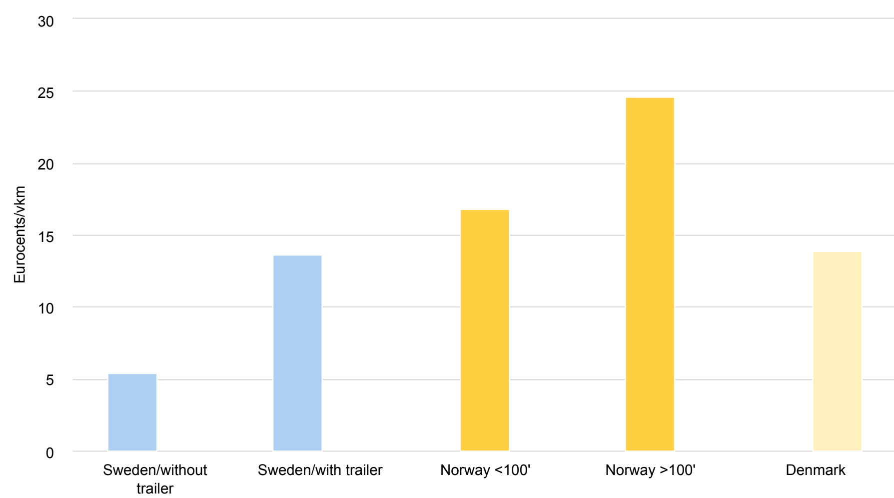

Figure 4.7: The values of noise from trucks in urban areas vary from 5 to 25 eurocents/vkm.

Table 4.10 and figures 4.8–4.9 illustrate the recommended values of noise/vehicle km from railways in Denmark, Norway and Sweden. Values are higher for freight trains than for passenger trains, higher in urban areas than in rural areas in Denmark and Norway, and in the case of Norway higher by night than by day. In rural areas, Norwegian values are higher than Danish values. In urban areas, Danish values are higher than Norwegian daytime values, and lower than Norwegian nighttime values.

Table 4.10: Recommended rail marginal noise values by country, vehicle type, degree of urbanization, time of day and year. Eurocents$_{2019}$/train km.

	Year	Area	Passenger Day	Passenger Night	Freight Day	Freight Night
Sweden	2019	All	9.8	9.8	50.0	50.0
	2040	All	13.8	13.8	70.5	70.5
Norway	2019	Rural	5	45	27	252
	2019	Urban	12	123	93	896
Denmark	2019	Rural	1.4	1.4	8.1	8.1
	2019	Urban	56.2	56.2	322.8	322.8
	2040	Rural	1.7	1.7	9.8	9.8
	2040	Urban	68.0	68.0	390.3	390.3

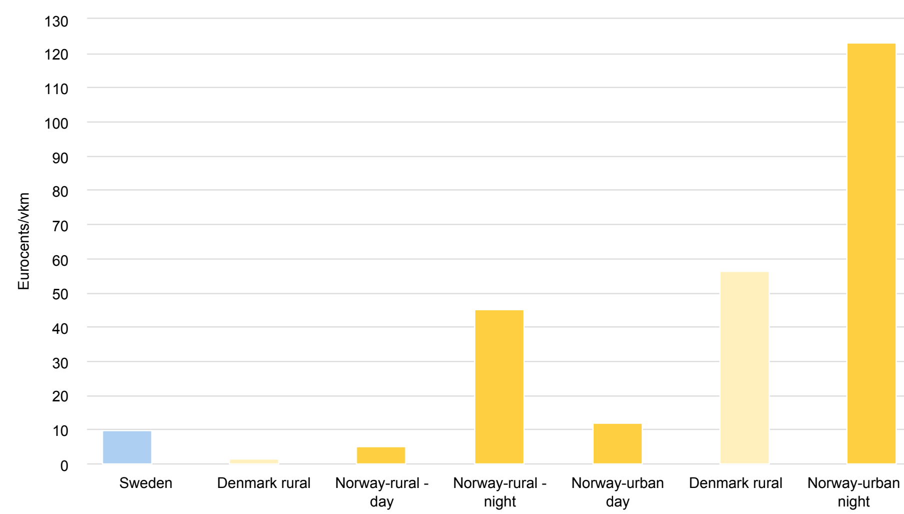

Figure 4.8: The values of noise from passenger trains are by far highest in urban areas in Norway by night.

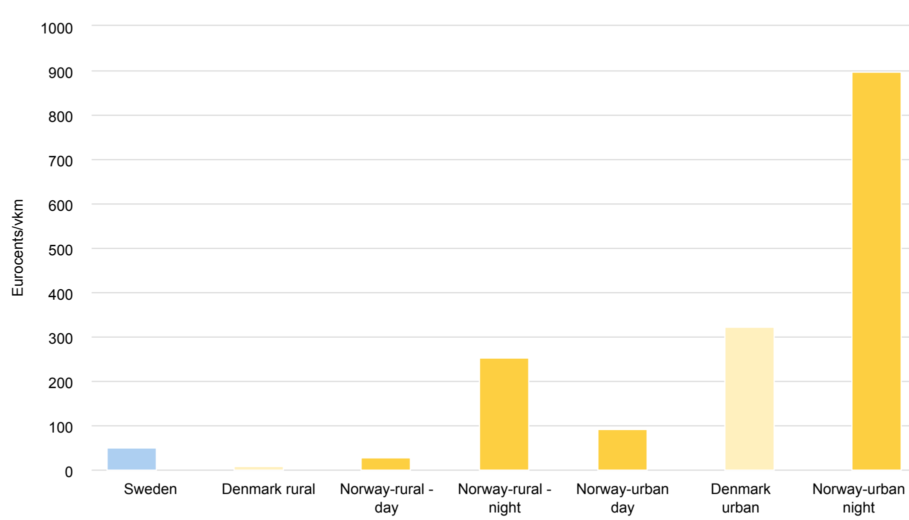

Figure 4.9: The values of noise from freight trains are by far highest in urban areas in Norway by night.

5 Emissions to air except climate emissions

All the large Nordic countries use recommended values related to emissions of PM and NO_x. In addition, Denmark, Finland and Norway have recommended values for SO_2, while Finland also use recommended values for HC (and for rail transport CH_4 and N_2O[6] as well) and Sweden recommends values for NH_3 (ammonia).

Table 5.1: Emissions with a recommended value, by country.

	PM	NO_x	SO_2	HC	CH_4	N_2O	NH_3
Denmark	X	X	X				
Finland	X	X	X	X	X	X	
Norway	X	X	X				
Sweden	X	X					X

The economic assessments in the Nordic countries are based on the Impact Pathway Approach for emissions.

Table 5.2: The Impact Pathway Approach for emissions. Source: SFT (2005).

Calculation of emission factors per vehicle km
Modelling the resulting exposure/concentration levels of pollution according to dispersion modelling and population distribution in the affected geographical area.
Modelling exposure-response functions between concentration levels and damage
Calculation of the damage based on exposure-response functions and the size of the affected population.
Monetary evaluation of damage.

In the case of Iceland, the value of emissions used in Mannvit (2017) is equivalent to approximately 0.37 €-cents/vehicle km.

6. CH_4 (methane) is the most simple of hydrocarbons (HC) and is a greenhouse gas. HC is a subset of volatile organic compounds (VOC).

5.1 Calculation of emission factors per vehicle km

Recommended emission factors per vehicle km have been calculated from various sources.

Denmark

In **Denmark,** emission factors for road, railroad, air and sea are supplied by DCE, mainly based on the COPERT model factors (used for submission of Danish emission inventories and projections to international organizations). Emission factors in Denmark include particulate matter from road dust, brakes and tire wear as well as from exhaust.

Finland

In **Finland,** air pollution from road traffic considers both exhaust fumes and road dust (Gynther et al.2012). For maritime transport, damage from waste and wastewater is also taken into consideration. The unit values also take into account externalities from the extraction, transportation, refining and distribution of fossil fuels.

Sweden and Norway

In **Sweden** and **Norway,** exhaust emission factors for road transport are based on the HBEFA model (Swedish Transport Administration 2019b, Holmgren and Fedoryshyn 2015). For MC and moped, emissions in Sweden are obtained from EMEP/EEA Tier 2. Emission factors include particulate matter from road dust, brakes and tire wear as well as from exhaust.

Swedish emission factors for railroad are based on EU Directive 1997/68/EG. Emission factors for railroad and air transport in **Norway** are calculated based on total fuel consumption and emissions according to Statistics Norway.

5.2 Modelling the resulting exposure/concentration levels of pollution according to geographical area

Denmark

In **Denmark,** a detailed atmospheric modelling of concentrations in the air is based on emissions in the northern hemisphere with extra details for Denmark through a 1 x 1 km grid. Exposure is modelled at two levels: regional and local. At the local level, 100% of the damage is within Denmark, but only a part of the emissions at the regional level on Danish territory affects Denmark. Between 1 and 72 percent of regional contributions from road traffic are estimated to affect Denmark, depending on the substance (1% of SO_x, 34% of NO_x, and 72% of $PPM_{2.5}$). Denmark also takes into consideration regional emissions from the energy sector, where between 8 and 21 percent are estimated to affect Denmark.

Finland

In **Finland**, the impact assessment for particulate matter has been done for five groups of areas: the region around Helsinki, large cities (Tampere, Turku, Oulu), medium-sized cities (50 000–100 000 inhabitants), small cities (10 000–50 000 inhabitants), and other municipalities. Similarly, the cost of emissions from nitrogen oxides varies between the Helsinki area, the large and medium-sized cities, and the small cities and other municipalities

Norway

In **Norway,** the increase in population weighted concentration level per kg of emissions has been calculated in great detail for the four cities of Oslo, Bergen, Trondheim and Drammen and in less detail for 27 other cities. For instance, 1 extra ton of PM released from road emissions in Oslo will increase the concentration level of PM in Oslo by 0,0075 mg/m^3.

Sweden

Exposure in **Sweden** is, according to attachment 2, calculated separately for 5 different areas based on the formula:

$$Exposure = 0.029 \times F_v \times B^{0.5},$$

where F_v is a "ventilation factor" for the urban area (exposure per person and kilogram of emissions), and *B* is the population of the urban area. The ventilation factors differ in five zones across the country and vary between 1.0 and 1.6.

5.3 Monetary evaluation of damage

Denmark

In **Denmark,** the monetary value is attached to exposure of NO_2, $PM_{2.5}$ and O_3[7]. For instance, 1 extra case of bronchitis is related to exposure from $PM_{2.5}$ valued at $€_{2019}$ 42 454 per case.

Norway

In **Norway,** monetary values are calculated per unit of PM_{10} and NO_2. For instance, the value of the long-term effect of bronchitis among children of an increased annual level of 1 $\mu g/m^3$ PM_{10} is estimated at $€_{2019}$ 0.0153 per person. Each case of bronchitis among children is then valued at $€_{2019}$ 75 000. Exposure that increases morbidity is calculated based on the loss of DALY.

Outside urban areas, recommended values for NO_x and PM_{10} are related to abatement costs equal to the level of the present tax on emissions of NO_x. Recommended values for SO_2 are related to cost estimates regarding acidification of the environment and damage to buildings.

7. NO2 and O3 are formed by complex temperature dependent reactions of the emissions of NOx and HC.

Sweden

The **Swedish** valuations are based on studies of the damage cost derived from the actual harm and damage that emissions to air have on human health and on the environment. The findings are reported in the final report from the project REVSEK (Söderqvist, 2019). VOC- and SO_2-emissions are not valued since the emissions from these have less impact (Swedish Transport Administration, 2020).

5.4 Recommended values per kg of emission

Actual recommended values in the Nordic countries in 2019 are presented in table 5.3 and illustrated in figures 5.1 – 5.3. Emission values vary a lot, both between countries, type of area and, in the case of Finland, also between road and railway.

Emissions of particulate matter (PM) cause predominantly local effects. This is reflected in the difference in valuation between rural and urban areas, where the urban values are many times higher than the rural values in Finland and Norway, and higher than in rural areas in Denmark. Sweden only recommends values in urban areas.

Norway recommends values for PM_{10} (which includes $PM_{2.5}$), while the other countries use values for $PM_{2.5}$, with Swedish values far greater than the values in Denmark and Finland.

Values of PM in road dust are treated along with emissions in Denmark and Finland, but separately from emissions in Norway and Sweden, based on the value of PM_{10}. Even for road dust, Norway uses values in both rural and urban areas, while Sweden recommends values only for urban areas.

Table 5.3a: Recommended values per kg of particulate matter (PM) for CBA in the Nordic countries. €$_{2019}$/kg[8].

	Emissions		Road dust	
	$PM_{2.5}$	**PM_{10}**	**$PM_{2.5}$**	**PM_{10}**
Finland electric train*	0.5			
Finland diesel train urban area	87			
Finland diesel train other areas	6.0			
Finland urban area road	143		143	
Finland rural area road	9.1		9.1	
Denmark urban area	174		174	
Denmark rural area	115		115	
Norway large urban area		330		796**
Norway small urban area		37		88**
Norway rural area		2.3		2.3**
Sweden urban area	689			172
Sweden rural area				0

*Emissions related to generation of electricity.
**Road dust has a higher value than emissions because the contribution to concentration is higher

The valuation of NO_x varies depending on urbanization in Denmark, Finland and Norway. Sweden only differentiates between parts (north, middle and south) of the country, with values ranging from 0,25 to 0,35 €/kg based on the effect on the environment. Sweden does not include a valuation of the health effects of emissions of NO_x.

Since Denmark and Norway differentiate more with respect to urbanization and also include health effects, these countries use values that are up to 100 times higher per kg of emissions in urban areas compared to Sweden. Values in Denmark and Norway are also far higher than Finnish values.

Emissions of SO_x have a relatively high value in large communities in Norway, but have a far lower value elsewhere. Sweden does not use a value for SO_x, but recommends a value for emissions of ammonia (NH_3).

8. According to Hanssen et al (2020), the recommended values of PM_{10} are 55,840 €/t for towns and smaller cities in Norway, 1210 €/t in Sweden and 74,884 €/t in Finland

Table 5.3b: Recommended values per kg of emission for CBA in the Nordic countries. $€_{2019}/kg$[9].

	NO_X	HC	SO_X	CH_4	N_2O	NH_3
Finland electric train*	0.6	0.03	0.4	0.88	13.0	
Finland diesel train urban area	0.6	0.03		0.88	13.0	
Finland diesel train other areas	0.3	0.03		0.88	13.0	
Finland urban area road	1.5	0.03				
Finland rural area road	0.3	0.03				
Denmark urban area	34		2			
Denmark rural area	16		2			
Norway large urban area	40.5		22.3			
Norway small urban area	9.1		1.1			
Norway rural area	2.3					
Sweden	0.3					0.8

*Emissions related to generation of electricity.

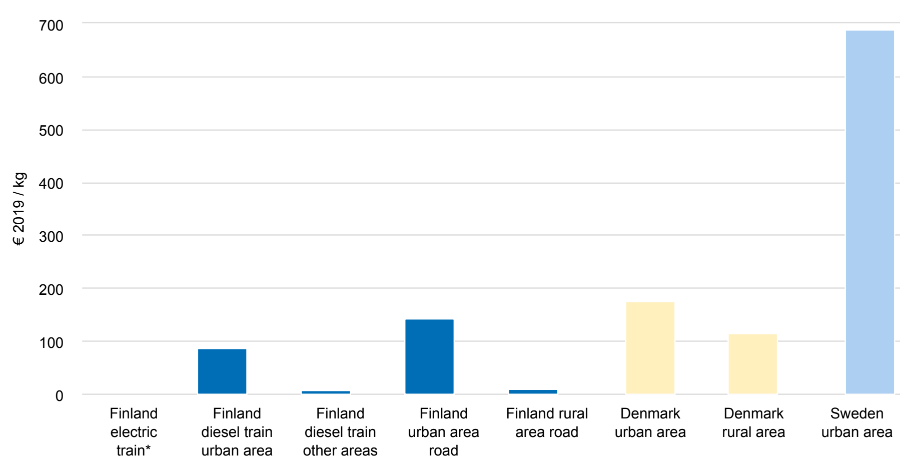

Figure 5.1a: The values of $PM_{2.5}$ are far higher in Sweden than in Denmark and Finland.

9. According to Hanssen et al (2020), the recommended values of NO_x are 6443 €/t for emissions outside cities in Norway, 4004 €/t in Sweden and 886 €/t in Finland. The data were collected from the public sources listed in the footnotes and confirmed in interviews with the local transport authorities in each country but are subject to change in all three countries.

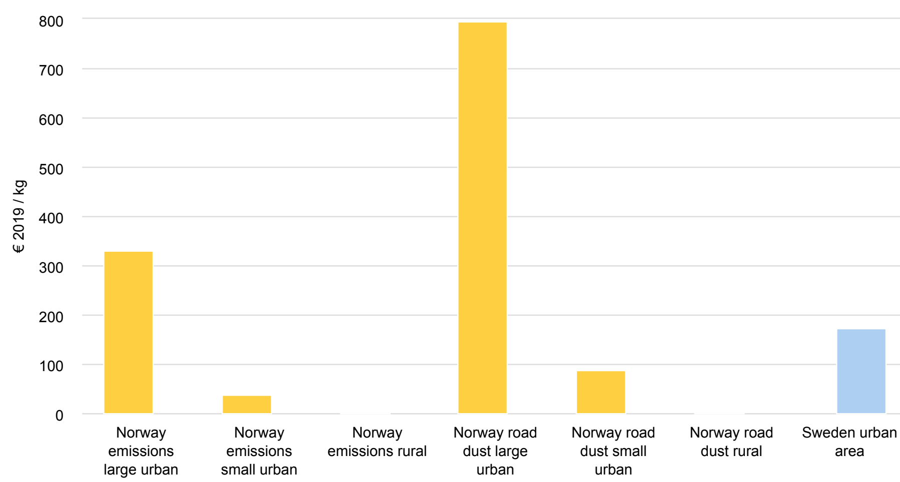

Figure 5.1b: Recommended values of PM10 are highest in Norway.

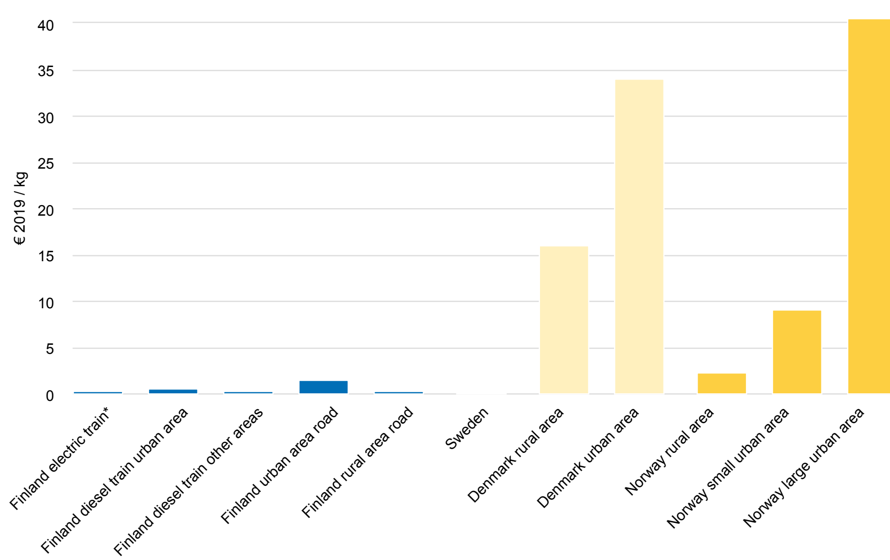

Figure 5.2: Recommended values of NO_x are very low in Finland and Sweden, but high in Denmark and Norway.

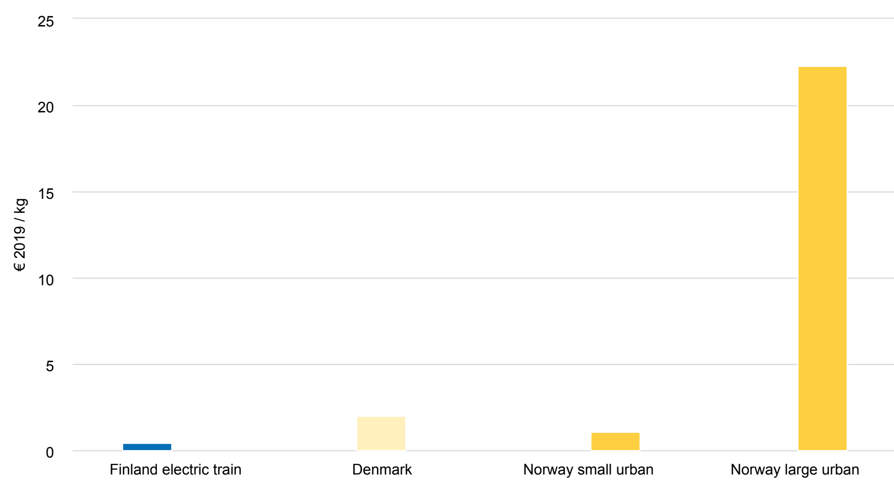

Figure 5.3: Recommended values of SO_x are the lowest in Finland and the highest in urban areas in Norway.

5.5 Recommended value of air pollution per vehicle km

Actual recommended values for emissions except climate emissions in the Nordic countries in 2019 are presented in tables 5.4 – 5.5 and illustrated in figures 5.4 – 5.5. The values for Finland are based on Attachment 2, since the valuation for each emission is virtually unchanged in the update presented in Attachment 4. This means that the presented valuations per vehicle km for Finland are still based on 2007 emission factors.

Focusing on the differences between the countries, we can observe that Sweden uses a higher value for emissions from petrol cars than the other countries, and Denmark uses a lower value than both Finland and Sweden. (Finland values cars with and without catalyzers differently, but presumably almost all cars had catalyzers by 2019.)

For diesel cars, the values are all within the range of 1.3 – 1.7 eurocents per vehicle, with the lowest value in Sweden and the highest in Norway. For electric and hybrid cars, valuations are far higher in Norway than in Denmark, mostly reflecting different valuations of road dust.

For heavy vehicles, the values are especially high for buses in Denmark and Norway. For trucks, it is interesting to note that trucks without a trailer have a higher value than trucks with a trailer in Denmark, while the opposite is true in Sweden and Finland.

Table 5.4: Recommended average values for air pollution for road traffic per vehicle km for CBA in the Nordic countries. €-cents$_{2019}$/km.

Vehicle type	Fuel	DK	SE	FIN	NO	ICE***
Car	Petrol	0.54	1.2	0.65*	0.82	0.37
Car	Diesel	1.49	1.3	1.55	1.65	0.37
Car	Hybrid	0.18			0.62	
Car	El/Hydrogen	0.15			0.62	
MC	Petrol			0.45	0.21	
Van	Petrol	1.18		0.95*	1.23	
Van	Diesel	2.73		2.22	1.75	
Van			1.7			
Highway bus	Diesel	12.9		5.45	11.01	
City bus	Diesel	12.9		5.45	17.08	
City bus	CNG				15.43	
Truck without trailer	Diesel	5.0	2.1	5.32	8.74**	
Truck with trailer	Diesel	3.0	1.4	6.06	8.74**	
Truck	El/Hydrogen				3.40	

* With catalyzer
** Average for all trucks
*** Value used for cars in CBA for an infrastructure project

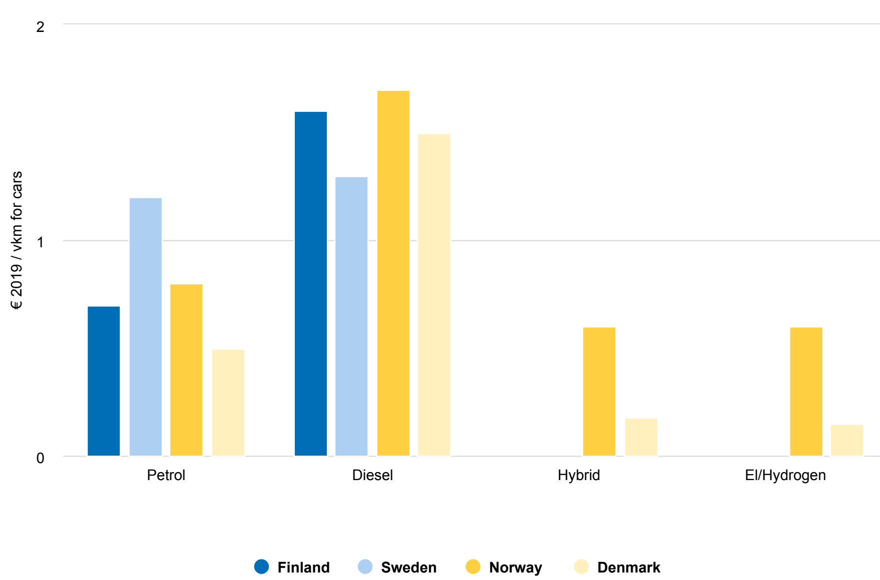

Figure 5.4: Recommended values for air pollution from petrol cars are highest in Sweden and generally higher for diesel cars then petrol cars.

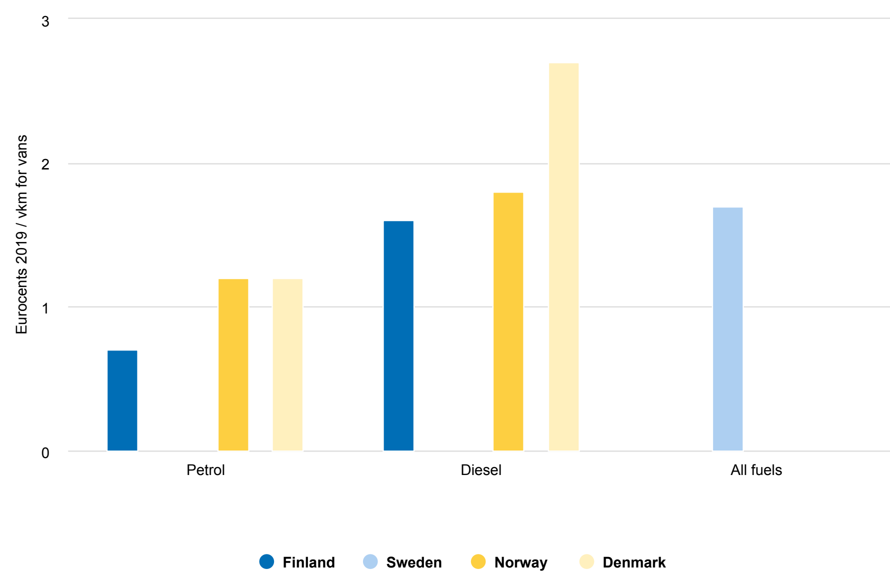

Figure 5.5: Recommended values for air pollution from vans km are highest in Denmark and generally higher for diesel vans then for petrol vans.

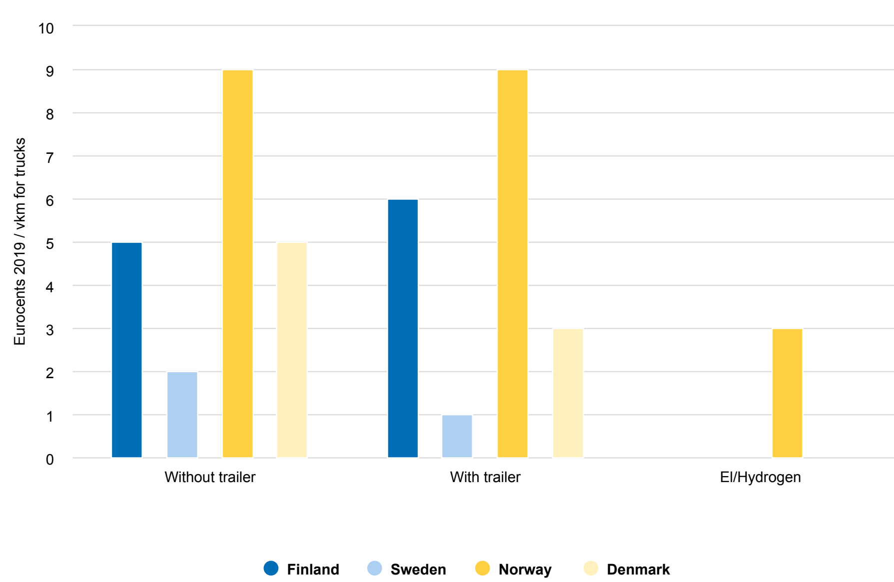

Figure 5.6: Norway has the highest recommended average values for air pollution for trucks.

When comparing average values per vehicle kilometer across the Nordic countries, it is very important to be aware that the average figures are highly influenced by the distribution of the vehicle fleet with respect to EUR-emission norms. This is determined by the registration year of the car, van or truck. In addition, the distribution of vehicle kilometers between urban and rural driving is also important, and both vary across the Nordic countries.

For modes of transport other than roads, some values for Denmark and Norway are stipulated in table 5.5.

Comparisons for rail and sea are difficult to comment on because of differences in segmentation, but Danish average values for diesel trains are well inside the range of Norwegian values for diesel trains in rural/urban areas. Electric trains in Denmark are valued based on the emissions from power production. In Norway, electric power is considered to be clean.

Emissions from aviation have far higher values in Denmark than in Norway. Emissions from aviation mainly affect rural areas, and the difference in emission values reflects the vast difference in valuation of NO_x and $PM_{2.5}$ in rural areas between Norway and Denmark.

Table 5.5: Recommended values for air pollution per vkm for CBA for modes of transport other than roads. €-cents$_{2019}$/km.

		DK	NORWAY			
Mode	**Fuel**	**Average**	**Average**	**Rural**	**Urban <100'**	**Urban >100'**
Passenger train	Diesel	76.3		14.1	68.2	382.2
Freight train	Diesel	412.1		75.8	366.6	2055.7
Passenger train	Electric	0.38				
Freight train	Electric	1.33				
Turboprop	Kerosene	53	8.9			
Domestic jet	Kerosene	211	14.9			
Coaster*	Marine fuel	1975		231/1 416	505/3 269	1 838/12 200
Container ship**	Marine fuel	5083		540–3 394	1 191–8 765	4 348–34 114

*dwt<1'/1'-5'
**dwt 1'-55'

6 Climate effects

The impacts of further increases in the concentration of climate gases are uncertain, and it is extremely difficult to assess the damage costs. Moreover, because the problem is global, the emphasis has in later years been on abatement costs. The most important climate gas is CO_2, while the impact of other gases such as CH_4, N_2O, HFK, PFK and SF_6 is calculated based on their climate effect compared to CO_2 and counted in CO_2-equivalents.

Finland values emissions of CO_2-eq based on long-term damage costs. Denmark uses the quota price in the EU ETS. Norway links the value to the Paris agreement, where global warming emissions should be limited to 1.5 degrees above the preindustrial level. Sweden links its value to the enforcement fee of its low carbon fuel standard.

6.1 Recommended values for climate emissions

Denmark

In **Denmark** the price of emission permits within the EU ETS is used for 2019 and 2020. From 2021 and onwards, the estimated reduction cost outside the EU ETS is used, based on an EU study presenting marginal non-ETS abatement costs at the European level. The result updated in January 2021 is a value per ton CO_2-eq. of $€_{2019}$ 24.2 in 2020, increasing to respectively $€_{2019}$ 35.8 for emissions inside ETS and $€_{2019}$ 43.5 outside ETS in 2030 based on presumed European abatement costs. In addition, the Ministry of Tranport[10] recommends an alternative calculation with an emission price of $€_{2019}$ 197.1 per ton CO_2-eq (1500 DKK_{2021}) for all years. Denmark also takes into account climate costs connected to electricity production of $€_{2019}$ 0.004/kWh in 2019 and $€_{2019}$ 0.0111 in 2040.

Finland

The value of a ton of carbon dioxide used in **Finland** originates from the ExternE-project (Bickel & Friedrich, 2001) and was updated in 2013 (Tervonen & Metsäranta, 2015) to the equivalent of $€_{2019}$ 40 per ton CO_2-eq. While Danish values are based on abatement costs in Europe, the Finnish value is based on the estimated long-term damages arising from climate change. Gynther et al. (2012) recommend that for projects far into the future, the value of CO_2 should be gradually raised. For electricity used for rail transport, the same CO_2-value is used to account for the fossil content in the electricity generation mix.

Iceland

The price used to calculate the value of climate impact in Mannvit (2017), page 31) is equivalent to approximately 0.007 €-cent/vehicle km (ISK 0,01/km).

10. Finansministeriet 2021: Nøgletalskatalog

Norway

The value of CO_2-eq used in **Norway** has so far been related to estimates of future prices of CO_2 in the EU Emission Trading System (EU ETS) in Klimakur 2020 (2012). The resulting recommendation is a price per ton CO_2-eq of $€_{2019}$ 41.3 in 2020 and $€_{2019}$ 102.7 in 2030.

Rødseth et al. (2019) look at the recommendations by Hagen-utvalget (NOU 2012:16). The basic recommendation by Hagen-utvalget is to price climate effects based on the marginal price of emissions that is required in order to reach certain emission targets. The estimates in Rødseth et al. (2019) relate to the Paris agreement, where global warming emissions should be limited to 1.5 degrees above preindustrial levels. This results in a recommendation of €222 in 2030, increasing to €3545 in 2100.

Hoel, Moss, and Vennemo, H. (2020) recommend a CO_2 price of approximately NOK 1000/ton for emissions not included in EU ETS in 2020, increasing with the discount rate in the future.

The latest recommendation was issued on July 3rd 2020 by the Ministry of Transport in a letter to the transport agencies. The letter recommends a value of NOK 1500/ton ($€_{2019}$ 152/ton) CO_2 in 2020 with a future annual adjustments equal to the discount rate. For the purpose of sensitivity analysis, values of both 500 and 2500 NOK/ton should be applied, at least in cases where the valuation is important for the result and/or the reduction of CO_2-emissions is the main purpose of the project.

Sweden

In **Sweden,** ASEK (2018) recommends that emissions of CO_2-eq. are valued at a shadow price derived from the penalty (enforcement fee) for not meeting the low carbon fuel standard. This implicates a present value of $€_{2019}$ 115 per ton. The latest revision to the value of CO_2 in ASEK was made in September 2019, to 7000 SEK/ton CO_2, applicable from April 1st, 2020 (Swedish Transport Administration, 2019). This translates to $€_{2019}$ 665 per ton CO_2.

Table 7.1 and figure 7.1 sum up the values that are used in each of the Nordic countries except Iceland. The value of 1 ton of CO_2-eq in 2019 varies from $€_{2019}$ 16.2 in Denmark to $€_{2019}$ 115 in Sweden.

With the revised price in Sweden, the range will increase to $€_{2019}$ 16.7–665 per ton in 2020.

Future prices for 2030 vary from $€_{2019}$ 25.8/44.8 per ton CO_2 in Denmark to $€_{2019}$ 665 in Sweden. The Swedish values are far higher than the values in the other countries in 2019–2030, but by 2050 the Norwegian value exceeds the Swedish value.

Table 6.1: Recommended values of CO_2 in the Nordic countries. $€_{2019}$/ton CO_2-eq.[11]

Country		Based on	2020	2030	2050
Finland		Damage cost	79		
Sweden		Penalty for not meeting fuel standard	665	665	665
Denmark	ETS	ETS carbon price	24.2	35.8	
	Non-ETS	ETS carbon price	24.2		
	Non-ETS	Non-ETS abatement cost Europe		43.5	
Denmark		Alternative price	197.1	197.1	
Norway		Abatement cost	152	225	493

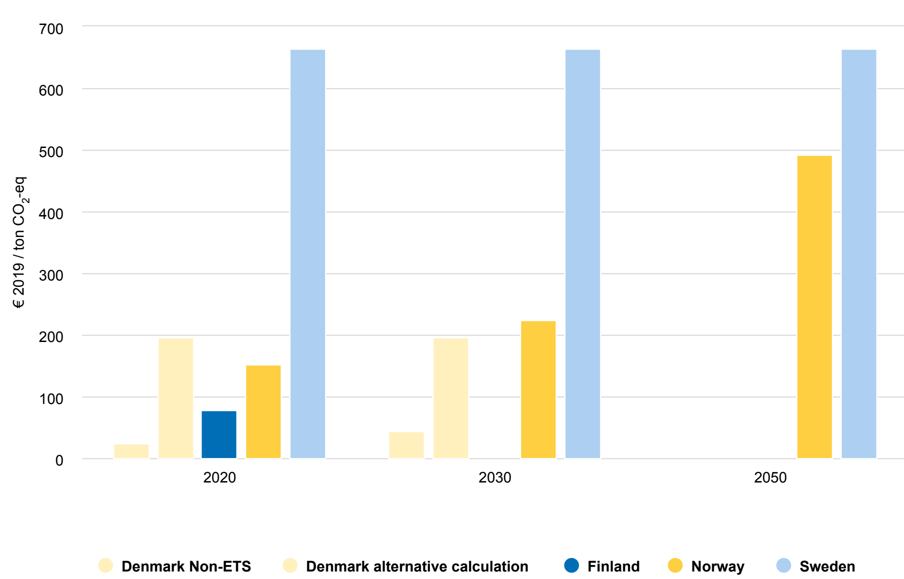

Figure 6.1: Recommended values per ton CO_2-eq increase over time, with Swedish valuation being the highest.

11. According to Hanssen et al (2020), the recommended values of CO_2 are 28 €/t in Norway, 153 €/t in Serden and 41 €/t in Finland.

7 Overall comparison of valuation methods

In this report we have established that the Nordic countries use different valuation methods, values and processes of updating the values used in cost benefit analysis in transport.

They also handle environmental effects without a monetary value differently.

The values used in CBA change rapidly, and a similar report written 1 year earlier would in many cases have provided different results since Norway, Sweden and Finland have provided updates in 2019 and 2020.

Given that the latest updates in Sweden and Finland are from 2020, the overall impression is that all the Nordic countries use recently updated values of environmental effects.

Values in Denmark are, on the other hand, updated regularly, but are still based on valuations from 2010. It also worth noticing that Denmark uses market prices including VAT to the extent that costs without VAT (for instance hospital costs) are recalculated to include VAT in CBA. The other countries use market prices, but without adjusting the costs without VAT. The existence of one single easily downloadable worksheet with authorized values for each year up to 2090 in Denmark is commendable because it simplifies the practical use of CBA and ensures consistent usage of the values in all sectors of transport.

Looking at the actual values in use, starting with **noise**, the main observation is that Finland uses older Swedish data where only nuisance is taken into consideration, while the other countries also include various health effects. Despite this fact, Finland recommends the highest total values for comparable levels of road noise.

Values for emissions of Particulate matter (PM) and Nitrogen oxides (NO_X) are used in all the countries, while values of emissions from Sulphur oxides (SO_X) are used in Denmark, Finland and Norway. Finland also recommends values of Hydrocarbons (HC), Methane (CH_4) and Nitrous oxide (N_2O) while Sweden includes values of Ammonia (NH_3).

For **PM**, the values are related to $PM_{2.5}$ in Denmark and Finland, to PM_{10} in Norway and to both $PM_{2.5}$ (for emissions) and PM_{10} (for road dust) in Sweden. Only Norway and Sweden use different values for emissions (exhaust) and road dust (from wear and tear), while Denmark uses the same value for road dust and emissions. Recommended values are generally far higher in urban areas than in rural areas, and, in the case of Sweden, zero outside rural areas. Sweden also uses the highest value of $PM_{2,5}$ in urban areas by far.

For **NO_X**, the values in Finland and Sweden are almost negligible compared to the values used in Denmark and Norway. Denmark, Finland and Norway also use higher values in urban areas than in rural areas, while Sweden only differentiates between the northern, middle and southern part of the country, but with far smaller values than for rural areas in Denmark and Norway.

Values of **SO_X** are relatively low, except in large urban areas in Norway. In the case of Finland, the low value of SO_X is used for emissions from electricity production connected to electric railways, but not for diesel trains or vehicles.

The most extreme and important difference between values in the Nordic countries relate to **global** warming **emissions** where the values of emissions in 2020 vary from €24/ton CO_2 in Denmark to €665/ton in Sweden. The values differ marginally less for future emissions since both Denmark and Norway use higher values for future emissions, but we are still looking at a variation of €45/ton CO_2 in Denmark to €665/ton in Sweden. This is an extreme difference in the valuation of emissions, but Denmark also recommends an alternative price of €197/ton CO_2-eq, reducing the differences in valuation between the Nordic countries to €79/ton for Finland compared to $665/ton for Sweden. This still represents an extreme difference since CO_2-emissions from many other sectors have a common European price through the price of permits in the EU Emission Trading System (EU ETS).

8 The methods used to integrate environmental effects without a monetary value

All the 4 countries have implemented the EU's Environmental Impact Assessment Directive.

In **Norway and Sweden**, the recommended treatment of non-monetized effects is based on a separate analysis of non-monetized environmental effects to avoid double-counting. The effects are then weighed against the monetized effects in the CBA to reach conclusions which take into consideration both the monetized effects and the non-monetized environmental effects of infrastructure projects.

In **Finland and Denmark,** infrastructure projects also require non-monetary assessments of environmental effects in addition to CBA based on effects with a value. This assessment may include environmental effects that are also included in the CBA.

Denmark

Finansministeriet (2017) presents a few recommendations concerning how to include or describe non-monetized effects in economic appraisals. They recommend evaluation based on observed behaviour or hypothetical valuation. Since a tailor-made evaluation study is usually not feasible, the standard is to report on quantitative, but non-monetarized effects only.

For most major construction projects in **Denmark,** is it mandatory to supply a report ("VVM-rapport") on the expected consequences for the environment (Miljøministeriet. 2009). Effects must be described and evaluated for both the construction phase and the operation phase. The report must include effects regarding:

- the size of the local population affected and how it is affected;
- effects on animals and plants;
- soil pollution;
- water pollution (surface and ground) and flooding;
- air pollution;
- climate (both micro climate and global warming) ;
- transport to the construction site;
- cultural heritage, architecture, archaeology etc.;
- landscape;
- local socio economy (social structure and local industries) ;
- noise;
- use of natural resources; and
- other effects (such as vibrations, light annoyances, smell and heat).

Finland

According to **Finnish** law, the environmental impacts of an infrastructure project must be assessed, described and analyzed. This is done within the framework of an environmental impact assessment (Tiehallinto, 2009).

The direct and the indirect impacts of an investment project on the environment must be assessed. These include impacts on (Tiehallinto, 2009):

- human health, living conditions, and welfare;
- soil, water (both surface and groundwater), and biodiversity;
- community structure, buildings, landscape, cityscape, and cultural heritage;
- exploitation of natural resources; and
- interactions between the aspects above.

Each impact of a project can be either positive or negative on the environment. They can (1) be long- or short term, (2) have a large or a small scope, (3) be certain or uncertain, (4) take place seldom or often, and finally, they can (5) be irreversible or reversible.

Norway

In **Norway**, the non-monetized environmental effects of an infrastructure project are divided into 5 main categories according to Håndbok V712 Konsekvensanalyser (Vegdirektoratet 2018). They are all related to land use:

- landscape picture: "The spatial and visual landscape";
- outdoor urban/rural life: "The landscape in terms of how people perceive and use it";
- nature diversity: "The ecological landscape";
- cultural heritage: "The cultural-historical landscape"; and
- natural resources: "The production landscape".

An overall assessment of all the environmental effects concludes with a ranking between alternatives based only on assessments of non-monetary effects. The next step is a break-even analysis where, for example, the rescue of a rare species is compared to the extra total assessed cost related to the rescue.

Sweden

In **Sweden,** the effects on land use (encroachment of the physical environment and visual intrusion in the landscape) are included in economic appraisal through a verbal description according to ASEK (2018).

By law, the planning of a new road or railroad in Sweden requires at least an environmental description of the project. The relevant environmental qualities, the expected impact on environmental qualities and the resulting consequences for the environment and human health have to be described.

If the local authorities decide that important environmental consequences are to be expected, a more thorough analysis of environmental effects is required. This analysis has to include issues such as possible alternative solutions, detailed descriptions of the environment before the start and after the conclusion of the project and measures to limit negative effects.

If time savings are the greatest positive impact of the project and physical intrusion is the largest negative impact, it is possible to weigh the value of the intrusions against the travel time savings in a sensitivity analysis. Release of land should be studied in a sensitivity analysis and should not be taken into consideration in the main calculation to avoid double counting. For projects where the winners and losers are separate groups, where the encroachment is to an area of national interest or where the encroachment is not in conflict with savings of travel time etc., ASEK (2018) concludes that expert assessment or an environmental consequences assessment should constitute the basis for an evaluation of the impact.

9 Considerations regarding the use of limited environmental goods

Considerations regarding limited environmental goods are to a large extent integrated in the described assessments of environmental effects without a specific recommended monetary value, since all the countries require a description/evaluation of either all the environmental effects caused by a transport project (Finland and Denmark) or just the effects without a monetary valuation (Sweden and Norway).

Intrusions to the visual landscape are limited goods mentioned in all the countries, whereas biodiversity and cultural heritage are specifically mentioned in Norway, Finland and Denmark. Denmark and Finland also report impacts on soil and water.

All the five specified categories of non-monetized effects in **Norway** are related to changes in the environment that are to some extent irreversible. A new bridge or road will in many cases change the visual landscape, and possibly outdoor leisure life, forever or for a very long time. Considerations regarding species threatened by extinction, cultural heritage and production potential in the affected area are also of concern with respect to the use of limited environmental goods.

The **Swedish** approach takes into consideration how future economic costs related to extreme weather events can be assessed. In addition, the non-monetary assessments take into consideration the effects on limited environmental goods such as encroachment of the physical environment, visual intrusion and the release of attractive and usable land.

The **Finnish** approach regarding environmental effects of infrastructure projects includes many impacts: Impacts on living conditions, soil, water, biodiversity, landscape, cityscape, cultural heritage and exploitation of natural resources are all effects that, at least partly, relate to the use of limited environmental goods.

In **Denmark**, many of the effects that must be included in the environmental report regard environmental goods that, in many cases, may be considered to be limited. These include effects on animals, plants, soil, water, cultural heritage etc., landscape and the use of natural resources.

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Attachment A:

Treatment of External Effects from Transport in Denmark with focus on the Valuation of Noise and Emissions

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A.1 Introduction

The Danish Ministry of Transport and Housing supplies a set of assumptions to be used for welfare economic appraisal within the transport sector in Denmark. They are presented in the "Transport Economic Unit Prices" that are collected and presented on-line by the Technical University of Denmark (DTU) on behalf of the ministry. Some of the unit cost estimates are supplied by DTU, but most have been adopted from other sources. The main part of the unit prices is driving costs, operation costs, value of travel time, and external costs.

The unit prices are published as a spreadsheet that is updated every, or every second, year. The spreadsheet with the unit prices can be found on-line at:

http://www.cta.man.dtu.dk/modelbibliotek/teresa/transportoekonomiske-enhedspriser

The spreadsheet is supposed to be self-documenting, but there are background reports documenting parts of the prices and this is the case for the external costs of transportation (Transportministeriet, 2010).

A.1.1 Content of the unit prices

The external costs include accidents, noise, congestion, air pollution, climate effects, road wear, and health effects (for cycling). They are presented both as unit costs (e.g. DKK per accident or kg of emission) and as marginal costs per kilometre driven by mode and a number of vehicle and vessel types. Most external cost estimates are based on damage cost. However, since Denmark is subject to a binding emission cap for greenhouse gases, climate change costs are based on emission reduction costs.

The latest version (1.91) of the Danish unit prices was published August 2019.The unit prices are presented for 2019 (the current year) in 2019-prices. In addition, a projection of unit prices for future years (up to 2090) is presented. Some of the costs are projected using the real GDP per capita projection published by the Danish

Ministry of Finance (Finansministeriet, 2019) with an elasticity of 1. Only the share of the costs involving income, production loss, and value of statistical life (VSL) are projected this way, the rest is held constant in the future.

All costs are presented at market prices. This means that a tax component is added to costs at firm or public sector level. This tax component reflects the average load of VAT and excise taxes in private consumption and is currently estimated to be 28% (Finansministeriet, 2019). The tax component is used to convert treatment costs, production loss and the price of CO_2 emission permits to market prices. Costs that are already expressed in market prices (as e.g. VSL) do not need this conversion.

The main focus in this report for the Council of Nordic Ministers is noise, air pollution and climate change. For the first two, the value of statistical life (VSL) plays an important role. The VSL is set to be 34 million DKK in 2019 corresponding to 4.56 million € (Finansministeriet, 2019). The value is based on a stated preference (SP) study performed by the Danish Economic Councils (DØRS, 2016). The VSL is converted to the value of lost life year (VOLY) to 0.188 € by the Ministry of Finance.

A consultant made in 2010 a general update of the external costs for the Danish unit prices (Transportministeriet, 2010), and many of the cost estimates are basically the same today. In the present unit prices, the numbers are projected to 2019 using the consumer price index and, as described above, GDP per capita growth for the shares related to income and VSL. In addition, since 2010 VSL has been revised and The Danish Centre for Environment and Energy (DCE, 2019) has made a revision of the air pollution costs and these are incorporated in the present unit prices. Also, the climate costs have been changed continuously as the emission reduction costs estimates have changed. These changes are included in the present version of the unit prices (vers. 1.91).

Since traffic externalities are often worse in urban than in rural areas, the costs components have estimates for both rural and urban areas. As regard to air pollution, the damage costs are further divided into Danish and foreign costs, and the foreign costs should, as the guidelines from the Ministry of Finance state (Finansministeriet, 2017), per default not be included in welfare economic appraisal. This is a consequence of a strict national point of view in welfare calculations. However, there is an option in the unit prices to count the foreign share in.

A.1.2 The unit prices in Danish cost benefit analyses

The unit prices are constructed to be consistent with the official Danish recommendations on how to perform welfare economic analysis in general By the Ministry of Finance (Finansministeriet 2017) and the related recommendations for the transport sector in Transportministeriet (2015a).

This method is implemented in a comprehensive spread-sheet model called TERESA which is used widely by agencies and consultants when performing cost-benefit analyses for infrastructure projects in Denmark. TERESA has an interface to the unit prices so that changes in the unit prices can be easily transferred to TERESA. TERESA can be found following this link:

http://www.cta.man.dtu.dk/modelbibliotek/teresa

As opposed to the other Nordic countries, national infrastructure investment plans are not prepared systematically in Denmark. There is continuously a portfolio of planned projects on the agenda, and from time to time the parliament agrees to initiate one or more of these and sometimes as a "grand agreement" on a package of projects for the coming years.

Thus, Denmark has like most of the Nordic countries a general CBA guide and common assumptions regarding interest rate, GDP-growth, value of statistical life and value of travel time, but in addition Denmark has a common CBA tool to ensure comparability across projects and modes.

In the sections below, the principles behind the current external estimates for these are presented along with the actual numbers. Conversion from DKK to Euro is done using the central exchange rate agreed with the EU of 7.46.

A.2 Noise

The basis for the noise cost estimates is relatively old – the estimates were originally determined in 2003 and has since then only been updated using inflation, GDP per capita growth and the current estimate for the value of statistical life (VSL).

The noise cost estimates are composed of two elements: health costs and annoyance costs. The latter is determined by observing housing prices. Both costs components are based on the dB level by the façade of the buildings, but this measure is converted to the so-called "noise load number" (SBT) which takes into account that the noise nuisance is increasing more than proportionately with the dB measure. Each dwelling is given the weight of a factor:

$$SBT \quad weight \quad for \quad each \quad dwelling = 4.22^{0.1 \cdot (dB - 73)}$$

This formula is derived from a study of how respondents feel annoyed at various noise levels. The percentage of respondents feeling strongly annoyed is used to form the basis for an estimation of this annoyance curve and this curve is applied to health effects as well.

A.2.1 Health costs

The health costs are estimated in a study from 2003 (Miljøstyrelsen, 2003a). The so-called Impact pathway method is used: the causal chain from noise emission to noise exposure to diseases to treatment/death and finally to the cost of treatment/death. The cost estimate is based on an international meta-study from 2002 (van Kempen et al., 2002) that reports an increase in the risk for heart disease of 9% for each 5dB increase in the daytime noise levels between 51 and 70 dB. The health effect is based on the two diseases cardiovascular disease and hypertension. For these two diseases, statistically significant risk increases from noise exposure have been documented. Other diseases, such as breast cancer and diabetes, are suspected to be partially caused by noise, but so far no firm conclusions have been reached, and they are therefore not included.

Since it takes some time from the exposure to the disease, a latency of 10 years is assumed, and the mean number of lost life years is supposed to be 5.

The components of the health costs covered are: treatment, net loss of production and welfare loss (death). Their size is shown in table A.2.1.

Table A.2.1: Noise health cost components for 2019

	2019-€ per SBT per year
Health treatment	83
production loss	7
Death	3019
Total health costs	3109

By far the largest share (97%) of the health costs are related to early death due to noise related diseases.

A.2.2 Annoyance costs

The annoyance cost estimates are based on two house price studies from 2003 (Miljøstyrelsen, 2003b and Bjørner et al., 2003). The first is a hedonic study using observed house prices and their relation to noise levels controlling for house size and quality. However, there is no control for air pollution which is most likely closely correlated with noise, so the cost estimate may include perceived air pollution to some degree. The latter study contains a similar hedonic evaluation for apartments along the same lines. The two studies are harmonized and compared by Transportministeriet (2010) and the results are weighted to form the following costs for apartments and houses converted to 2019-level. See table A.2.2.

Table A.2.2: Noise annoyance cost 2019

2019-€ per SBT per year	2019-€	weight
Apartments	688	55%
Houses	3165	45%
Average	1803	100%

The weighted average of the two dwelling types is based on a weighting from the Danish mapping of noise loaded dwellings (Vejdirektoratet, 1998). The weighting cover all Danish dwellings, but dwellings with noise levels below 55 dB have been excluded.

A.2.3 Total unit costs for noise

The total costs of noise including both health and annoyance is found by adding the two together. This is done even though there may be some overlap between the two components. The overlap may occur because the risk of disease may be included in the annoyance cost estimate to the degree that the risk is perceived by the persons demanding housing. The total costs are presented in table A.2.3

Table A.2.3: Total noise costs

2019-€ per SBT per year	2019	2040
Annoyance costs	1803	2180
Health costs	3109	3759
Total costs	4912	5939

99.9% of these costs are related to production loss or value of statistical life and are therefore projected using GDP per capita. The above values together with the SBT-weight formula implies the following total noise costs per dwelling per year at different dB levels by the façade (table A.2.4):

Table A.2.4: Total noise costs per dwelling per year in 2019-€

dB	2019	2040
55	368	445
60	756	914
65	1552	1877
70	3189	3856
75	6551	7921

These noise costs are assumed to cover both road and rail noise. Note that the costs cover the household in the dwelling. According to Statistics Denmark, on average the number of persons in a Danish household was 2.15 by the beginning of 2019.

A.2.4 Marginal noise costs

The unit prices also present marginal noise cost per km for a number of vehicle types. The marginal costs are based on the costs per SBT above combined with detailed calculations of the increase in noise related to a marginal increase in traffic. The method is described in Transportministeriet (2010).

For road traffic a detailed mapping based on noise models of the noise level for selected representative cities along with a conversion to SBT figures has been performed. The noise effects of a general increase in the traffic level of 10% is analysed in a noise model for these cities and the results are weighted together to country level taking into account the population densities. The results are broken down on vehicle category using existing knowledge on the relation between speed and noise for each category and a mapping of the geographical distribution of traffic and typical vehicle speed by geography. In this process separate estimates for urban and rural areas are calculated.

For EV's a cost reduction of 67% in the cities and 0% in rural areas compared to conventional cars is assumed based on Copenhagen Economics (2008). Plug-in hybrids are assumed to have the same noise levels as EV's, whereas ordinary hybrids for the lack of better are given marginal costs halfway between conventional cars and EV's.

No reductions due to any future reductions in the noise from conventional engines, road surface or tires are taken into account when presenting marginal cost estimates for the future.

For rail similar calculations as for cars have been performed for a few selected track sections considered to be representative. Two types of trains are included, passenger and freight, and no distinction is made between diesel and electric trains.

For air and sea transport no cost estimates are included in the Danish unit prices.

In table A.2.5 the resulting marginal noise costs are presented.

Table A.2.5: Marginal external noise costs

2019-€ cent per vehicle km		2019			2040		
		Average	Urban	Rural	Average	Urban	Rural
Passenger car	Gasoline	1.1	2.4	0.1	1.3	2.9	0.1
	Diesel	1.1	2.4	0.1	1.3	2.9	0.1
	Hybrid	0.7	1.6	0.1	0.9	1.9	0.1
	Plug-in hybrid	0.4	0.8	0.1	0.5	1.0	0.1
	Electric	0.4	0.8	0.1	0.5	1.0	0.1
Van	Gasoline	1.5	3.8	0.2	1.8	4.6	0.2
	Diesel	1.5	3.8	0.2	1.8	4.6	0.2
Truck	Diesel	2.1	13.9	0.7	2.6	16.8	0.9
Buss	Diesel	4.6	7.8	0.4	5.6	9.5	0.5
Passenger train		6.9	56.2	1.4	8.3	68.0	1.7
Freight Train		39.5	322.8	8.1	47.8	390.3	9.8

A.3 Air pollution

The cost estimates for air pollution are very recent and up-to-date. They come from Danish Centre for Environment and Energy (DCE) at Aarhus University (DCE, 2019) and include SO_x (SO_2 and SO_4), NO_x (NO_2, NO_3 and O_3) and $PPM_{2.5}$. Earlier, emissions of CO and HC (NMVOC) were also included. However, their contribution to costs were very small. As for the noise related health costs, the air pollution estimates are based on the impact pathway method:

- Detailed atmospheric modelling of concentrations in the air based on emissions in the northern hemisphere with extra details for Denmark through a 1 x 1 km grid.
- Mapping of the exposure in Denmark based on population data.
- Estimates of health effects (illness and death) based on dose-response functions
- Valuation of the health effects. Only costs caused by emissions from Danish area are included.

The exposure is modelled at two levels: regional and local. Only a part of the emissions at regional level from Danish area affects Denmark. At the local level 100% of the damages are within Denmark.

In general DCE applies the same assumptions as published in Finansministeriet (2019), most importantly the value of statistical life estimate of 4.56 million €. However, in addition DCE assumes a 50% higher cost for babies.

A.3.1 Unit air pollution costs

DCE presents results in DKK per kg pollutant emitted for a number of sectors. Here, SNAP1 (energy sector) and SNAP7 (road transport) are relevant. For air and sea transport the costs from rural road transport has been applied in the unit costs presented.

The included basic health effects and their cost estimates are presented in table A.3.1.

Table A.3.1: Morbidity costs (illness)

	2019-€	Unit
Bronchitis ($PM_{2,5}$)	42 454	Per case
Hospitalization, respiratory	10 698	Per case
Hospitalization, cardiovascular	17 220	Per case
Lung cancer ($PM_{2,5}$)	23 476	Per case
Asthma symptoms, children ($PM_{2,5}$)	1426	Per year
Asthma, bronchitis, children ($PM_{2,5}$)	174	Per year
Sick days ($PM_{2,5}$ and NO_2)		
- Work days (20–65 years)	293	Per day
- All days, net	160	Per day
Sick days (O_3)	84	Per day

The marginal cost effects are calculated using a scenario assuming a 30% reduction of emissions. DCE presents regional results together with the Danish share as shown in table A.3.2 for the transport and energy sectors.

Table A.3.2: Marginal external costs from regional contributions

Emission	SO_x	NO_x	$PPM_{2,5}$
Related substances	SO_2, SO_4	O_3, NO_2, NO_3	
Energy sector (SNAP1), 2019-€ per kg	19	20	38
- of which in DK	9%	8%	21%
Road Transport (SNAP7), 2019-€ per kg	166	30	130
- of which in DK	1%	34%	72%

In addition, for NO_x and $PPM_{2.5}$ there are costs from local contributions from transport. They are shown in table A.3.3.

Table A.3.3: Additional marginal external costs from local sources (SNAP7)

Area	Population density	NO_x	$PPM_{2.5}$
	Persons per km^2	2019-€ per kg	2019-€ per kg
Central Copenhagen	8285	51	186
Aarhus city	2744	25	63
Aalborg city	2263	12	50
Odense city	2237	20	53
Denmark in general	132	11	39

The air pollution costs are split into urban and rural areas using such additional costs from local sources. Table A.3.3 is not used directly, but more detailed population density based data are used, such that areas with population density above 1500 persons per km^2 are considered urban and the rest rural. A small correction is made to ensure that the national cost average using the official split on urban and rural road traffic (which is based on a city criteria of 5000 inhabitants) reach the national average from DCE.

Adding up the regional and the local contributions, the costs presented in table A.3.4 are found. Here, only the costs affecting Danish residents are included in accordance with the principles in the Danish Ministry of Finance's manual for CBA.

Table A.3.4: External costs for emissions from road transport

2019-€ per kg	Urban	Rural
$PM_{2,5}$	174	115
NO_x	34	16
SO_2	2	2

A.3.2 Marginal air pollution costs

To transform unit costs for emissions to the marginal external cost per vehicle or vessel kilometre, the unit costs per kg are multiplied by emission factors for the different vehicles and vessels at a detailed level. The emission factors are supplied by DCE and are partly based on the COPERT model factors that are used when reporting Danish emission inventories and projections to international organisations. They reflect the emissions of the average fleet in 2015, not only new vehicles. For air and sea DCE has supplied emission factors for specific typical domestic vessels.

For EV’s emission factors per km are based on the emission factors per kWh from average Danish power supply for 2017 from Energinet.dk including an average grid loss of 5% and these are combined with the energy efficiency data of the EV’s from DCE. For plug-in hybrids it is assumed that 65% of the kilometres are driven by grid power and the rest is gasoline driven.

As emissions depend on the speed and driving pattern, the emission factors for road transport are split on urban and rural conditions and they are reported at a very detailed level (for instance there are 12 types of trucks). Further, there are different factors for gasoline and diesel engines. The many types of vehicles are weighted, and the results from each of the three substances $PM_{2.5}$ (including non-exhaust particles), NO_x, and SO_2 are added together to form the following cost estimates per km (table A.3.5).

Table A.3.5: Marginal air pollution costs per vehicle kilometre

2019-€-cent per vehicle km		2019			2040		
		Average	Urban	Rural	Average	Urban	Rural
Passenger car	Gasoline	0.5	1.3	0.4	0.6	1.6	0.4
	Diesel	1.5	3.2	1.1	1.8	3.8	1.3
	Hybrid	0.2	0.5	0.2	0.3	0.7	0.2
	Plug-in hybrid	0.2	0.3	0.1	0.2	0.4	0.2
	Electric	0.1	0.2	0.1	0.2	0.2	0.2
Van	Gasoline	1.2	2.6	0.8	1.4	3.1	1.0
	Diesel	2.7	5.3	2.0	3.3	6.5	2.5
Truck	Diesel	4.5	14.2	4.0	5.5	17.2	4.8
Buss	Diesel	12.9	21.3	7.1	15.6	25.8	8.6
Passenger train	Electric	0.4			0.5		
	Diesel	76.3			92.2		
Freight Train	Electric	1.3			1.6		
	Diesel	412.1			497.9		
Passenger plane	Jet	211			255		
	Turbo prop	53			63		
Coaster		1975			2387		
Container ship		5083			6142		

The national average of the urban and rural estimates is found using traffic shares for each mode and vehicle type.

Although Euro norms are expected to reduce emission factors in the future, emission factors are held constant in the unit prices. Thus, changes in the marginal external costs in future years reflect only higher unit costs due to growth in GDP per capita (99,5%).

A.4 Climate change

A.4.1 Unit climate costs

The climate cost estimates are based on abatement costs, not damage costs.

The climate costs include effects from CO_2, CH_4 and N_2O. The emissions from each of them are transformed to CO_2-equivalents using the weights 1 for CO_2, 28 for CH_4 and 265 for N_2O. For the years 2019 and 2020 the price of emission permits within the European Emission Trading Scheme (ETS) is used as an estimate of the abatement costs. From 2021 and on estimates of the reduction costs outside of the ETS are used as abatement costs, since each country has individual emissions caps for the non-ETS sectors for the period 2021 to 2030. The Ministry of Finance (Finansministeriet, 2019) and The Danish Energy Agency (Energistyrelsen, 2018) publish the assumptions about the prices. Currently, the prices for the transport sector are based on a EU-study (European Commission, 2014) presenting marginal non-ETS abatement costs at European level. The prices are shown in table A.4.1.

Table A.4.1: Price of CO_2 reductions

2019-€ per tons	ETS	Non-ETS
2019	**16.2**	16.2
2020	**16.7**	16.7
2021	17.2	**29.9**
2022	17.9	**31.0**
2023	18.6	**32.3**
2024	19.4	**33.6**
2025	20.2	**35.1**
2026	21.2	**36.8**
2027	22.2	**38.5**
2028	23.3	**40.5**
2029	24.5	**42.5**
2030 and on	25.8	**44.8**

In the Danish unit prices 28% are added to these prices to convert to market prices.

For electricity, the external costs of CO_2 emissions are calculated using the average greenhouse gas emission from the Danish power supply mix in 2017 of 193.4 g CO_2-equivalents per kWh (including 5% grid loss) and the ETS price estimate. This gives the following prices in market prices per kWh (table A.4.2):

Table A.4.2: Climate cost per kWh Danish power supply

2019-€-cent per kWh	2019	2040
	0.40	1.11

The estimate for the future is based on the assumption that the power mix will remain the same as today. However, this is not likely to happen since there are plans to further increase the share of renewables in Danish power production.

It is worth noticing that in welfare economic analyses the climate change cost of power consumption is assumed to be zero, as the ETS is assumed to internalize the external costs and hence the price of the emission permits is reflected in the power price. The recent revision of the ETS makes it possible to withdraw emission permits from the market and therefore the assumption of zero emissions from power marginal consumption may be replaced in the future.

A.4.2 Marginal climate costs

The marginal external costs per vehicle or vessel kilometre are calculated by multiplying the unit costs per kg CO_2 by emission factors for the different vehicles and vessels at a detailed level. The emissions factors for CO_2, CH_4 and N_2O come from the same source as the air pollution factors i.e. DCE (2019).

The emission factors are specified at the same detailed level as for air pollution, i.e. for a large number of vehicles/vessels, and for road transport they are split on urban and rural areas. They are higher in urban areas as a consequence of the more varying driving pattern.

The marginal climate costs are shown in table A.4.3.

Table A.4.3: Marginal climate costs per vehicle kilometre

2019-€-cent per vehicle km		2019			2040		
		Average	Urban	Rural	Average	Urban	Rural
Passenger car	Gasoline	0.3	0.5	0.3	0.9	1.3	0.8
	Diesel	0.3	0.4	0.3	0.8	1.1	0.7
	Hybrid	0.2	0.3	0.2	0.6	0.8	0.6
	Plug-in hybrid	0.2	0.2	0.1	0.4	0.6	0.4
	Electric*	0.1	0.1	0.1	0.2	0.2	0.2
Van	Gasoline	0.5	0.9	0.4	1.4	2.4	1.2
	Diesel	0.4	0.6	0.4	1.2	1.5	1.1
Truck	Diesel	1.5	2.0	1.5	4.1	5.5	4.0
Buss	Diesel	1.4	1.8	1.3	3.9	5.0	3.6
Passenger train	Electric*	4.0			10.9		
	Diesel	8.6			23.7		
Freight Train	Electric*	13.8			38.2		
	Diesel	23.1			64.0		
Passenger plane	Jet	47.7			132.0		
	Turbo prop	16.3			45.1		
Coaster		48.5			134.1		
Container ship		124.7			345.1		

*In welfare calculations the cost is set to zero since the ETS is assumed to internalize the external costs

In spite of the general expectation of more fuel efficient cars in the future, emission factors are held constant after 2019. The reason for the high marginal costs in 2040 is the expectation on increasing unit cost for CO_2. Since all the costs are related to abatement cost, and therefore not related to income or VSL, no projection related to the GDP per capita growth is necessary.

A.5 Other external costs

Besides emissions and noise, the unit prices also contain estimates for other external effects from transport. These are accidents, congestion, road wear and for cycling also positive external effects from improved health. Accidents and congestion are the most important costs for road transport. See table A.5.1.

Table A.5.1: All marginal external costs in 2019. Average across urban and rural estimates.

2019-€-cent per vehicle km		Total	Air pollution	Climate	Noise	Accidents	Congestion	Road wear	Health
Bicycle		-31.5	0.0	0.0	0.0	15.5	0.0	0.0	-47.0
Passenger car	Gasoline	12.0	0.5	0.3	1.1	4.5	5.5	0.2	
	Diesel	13.0	1.5	0.3	1.1	4.5	5.5	0.2	
	Hybrid	11.3	0.2	0.2	0.7	4.5	5.5	0.2	
	Plug-in hybrid	10.9	0.2	0.2	0.4	4.5	5.5	0.2	
	Electric	10.7	0.1	0.1	0.4	4.5	5.5	0.2	
Van	Gasoline	14.6	1.2	0.5	1.5	3.5	7.7	0.3	
	Diesel	16.0	2.7	0.4	1.5	3.5	7.7	0.3	
Truck	Diesel	60.7	4.5	1.5	2.1	26.6	9.4	16.6	
Buss	Diesel	48.3	12.9	1.4	4.6	9.9	10.3	9.1	
Passenger train	Electric	71.9	0.4	4.0	6.9	60.7			
	Diesel	152.5	76.3	8.6	6.9	60.7			
Freight Train	Electric	125.0	1.3	13.8	39.5	70.3			
	Diesel	545.0	412.1	23.1	39.5	70.3			
Passenger plane	Jet	258.7	210.9	47.7					
	Turbo prop	68.7	52.5	16.3					
Coaster		2024	1975	48.5					
Container ship		5208	5083	124.7					

A.6 Non-monetary effects

Finansministeriet (2017) presents a few recommendations concerning how to include or describe non-monetized effects in welfare economic analyses. They encourage trying to evaluate such effects using observed behaviour or hypothetical valuation. Otherwise, they encourage to report quantitative effects such as the number species of insects or m^2 meadow affected by the project. Since a tailor-made evaluation study is usually an infeasible task, the standard is to report quantitative, but non-monetarized, effects only.

Where relevant, considerations about the distribution of gains and losses for different populations groups are sometimes presented. Further, arguments in favour of a project due to employment effects are frequently seen, but this is discouraged in the official recommendations (Transportministeriet, 2015a) as it is considered as a macro-economic effect that would mostly occur also with the alternative use of the funding without the project.

For most major construction projects is it mandatory to supply a report ("VVM-rapport") on the expected consequences for the environment (Miljøministeriet, 2009). Here, a number of effects have to be described and evaluated for both the construction phase and the operation phase. The report has to be approved before the work can begin. The report must include effects for:

- The size of the local population affected and how it is affected
- Effects for animals and plants
- Soil pollution
- Water pollution (surface and ground) and flooding
- Air pollution
- Climate (both micro climate and global warming)
- Transport to the constructions site
- Cultural heritage, architecture and archaeology
- Landscape
- Local socio-economy (social structure and local industries)
- Noise
- Use of natural resources
- Other effects (such as vibrations, light annoyances, smell and heat)

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Attachment B:

Treatment of climate- and environmental consequences in benefit-cost analyses in the transport sector. Finland and Sweden.

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B.1 Introduction

Unit prices for environmental goods make it possible to calculate the environmental impact of an action and compare it with both the investment cost and other actions with market prices. The methodology for determining the shadow prices of environmental goods varies but is for most part based on a damage function approach, willingness to pay to avoid an environmental bad, costs for remedial measures, or the necessary cost to reach a given goal, for example a given reduction of emissions.

The value of environmental goods is expected to change over time, and for some environmental factors there are concrete price or cost plans that are used in the CBA. This is the case at least for the greenhouse gases, where the expectation is of higher prices in the future. The purpose of this report is to examine what these values are, who decides about them, and how the values have been arrived at. In this PM, the cases of Finland and Sweden are examined.

The shadow price of some environmental goods has not been estimated. It is still possible to take these goods into consideration in cost-benefit analyses (CBA). Examples of non-priced goods can be the landscape, recreational values, biodiversity, cultural heritage, and natural resources. Which environmental effects are considered, directions for how the non-priced environmental effects should be systemized and to which extent is a possible future shortage of the non-priced environmental goods taken into consideration will also be discussed.

B.2 Finland

B.2.1 Background

Finland uses a hierarchical system of land-use and spatial plans. No national spatial, or transport infrastructure plan exists, but the government develops national land-use objectives to steer policy on regional spatial structures that are important for the whole country.[12] Moreover, the national government also influences spatial policy indirectly through the Centres for Economic Development, Transport and the Environment (ELY Centres) (OECD, 2017). The planning for new infrastructure is thus done at the level of a city, a county, or over county borders. The responsibility for making and following up a transport system plan lies at the county associations. Other parties participating in the planning are municipalities, ELY Centres and the Finnish Transport Infrastructure Agency (Centres for Economic Development, Transport and the Environment, 2018).

The process of infrastructure planning in Finland can be seen to have three stages: pre-planning, general planning, and road/railway planning. Cost-benefit analysis (CBA) functions as a tool to compare different alternatives for a project in the first two stages of project planning, and it is also used as a means for studying the prerequisites for continued project planning. When planning roads and railroads, usually only one project alternative is studied, however, i.e., information is obtained only about this alternative. It is obligatory by law to make a CBA for infrastructure projects, which are made at the Finnish Transport Infrastructure Agency.[13] Once the pre- and general plans have been approved, their implementation enters the political decision-making phase under the direction of the Ministry of Transport and Communications.[14]

Method and the unit values to be used in transport sector project evaluation are recommended by the Finnish Transport Infrastructure Agency. The values are updated every five years; at the time of writing (August 2019), an update is underway, as is a first 12 year National Transport Infrastructure Plan. The reason for the five-yearly updating cycle has been to make it possible to compare values between projects which have been evaluated at different times. In the future, the aim is to update the values at four-year intervals, about a year before a new National Transport Infrastructure Plan is introduced. Once the unit values have been updated, they will be used to update the project evaluations so that they will be comparable with one another.[15]

The general guide to project evaluation in Finland dates from 2011 (Finnish Transport Infrastructure Agency, 2011). Besides the general guide, specific guides exist for road projects (Finnish Transport Infrastructure Agency, 2015a), rail projects (Finnish Transport Infrastructure Agency, 2013a), and maritime projects (Finnish Transport Infrastructure Agency, 2013b).

12. The first national 12-year transport infrastructure plan is under preparation at the time of writing.
13. Laki liikennejärjestelmistä ja maanteistä, 23.6.2005/503 and Ratalaki, 2.2.2007/110.
14. Source: transport economist Anton Goebel at the Finnish Transport Infrastructure Agency in an e-mail from 26 August 2019.
15. Source: transport economist Anton Goebel at the Finnish Transport Infrastructure Agency in an e-mail from 26 August 2019.

The first guide for the unit values to be used in project evaluation in Finland was published in the late 1990s. The values were calculated using the Impact Pathway Method, which was developed within the ExternE-project. The same methodology was used even in the update published in 2012 (Gynther, et al., 2012).

B.2.2 Methodological considerations

The most recent update of the unit values used for doing project evaluations for transport infrastructure investments in Finland is from 2012 (Gynther, et al., 2012). The values are based on the emissions and the transport system in 2007 and are presented in 2010 prices. These prices were updated to 2013 terms in Tervonen and Metsäranta (2015), and further transformed into 2019 terms using the consumer price index (CPI) in the present report.[16]

Factors taken into consideration when calculating the unit values of different types of emissions are their impact on health (morbidity and mortality), on vegetation (reduced growth of crops and forests), and the costs of climate change. When considering air pollution, Gynther et al., (2012) consider both exhaust fumes and dust from roads and streets. When considering maritime transports, the study also considers waste and wastewater emissions to water. Besides taking the consumption of fuels into account, the study also considers externalities arising from the extraction, transportation, refining, and distribution of fossil fuels. This does not mean that a full life-cycle analysis has been made, however.

The main method used for valuing emissions to air is the Impact Pathway Approach. The method starts by determining the amount of emissions and the concentrations which they lead to. After this, the environmental impact, and the costs arising from this are assessed. The main method for calculating the economic costs of emissions is the damage cost method. Factors that have been included in the calculation are costs covered by the taxpayer, impact on productivity, individual welfare (earning power and consumption), and some sources of intangible utility. Impacts on vegetation can be calculated using the value of lost production as a measure. The value of health impacts uses partly market values from national accounts and the costs of health care. To measure the impact on health outcomes and utility (consumer surplus), studies that were made in Finland are complemented with international studies. For impacts that are difficult to value using the damage cost method, such as contamination and oil spills, the avoidance cost method or the replacement/restoration cost method has been used (Gynther, et al., 2012).

With regard to climate change, the unit values combine an estimate of the damage costs to a measure arising from climate policy (a policy-based measure). The value of greenhouse gases also takes the share of biofuels in the fuel mix into consideration. During the assessment year (2007), the share of biofuels was still very low, however. The costs arising from emissions to water from maritime transport have been assessed using the abatement costs as a proxy. The same applies for street dust – Gynther et al. (2012) recommend using the cost of street cleaning. Some components of street dust are included in the health values of small particulate matter, too. In some situations, several methods can be used together. (Gynther, et al., 2012).

16. The values were updated for inflation only; the below described updating of the figures was not made in this report.

For rail transport, separate values are calculated for diesel and electric locomotives in freight and passenger transport. Because the rail transport system to a large part uses electricity as a source of energy, emissions from electricity generation have been included based on the average fuel mix used in Finland. The values for maritime transport consider passenger and freight ships, ice breakers, vessels used by public officials, and leasure boats; the latter three with a lower weight than the former two (Gynther, et al., 2012).

The unit values are assumed to change over time as incomes grow. For this reason, the general guide to project evaluation (Finnish Transport Infrastructure Agency, 2011) recommends that unit values are counted up with a factor of 1.5 per cent per year. This is based on an assumption of an average GDP growth of 2 per cent per year, combined with the average elasticity of the valuation to income, which is 0.75 (2 % × 0.75 = 1.5 %). As is noted by Tervonen and Metsäranta (2015), the prognosis for average growth in the period 2013–2022 is 1.6 per cent, and 1.4 per cent over the period 2023–2032. Using these values of GDP growth to update the unit values results in a lower multiplier (1.2 and 1.05, respectively).

The measure of profitability used in Finland is the benefit-cost ratio. A ratio with a value in excess of 1 indicates a project whose benefits exceed the costs; below 1, the costs exceed the benefits.

B.2.3 Recommended monetary values

B.2.3.1 Noise

Unit values for noise describe the damages that arise from one year of exposure to noise along a given area within a public road. No national assessment of noise values has been made in Finland. Instead, the values used are Swedish values pertaining to ASEK 4 (see the section about Sweden for ASEK) (SIKA, 2009). The valuation of noise from rail transport is based on the valuation from road transport so that the noise costs from road transport have been transposed to one noise class higher for railroad noise (Tervonen & Metsäranta, 2015). Unit values are summarized in Table B.2.1.

Table B.2.1: Value of road and rail transport noise, EUR per person and year. 2019 terms.

Source: Tables 26 and 40 in Tervonen and Metsäranta (2015).

DB(A)	Road transport	Rail transport
55–60	112	39
60–65	201	112
65–70	384	201
70–75	979	384
75–	1 796	979

The guide to the unit values to be used (Tervonen & Metsäranta, 2015) does not differentiate between rural and urban areas, only between the two types of sources of noise. Nevertheless, since the exposed population varies, the valuation differs between different areas. The original source (SIKA, 2009) differentiates between road noise indoors and outdoors, and for situations with fewer than 150 passing trains per day uses equation (1) to calculate the value of rail noise in SEK per person and year:

1. $$Noise_{\frac{SEK}{person,\quad year}} = 6.9 \times (70+t)^{1.1} \times exp\left\{\left[0.18 \times (N-45)^{0.88}\right] - 1\right\},$$

where t is the number of trains per day ($t \leq 150$) and N is the maximum noise indoors in dBA. For situations with more than 150 trains per day, the value of noise is calculated using functions (2) and (3):

2. $$M = 1 + \frac{(T-150)}{1050}$$

3. $$Noise_{\frac{SEK}{person,\quad year}}\left(for \quad T > 150\right) = Noise_{\frac{SEK}{person,\quad year}}\left(for \quad t = 150\right) \times M$$

T is the number of trains per day ($T > 150$), and the first term on the right-hand side of equation (3) is the maximum value of equation (1).

The guide for unit values in maritime transport (Karvonen & Lappalainen, 2014) does not determine noise values. None of the guides contains information about the noise values used for aviation.

B.2.3.2 Air pollution excluding carbon dioxide

The value of a life year lost (VOLY) and the value of a statistical life (VSL) are used to calculate the impacts of air pollution on mortality and morbidity. The currently applicable values are based on the values from the ExternE-project and are summarized by Tervonen (2010) in year 2000 price terms. Newer values, including values for emissions from transport are given by SYKE (2018). Both values are summarized in Table B.2.2.

Table B.2.2: Value of life year lost (VOLY) and value of statistical life (VSL) from two Finnish sources. EUR per year for VOLY, mean value for VSL. 2019 price terms.

Sources: Tervonen (2010), SYKE (2018).

		Tervonen (2010)	SYKE (2018)
Value of Life Year lost (VOLY)	Chronic disease	126 025	
	Acute	216 397	
	Mean		161 274
	Median		69 549
Value of Statistical Life (VSL)		1 541 029	2 671 101

Unit values for exhaust fume emissions from road transport describe the economic consequences of health-, climate, and crop loss impacts from these emissions (Tervonen & Metsäranta, 2015; Gynther, et al., 2012). The corresponding values for the rail sector describe the economic damages caused on health and nature, of which the weight on health is larger. Only emissions that are large enough to give a sizable economic cost have been valued. For this reason, emissions of sulphur dioxide (SO_2), carbon monoxide (CO), methane, and nitrous oxide are no longer included in the valuation of emissions from the road sector; emissions have been reduced considerably and despite the high value of emissions per ton, total damages are small. SO_2 is included in the emissions values from the rail sector, however. The reason is that while the emissions of SO_2 from diesel driven trains have been reduced considerably, emissions still arise in conjunction with the generation of electricity, because of the fossil fuels being included in the fuel mix (Tervonen & Metsäranta, 2015). The unit prices for emissions from road and rail transport are summarized in Table B.2.3.

Table B.2.3: Valuation of air pollution, effects in urban areas and the countryside, EUR per kg of emissions. 2019 price level.

Source: Tables 25 and 39 in Tervonen and Metsäranta (2015).

Emissions of	Road transport, EUR/kg emissions			Rail transport, EUR/kg emissions		
	Urban areas	Country-side	Average	Electric	Diesel	
					Cities with a station	Other areas
NO_X (Nitrogen Oxides)	1.49	0.32	0.90	0.60	0.60	0.30
Particulate Matter (primary, $PM_{2.5}$)	143.7	8.94	76.3	0.49	86.0	5.98
HC (Hydrocarbons)	0.03	0.03	0.03	0.03	0.03	0.03
CO_2 (Carbon Dioxide)	0.04	0.04	0.04	0.04	0.04	0.04
SO_2 (Sulphur Dioxide)	-	-	-	0.39	0	0
CH_4 (Methane)	-	-	-	0.87	0.87	0.87
N_2O (Nitrous Oxide)	-	-	-	12.85	12.85	12.85

Gynther et al., (2012) also present a finer division of the costs of the different pollutants, and according to their source (health impacts from particulate matter and ozone, the impact of ozone on harvests and forests, and climate change). The impact assessment for particulate matter has been done for five groups of areas: the region around Helsinki, large cities (Tampere, Turku, Oulu), middle sized cities (50 000–100 000 inhabitants), small cities (10 000-50 000 inhabitants), and other municipalities. Similarly, the cost of emissions from nitrogen oxides varies between the Helsinki area, the large and middle-sized cities, and the small cities and other municipalities. The finer division for these two pollutants from road transport is shown in Table B.2.4.

Table B.2.4: Unit costs of primary particulate matter and nitrogen oxides per type of area in 2007. EUR/kg, 2019 prices.

Source: Table 60 in Gynther et al., (2012).

	Helsinki region	Large cities	Mid-sized cities	Small cities	Other areas
Primary particles	262	221	59.9	31.7	8.94
NO_X	2.01	0.96		0.32	

Finally, marginal costs in (Euro) cents per vehicle kilometer travelled (VKT) for 2007 in 2019 price terms are shown in Table B.2.5. The number is a composite of the costs arising from all emissions. The largest part of the cost is made up by carbon dioxide. Since the figures have been calculated for the car fleet in 2007, they cannot be used to analyze the costs in any other years.

Table B.2.5: Marginal cost of emissions from different types of vehicles in 2007, 2019 price terms. (EUR) cent per vehicle kilometer travelled.

Source: Table 61 in Gynther et al., (2012).

	(EUR) CENT/VKT
Car, gasoline, no catalyzer	0.86
Car, gasoline, catalyzer	0.65
Car, diesel	1.55
Light truck, gasoline, no catalyzer	1.15
Light truck, gasoline, catalyzer	0.95
Light truck, diesel	2.22
Bus	5.45
Heavy truck, no trailer	5.32
Heavy truck, trailer	6.06
Motorcycles and mopeds	0.45

The unit cost of passenger trains in intercity traffic in 2007, in 2019 price terms was 0.12 (EUR) cents per passenger kilometer. The cost for commuter trains was 0.07 cents per passenger kilometer. Finally, the cost for freight trains was 0.11 cents per ton kilometer (Gynther, et al., 2012, table 66).

B.2.3.3 Carbon dioxide

The value of a ton of carbon dioxide used in Finland comes from the ExternE-project (Bickel & Friedrich, 2001). The value was originally set at 32 EUR/ton CO_2 in 2000 price terms and was updated to 40 EUR/ton CO_2 in 2013 (Tervonen & Metsäranta, 2015). The value shown in Table B.3 has been updated to 2019 terms using the consumer price index. The value is based on the estimated long-term damages arising from climate change. Gynther et al., (2012) recommend that for projects far in the future the value of CO_2 should be gradually raised. While the rest of the values will be raised by a common multiplier that takes into account increased standard of living, they recommend that the value of emissions of carbon dioxide should have an own multiplier.

The confidence interval of the damage costs in ExternE was quite large. The value adopted to be used in the impact assessment in Finland was from the middle of the interval. Once adopted, the value has only been updated for inflation. It is notable that in 2015 the carbon dioxide tax rate on fuels was 58 EUR/ton CO_2 (excluding

VAT), considerably higher than the valuation used for project evaluation (Tervonen & Metsäranta, 2015).

B.2.4 Methodology used for integrating effects without a monetary value

According to Finnish law, the environmental impacts of an infrastructure project must be assessed, described, and analyzed. This is done within the framework of an environmental impact assessment (Tiehallinto, 2009). The environmental impact assessment and the project evaluation are two different processes that both have to be completed. They complement each other, but one cannot replace the other.

The direct and the indirect impacts of an investment project on the environment have to be assessed. These include impacts on (Tiehallinto, 2009):

- Human health, living conditions, and welfare.
- Soil, water (both surface and groundwater), and biodiversity.
- Community structure, buildings, landscape, cityscape, and cultural heritage.
- Exploitation of natural resources.
- Interactions between the aspects above.

The impacts of a project can be either positive or negative on the environment. They can be of long- or short term, with a large or a small scope, certain or uncertain, take place seldom or often, and finally, they can be irreversible or reversible. The comparison is made between status quo and given that a project is realized. Even the fact that some environmental quality does not change can be considered an impact.

B.2.5 Considerations regarding the use of limited environmental goods

While it is clear that the use of limited environmental goods, for instance land liberated by the building of a tunnel, demolishing an ugly bridge etc. are considered in Finland, no guidelines as to how these should be incorporated in a CBA have been found. Despite searches in known projects' documentation, no practical examples of these kinds of considerations have been found either.

B.3 Sweden

B.3.1 Background

The process of infrastructure building in Sweden starts with the Swedish Transport Administration identifying a deficiency in the transport system and conducting a solution study. The Administration examines possible ways to solve the deficiency using the so-called four stage principle. In the first stage of the principle, it is examined whether the problem can be solved by reducing the need for transportation or whether other transport modes can be used to solve the deficiency. In the second stage, possibilities for increasing the efficiency of the transport network are identified, e.g., by changing the speed limits or through traffic regulations. In the third stage, the deficiency is solved by enhancements and small additions to existing infrastructure, e.g. by broadening or lengthening platforms at the stations, straightening curves etc. If none of the three first stages suffice to solve the deficiency, in the fourth stage, new investments or large additions to existing infrastructure are considered. These can be new road junctions, new roads or railroads. The solution study answers the question of why new infrastructure needs to be built (Swedish Transport Administration, 2017).

The next stage in a project's life is the planning process, which leads to the creation of a road or railroad plan, i.e., a specific plan for where and how a road or a railroad will be built. Before a project can enter this phase, the project is included in a long-term economic plan for the entire transport system for roads, railroads, maritime- and air transport, however. This plan is called the National Transport Infrastructure Plan. It is at this stage of the planning process that a CBA is made for most of the proposed investment objects using uniform methodology and appraisal values, and the objects are ranked based on their net present value – cost quotient. The decision about taking the National Transport Infrastructure Plan is made by the government, based on a proposal from the Transport Administration. Besides a national plan, every county also takes a county plan for regional transport infrastructure. The party responsible for building this infrastructure is respective county (Swedish Transport Administration, 2017).

The uniform methodology and the appraisal values to be used in project evaluations are recommended by the Swedish Transport Administration in the so-called ASEK-report (Swedish Transport Administration, 2018). The report is revised every year, and a new version is published on April 1st. However, the values used for appraisal are not changed every year in order to ensure comparability of evaluation results over time. For this reason, larger changes are only made every 3–4 years. During the years between only small adjustments and corrections to the report are undertaken (Swedish Transport Administration, 2018). The Swedish Transport Administration is currently working on a next version of the ASEK (ASEK 7), and a decision on the new values is expected during the spring of 2020. The values presented in this study refer to ASEK version 6.1 except for the value of carbon dioxide, which has already been decided and published.

While the Swedish Transport Administration is ultimately responsible for developing the methodology and values used in the ASEK-report since 2010, the work with

ASEK also involves other agencies. Thus, besides the Transport Administration, Swedish Transport Agency, Swedish Maritime Administration, Swedish Environmental Protection Agency, Swedish Energy Agency, National Board of Housing, Building and Planning, Region Stockholm (Stockholms Lokaltrafik), Vinnova, and Transport Analysis are involved in the work. There is also a scientific advice committee involving expertise in economics, environmental economics, regional economics, and transport analysis connected to work with ASEK (Swedish Transport Administration, 2018; Swedish Transport Administration, 2018).

The aim of the work with ASEK is to recommend *methods* to be used both with regard to economic analyses and the principles of calculation for transport projects. ASEK also recommends the *values* to be used in economic analyses (CBA) and traffic prognoses. Moreover, ASEK contributes towards the coordination of research and development within the area. The work within ASEK is based on established scientific knowledge and praxis within economics and should also actively relate to the recommended principles by the EU Commission for analyses within the transport sector (see the proposal for harmonized economic analyses within the transport sector, HEATCO) (Swedish Transport Administration, 2018; Swedish Transport Administration, 2018).

B.3.2 Methodological considerations

The base year used in the present version of the ASEK (Swedish Transport Administration, 2018) is 2014. ASEK includes recommendations as to how to update nominal or real prices to new price levels. This methodology varies between values that are derived from willingness to pay studies, values of time, and finally, investment, operation, maintenance, vehicle, and trafficking costs. Especially values based on willingness-to-pay studies will have to be updated both with regard to inflation and real changes in income since willingness to pay often rises with higher real income. Thus, ASEK (2018) recommends that both the values of noise and air pollution are revised using both the consumer price index (CPI) and the gross national product (GNP) per capita.[17] The value of carbon dioxide (CO_2) is set to increase by 1,5 percent per year in real terms. The increase in value is calculated from the base year (2014) until the break year, which in the most recent version is set to 2040. In this report, all the values have only been adjusted to CPI.

Environment-related external effects arising from transportation that are considered by ASEK are summarized in Table B.3.1. Some of the externalities are internalized by taxes and fees that correspond to the external effect. This is especially the case for the climate externality, because the damage cost in Sweden is assumed to be equal to the rate of the carbon dioxide tax.[18]

17. These recommendations follow those by HEATCO (2006a; 2006b).
18. There are dissenting views about whether this is a correct interpretation; see, e.g., Carlén (2014). Moreover, it seems that this coupling of the CO_2 valuation and the tax rate will be broken in ASEK 7; instead a value of 7 SEK per kilogram of CO_2 (0.67 EUR/kg CO_2) has been proposed. This valuation is obtained from the penalty imposed within the low carbon fuel standard, in place since 2018, for non-fulfillment of the CO_2 reduction obligation.

Table B.3.1: Environmental externalities arising from infrastructure investments and transportation.

Source: Tables 4.2 and 4.3, section 4.4 in ASEK (2018).

Externality arising from transport or an infrastructure investment	Consequences from/ the cost of the external effect
Air pollution	Health effects from exhaust fumes and wear.
Damages on the natural environment etc.	
Emissions of climate gases	Global climate change.
Noise	Disturbance- and health effects.
Water pollution	Damages on the natural environment and on animal health.
Erosion of beaches or the sea floor	Damages on the natural environment and on animal health.
For maritime, cycling and walking modes: transfer effect	Changed externalities from other transport modes due to a transfer to/from maritime/ cycling/ walking.

The measure of profitability used in Sweden is the net present value to investment cost -ratio. Since 2018, even operation and maintenance costs (including costs of reinvestment) are to be included in the investment cost-part of the ratio. (Swedish Transport Administration, 2018).

B.3.3 Methodological considerations for the valuation of air pollution and carbon dioxide

In order to value the impact of air pollution emissions, the physical emissions must be quantified. This is done using so called emission factors, which convert vehicle kilometers travelled (VKT) to emissions expressed in gram per VKT (g/VKT). The quality of the emission factors naturally has a direct impact on the valuation.

For road transport, the emission factors are derived from the HBEFA model (Swedish Transport Administration, 2019b). The emission factors include driving with warm motor, cold starts, evaporation, and reduced performance because of aging. The effects are calculated as a mean for the entire Swedish road network. Since the HBEFA model does not include emissions of particulate matter from motorcycles and mopeds, these emissions are obtained from EMEP/EEA Tier2.

The emissions factors that the unit costs of railroad transports build on are the norms for mobile machines found in Directive 1997/68/EG. Table B.3.2 shows emission values for motors in diesel driven motor carriages and locomotives, an estimation of typical emissions from unregulated motors, and consumption of fuels according to a technical study of Directive 1997/68/EG by the Joint Research Centre (European Commission, 2008). The emission factors for CO_2 are for emissions from diesel in environmental class I without addition of biofuels, and refer to emissions from the combustion of fuel, not a life-cycle perspective. In order to be able to use the emission factors in the economic analyses and tools, the values in Table B.3.2 have to be converted into grams per liter diesel.

Table B.3.2: Emission factors and fuel use from railroad transport. Grams per kWh.

Source: Table 11.10 in ASEK (2018).

	Fuel use	NO_X	HC	PM	SO_2[19]	CO	CO_2
Motor carriage unregulated	224	13.7	1.3	0.5	0.0004	3.5	716
Motor carriage stage IIIA	216	3.7	0.3	0.5	0.0004	3.5	641
Motor carriage stage IIIB	216	2	0.19	0	0.0004	3.5	641
Locomotive unregulated	230	15.4	1.3	0.3	0.0005	3.5	697
Locomotive stage IIIA	206	6	0.5	0.2	0.0004	3.5	672
Locomotive stage IIIB	206	3.7	0.3	0	0.0004	3.5	672

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The average emission factors for maritime transports are shown in Table B.3.3. The fuels covered by the table are diesel and maritime gas, i.e., fuels that are used within the SECA area with limitations to the sulphur content of fuels. The figures are an average of the different types of ships and ship sizes that are used today.

Table B.3.3: Average emission factors for maritime transport. Kilogram emissions per kilogram fuel used.

Source: Table 11.16 in ASEK (2018).

Fuel	NO_X	VOC	SO_2	CO_2
Maritime diesel/ gas	0.07	0.002	0.002	3.09

19. The valuation is calculated by ASEK (2018) based on the actual sulphur content of Swedish diesel.

B.3.4 Recommended monetary values

B.3.4.1 Noise

Noise can be described either as equivalents or maximum levels. The equivalent level is a weighted average of noise levels over a longer time, while the maximum level describes the level of noise at single passages. The maximum level suits best for describing railroad noise because it has the characteristic of temporary disturbances.

The noise values used in ASEK (2018) have been recently revised based on Swärdh (2015), who based his recommendations on two other studies, Swärdh et al., (2012) and Andersson et al., (2013). Andersson et al., estimates a hedonic model with data from small house sales from seven Swedish municipalities in different parts of the country. Based on the demand curve, the study calculates the willingness to pay for non-marginal changes in noise exposure from road traffic. Similar methodology was used also in Swärdh et al., (2012), which estimated willingness to pay for railroad noise. Consequently, the results from the two studies are well comparable to one another. The results were generalized in ASEK to be applicable for the entire Sweden. The value of noise was estimated in 2012 price terms and has been updated to 2014 values in ASEK (2018). The studies yield a value for the disturbance component of the total cost of noise and is not assumed to account for the health consequences of noise.

Health effects of noise are based on studies by the World Health Organization (WHO, 2011; 2012). Health effects obtained from the studies have then been related to the base risk for heart infarct in the Swedish population. The statistics used for this are from 2013. Measures for the consequences of heart-related illnesses have been obtained from the ExternE (Bickel & Friedrich, 2005). The values used for the valuation of health effects are reproduced in Table B.3.4.

Table B.3.4: Valuation of health effects for the health effects of noise.[20]

Source: Nerhagen et al., (2015) as reproduced in ASEK (2018).

Variable	Unit	Value, euro in 2019 prices
Early death	Value of a lost life year (VOLY)	110 255
Symptoms of heart infarct	Per case	23 058
Symptoms of angina pectoris	Per sick day	1671
Loss of productivity – absence from work	Per day	136
Healthcare costs	Per hospital day	292

20. The values have been converted from SEK in 2012 terms to 2019 terms by using a CPI inflator of 1,06 and from SEK to Euros using the exchange rate of 10,52 SEK/Euro.

Certain noise reducing measures only have an impact indoors, e.g., triple glazing. For this reason, value of noise indoors has been estimated by weighing up the valuation indoors and outdoors, and by making assumptions of how much the façade reduces noise. An earlier assumption for road noise was that the indoor value was 60 per cent of the total value, and the outdoors value was 40 per cent. The façade reduction factor was set at 25 dB. Since houses have become better insulated, these values have been updated, and it is now assumed that 50 percent of the value is from outdoors and the remaining 50 per cent indoors. The noise level indoors is expected to be equal to the outdoors noise level minus a façade reduction factor of 27 dB for road noise (Swedish Transport Administration, 2018).

As was noted above, the cost of noise is divided into two: noise disturbance and health effects. The value of noise from road and rail transportation outdoors is set to zero below 50 dB, while the indoors value for road noise is set to zero below 23 dB (50 dB as measured by the façade of the house minus the reduction by the facade by 27 dB). For rail noise, the indoors value is zero for noise levels below 19 dB (50 dB at the façade minus 31 dB; in practice, the value is zero until 23 dB). The basic values for outdoors noise from road and rail transport per person and year are shown in Table B.3.5.

Table B.3.5: Value of road and rail transport noise outdoors (by the façade), EUR per person and year. 2019 terms (Jan–July). The 2040 value is a prognosis in 2019 price terms.

Source: Swedish Transport Administration (2019a).

Noise equivalent outdoors (DB)	Road transport				Railroad			
	Disturbance	Health effects	Total cost, Euro		Disturbance	Health effects	Total cost, Euro	
	2014	2014	2014	2040	2014	2014	2014	2040
50	8	0	8	11	6	0	6	9
51	24	0	24	36	19	0	19	28
52	50	0	50	73	39	0	39	58
53	84	0	84	123	66	0	66	97
54	127	0	127	186	90	0	90	132
55	178	0	178	262	115	0	115	169
56	238	0	238	350	137	0	137	201
57	307	0	307	452	166	0	166	243
58	385	3	389	571	181	3	184	271
59	472	6	478	702	184	6	190	280
60	567	10	577	848	221	10	232	341
61	671	15	686	1008	262	15	277	407
62	784	21	805	1183	306	21	327	481
63	905	29	934	1373	353	29	382	561
64	1035	37	1072	1576	404	37	441	648
65	1174	46	1220	1794	458	46	504	741
66	1322	57	1378	2026	515	57	572	840
67	1478	68	1547	2273	576	68	644	947
68	1643	81	1725	2535	640	81	722	1061
69	1817	95	1913	2812	708	95	803	1181
70	2000	112	2111	3104	779	112	890	1309
71	2191	128	2320	3410	853	128	982	1443
72	2391	147	2538	3731	931	147	1078	1584
73	2600	166	2767	4067	1012	166	1179	1732
74	2818	187	3005	4418	1097	187	1284	1888
75	3044	210	3255	4784	1185	210	1395	2051

Noise from air and maritime traffic should, according to ASEK (2018), be valued at the same level as road noise, multiplied by a factor of 1.4. This is because of a lack of studies that measure the valuing of noise from these sources.

ASEK also contains marginal costs of noise for different types of transport modes. These are expressed as the marginal damage from noise caused by the passage of one more vehicle. For road noise, marginal costs are shown in Table B.3.6.

Table B.3.6: Marginal cost of noise in the countryside and urban areas from different sources of road transport. The average refers to the average for the urban areas. (EUR) cents per vehicle kilometer travelled (VKT), 2019 price terms.

Source: Swedish Transport Administration (2019a).

Marginal cost of noise, euro/vkt	Countryside		Urban areas	
	2014	2040	2014	2040
Car, all fuels / average	0.3	0.4	1.8	2.7
Car, all fuels, sparsely populated			1.7	2.4
Car, all fuels, medium populated			1.8	2.7
Car, all fuels, dense			2.0	3.0
Highway bus / average	1.3	1.9	9.2	13.6
Bus, sparsely populated			8.3	12.2
Bus, medium populated			9.1	13.4
Bus, dense			10.1	14.9
Heavy truck 3,5 – 16 ton (with/without a trailer) / average	1.8	2.6	12.9	19.0
Heavy truck 3,5 – 16 ton (with/without a trailer), sparsely populated			11.6	17.1
Heavy truck 3,5 – 16 ton (with/without a trailer), medium populated			12.8	18.8
Heavy truck 3,5 – 16 ton (with/without a trailer), dense			14.1	20.8
Heavy truck > 16 ton, high speed (with/without a trailer) / average	4.1	6.0	29.5	43.3
Heavy truck > 16 ton, high speed (with/without a trailer), sparcely populated			26.5	39.0
Heavy truck > 16 ton, high speed (with/without a trailer), medium populated			29.2	43.0
Heavy truck > 16 ton, high speed (with/without a trailer), dense			32.3	47.4
Heavy truck > 16 ton, slow speed (with/without a trailer) / average	8.9	13.1	64.5	94.9
Heavy truck > 16 ton, slow speed (with/without a trailer), sparcely populated			58.1	85.5
Heavy truck > 16 ton, slow speed (with/without a trailer), medium populated			63.9	93.9
Heavy truck > 16 ton, slow speed (with/without a trailer), dense			70.7	103.9

The marginal cost of noise from road transport is determined by the properties of the vehicle and the tires, the road surface and other geographical circumstances, and the number of individuals impacted. Consequently, the marginal cost is to a large extent specific to a geographical area. For this reason the Swedish Transport Administration (2019a) differentiates between the countryside and urban areas, and besides, urban areas with three different levels of population density.

The marginal costs of rail noise are based on the above-discussed study by Swärdh et al., (2012), the results having been complemented to include several types of trains and rail sections with different marginal costs. These calculations even take the speed and the number of impacted persons into account. The conversion factors to calculate detailed noise effects are not shown here; Table B.3.7 shows values for eight types of passenger trains and three freight trains.

Table B.3.7: Marginal cost of noise from different types of train. (EUR) cents per train kilometer, 2019 price terms.

Source: Swedish Transport Administration (2019a).

Noise (disturbance and health effects) euro/train kilometer	2014	2040
x60	5.2	7.7
y31s	0.4	0.5
x50–54	4.4	6.5
x31	7.5	11.0
x2	17.8	26.2
x40	11.6	17.0
x10–14	2.9	4.2
RC pass	37.1	54.5
Freight, electrically operated	47.4	69.7
Freight, diesel	34.6	50.9
All passenger trains	9.1	13.3
All freight trains	46.5	68.4

As with road noise, the most important determinant of the marginal cost of noise from rail transport is the number of persons affected. Other important factors are the type and length of the train, technical properties like the speed, geographical location, fuel (electricity or diesel) and the breaks. Especially the breaks for freight trains make a large difference, so called K-block breaks reduce noise by a factor of 6–10.

B.3.4.2 Air pollution exclusive carbon dioxide

Exhaust fumes and particulate matter from the burning of fossil fuels, and particulate emissions from the tires have a negative impact both locally, regionally, and globally. These externalities are usually not priced on the market. To the extent that there are taxes or fees that indeed internalize these externalities, three alternatives arise for valuing the impacts in a CBA, however. First, it is possible to value the entire real environmental cost and exclude the financial impacts (e.g., the cost of taxes on travelers and the tax income to the state). Second, it is possible to include both the real environmental cost and the financial effects. A third alternative is to include the cost of environmental taxes and/or fees to the travelers and the net cost of the environmental effects to the rest of the society. In the latter case, the budgetary effects on the state should not be included (Swedish Transport Administration, 2018).

The most important local air pollutants are the nitrogen oxides (NO_X), sulphur dioxide (SO_2), and Volatile Organic Compounds (VOC). The particulate matter that is included in the valuation are the so-called exhaust particles, i.e., very small particulates (PM2.5) that can be inhaled. Particulate emissions from tires (PM10) have not been included in the valuation so far. Carbion dioxide (CO_2) is a global pollutant. For this reason, the former three are considered separately from the latter, which is discussed in the next section.

The local effects of emissions to air consist mainly of negative health effects, contamination of and material damages to buildings, machines etc. Measurable local effects exist mainly in urban areas since the total effect depends on the number of exposed individuals and how many buildings and other materials that are exposed to damages. On a regional level, some of the chemicals and particulates that cause (primary) local effects are transformed to other chemicals which give other types of effects. These secondary chemical compounds spread over larger geographical areas causing, e.g., acidification, overfertilization of land and water and lead to the creation of ground-level ozone. Ground-level ozone in turn damages crops, forests, cause health effects etc.

Emissions on the countryside cause only regional damages on nature. Emissions in the urban areas cause both regional damages on nature and local health effects and material damages.

Table B.3.8 shows recommended values for local and regional effects of emissions to air. The cost, which is given per kg emissions, on local effects depends on the cost per impacted unit and the number of units impacted.

Table B.3.8: Valuation of air pollution local and regional effects, EUR per exposure unit for the local effects and EUR/kg emissions for the regional effects. 2019 price level and prognosis to 2040 in 2019 price level.

Source: Swedish Transport Administration (2019a).

	Local effects (only urban areas), euro/ exposure unit		Regional effects, euro/kg emissions	
	2019	Prognosis 2040	2019	Prognosis 2040
NO_X (nitrogen oxides)	0.21	0.29	8.66	12.7
VOC	0.35	0.50	4.33	6.37
SO_2 (sulphur dioxide)	1.73	2.48	2.92	4.30
Particulate matter	59.1	84.6	0	0

The method for valuing local effects of air pollution is done in two steps:

1. Calculate the number of exposure units per kilogram emissions at the specific location. This is done with the following formula:

$$Exposure = 0.029 \times F_y \times B^{0.5},$$

where F_y is a "ventilation factor" for the urban area (exposure per person and kilogram of emissions), and B is the population of the urban area. The ventilation factors differ in five zones over the country and vary between 1.0 and 1.6.

2. To calculate the value of emissions in Euro/kg for a specific location, the specific exposure for that location is multiplied by the value per exposure unit for respective pollutants (Table B.13). This method is used when it is known for certain that a policy measure affects a given urban area.

   If the impact of a policy is difficult to attribute to a specific urban area, a standard value of the ventilation factor and the size of the urban population is used. The urban reference area in Sweden is the municipality of Kristianstad with 35 700 inhabitants. The value of the ventilation factor is set to 1.0 in the reference urban area.

The valuations shown in Table B.3.9 are based on studies of individuals' willingness to pay. The local effects of air pollution are valued using impact modelling as recommended in the ExternE (SIKA, 2002). To calculate the local effects in the Stockholm area, the ventilation factors are obtained from the Stockholm Study on the Health Effects of Air Pollution and their Economic Consequences (SHAPE) (Forslund, Marklund, & Samakovlis, 2007). The health effects consist partly of a mortality effect, partly of increased morbidity, where the valuation of mortality is based on a Value of a Lost Life Year (VOLY). VOLY has been derived from the estimated Value of Statistical Life (VSL). The VSL in turn is based on the value of a death in a car accident.

The regional effects consist of a damage to the nature -effect. The value of the regional effects is based on the cost of reaching politically set environmental goals (SIKA, 2005).

ASEK (2018) also reports marginal costs of road and rail transport. The marginal costs for different types of road vehicles, Eurocent per vehicle kilometer are shown in Table B.3.9.

Table B.3.9: Marginal costs and a prognosis for 2040 for air pollution from road transport, based on emission factors according to HBEFA3.1 and vehicle kilometers travelled in 2012. (EUR) cents per vehicle kilometer travelled, 2019 price level.

Source: Swedish Transport Administration (2019a).

Emissions excl. CO_2 (according to hbefa3.1)	**Countryside**		**Urban areas**		**Average all transport environments**	
	Emission factor 2012	Prognosis 2040	Emission factor 2012	Prognosis 2040	Emission factor 2012	Prognosis 2040
Car, gasoline	0.31	0.19	1.26	0.96	0.69	0.49
Car, diesel	0.37	0.19	1.44	0.38	0.80	0.27
Car, E85	0.13	0.17	0.78	0.91	0.39	0.46
Car, CNG	0.07	0.13	0.30	0.71	0.16	0.36
Car, average	0.32	0.20	1.25	0.58	0.69	0.35
Highway bus	3.96	0.42	11.43	3.31	6.04	1.22
City bus, diesel			12.70	1.24	12.70	1.24
Light truck (< 3.5 ton), gasoline	0.64	0.29	2.10	1.60	1.22	0.81
Light truck (< 3.5 ton), diesel	0.80	0.41	3.01	0.61	1.67	0.49
Light truck (< 3.5 ton), average	0.77	0.40	2.91	0.65	1.62	0.50
Heavy truck (> 3.5 ton) without trailer	3.56	0.56	9.55	2.23	0.00	
Heavy truck (> 3.5 ton) with trailer	5.40	0.63	15.23	5.06	0.00	
Heavy truck (> 16 ton) without trailer					5.13	1.01
Heavy truck (> 16 ton) with trailer					8.02	1.88

The marginal costs are derived from the values of emissions shown in Table B.3.9. In the calculation of marginal costs for urban areas, the reference municipality of Kristianstad has been used. Emission factors are obtained from the HBEFA model (Swedish Transport Administration, 2019b). Together, these data can be used to calculate the marginal cost of emissions for different types of vehicles and areas.

The average marginal cost for the entire country depends on how traffic is distributed in the road network. In order to calculate the average value, marginal costs for different areas have been weighed together with data for VKT in these areas.

Besides marginal costs for road transport, ASEK also includes marginal costs for railroads. These are shown in Table B.3.10.

Table B.3.10: Marginal costs and a prognosis for 2040 for air pollution from rail transport, based on emission factors according to HBEFA3.1 and vehicle kilometers travelled in 2012. (Euro) cent per liter diesel, 2019 price level.

Source: Swedish Transport Administration (2019a).

Emissions (excl. CO_2)	Countryside (only regional impacts)		Urban areas (local and regional impacts)		Average	
	2014	2040	2014	2040	2014	2040
Motor carriage unregulated	45.28	66.57	114.36	168.11		
Motor carriage stage IIIA	12.52	18.41	38.81	57.04		
Motor carriage stage IIIB	6.86	10.08	10.91	16.03		
Locomotive unregulated	49.33	72.51	95.44	140.30		
Locomotive stage IIIA	21.45	31.53	50.17	73.75		
Locomotive stage IIIB	13.20	19.40	18.29	26.88		
Motor carriage in average					27.55	10.56
Locomotive in average					35.02	20.00

B.3.4.3 Carbon dioxide

Uncertainty about the impact of climate change is very large. The goal of climate policy is to reduce the risks that follow from not reducing the emissions of climate gases, of which carbon dioxide (CO_2) is the most important one. The focus today is to avoid warming that exceeds 2°C; discussions about reducing this to 1.5°C are ongoing.

The Swedish Transport Administration (2020) recommends that from May 2020, emissions of CO_2 or CO_2-equivalents are valued at a 7 SEK per kg CO_2-ekv, which translates to 0.665 EUR per kg CO_2-ekv. The reason for choosing 7 SEK/kg CO_2 as a value is that the penalty for not meeting the low carbon fuel standard is set at this rate. Furthermore, the Transport Administration recommends that the value of CO_2 will not be indexed to a yearly growth factor over the calculation period, which has been the case with earlier versions of the ASEK-guidelines. For sensitivity analyses, a value of 15 SEK per kg CO_2-ekv, 1,43 EUR per kg CO_2-ekv is recommended.

The first valuation of CO_2 in ASEK 1 from 1995 was based on the level of the carbon tax at that time. The level in 1997 price terms along with the development of the valuation since is shown in Table B.3.11. From ASEK 2, the valuation was based on the theoretical shadow price which was estimated to be needed to reach the then goal of keeping emissions from transport sector in 2010 to the same level as in 1990. By the time of ASEK 4, this value had lost its meaning. However, since no new sectoral goal was set for the transport sector, which could have been used to derive a new shadow price, it was decided to hold on to the value of 1,50 SEK/kg CO_2 in nominal terms (the price level in 2006). Since ASEK 5, the valuation was again tied to the carbon tax rate. The latest revision to the value of CO_2 in ASEK was made in June 2020, to 7 SEK/kg CO_2 (Swedish Transport Administration 2020).

Table B.3.11: The development of the valuation of CO_2 in ASEK.

Source: ASEK 2018, Swedish Transport Administration 2020

	Originally expressed in price levels of year	Recommended value of CO_2, sek/kg in nominal terms	Euro/kg in 2019-terms
ASEK 1	1997	0.38	0.047
ASEK 2		1.50	0.184
ASEK 3	2001	1.50	0.178
ASEK 4	2006	1.50	0.167
ASEK 5	2010	1.08	0.113
ASEK 6	2014	1.14	0.115
ASEK 7	2020	7.0	0.665

CO_2 is not the only climate gas. (Swedish transport Administration, 2020) recommends that the valuation of other greenhouse gases than CO_2 should be based on their global warming potential values, i.e., they should be calculated to carbon dioxide equivalents. The calculation should be based on the recommendations from the Intergovernmental Panel on Climate Change (IPCC, 2007).

The marginal cost of CO_2 from the transport sector is based on the above discussed value of CO_2 and information about the amount of CO_2 emitted from each type of vehicle. The recommended marginal values from ASEK 7 are shown in Table B.3.12, including two prognoses for 2040. Since the value of CO_2 does not increase in real terms over time, the difference between marginal costs in 2017 and 2040 depends on differences in emission factors. The development of these factors over time is a function of, among others, the vehicle fleet and fuel use.

Table B.3.12: Marginal costs and two prognoses for 2040 for CO_2 valuation from road transport, based on emission factors according to HBEFA. (EUR) cent per VKT, 2019 price level.

Source: Swedish Transport Administration (2020).

	Rural			Urban			Average		
	MC 2017	Prognosis A: 2040	Prognosis B: 2040	MC 2017	Prognosis A: 2040	Prognosis B: 2040	MC 2017	Prognosis A: 2040	Prognosis B: 2040
Car, all fuels	9.2	3.5	0.59	11.3	4.5	0.78	9.9	3.9	0.68
Car, gasoline	10.8	7.2	2.1	13.5	9.2	2.6	11.7	7.8	2.3
Car, diesel	7.2	4.4	2.0	9.1	5.6	2.4	7.9	4.8	2.1
Light truck, all fuels	10.1	3.7	0.78	10.6	4.0	0.88	10.3	3.8	0.88
Truck without a trailer	29.8	11.2	3.3	35.7	13.4	4.0	31.7	11.9	3.5
Truck with a trailer	43.6	24.9	9.0	54.4	30.9	11.0	45.8	26.1	9.4

Marginal costs for 2040 have been calculated from two different prognoses for fuel use. Prognosis A is based on existing policies, i.e., on the present level of biofuel use. The starting point for Prognosis B is that the transport sector goal of a 70 percent lower emissions in 2030 compared to 1990 is reached by increased use of ethanol and hydro-treated vegetable oils (HVO) in gasoline and diesel. Electric vehicles or hydrogen as a fuel are not mentioned by the Swedish Transport Administration (2020).

The size of the average marginal cost for the entire country depends on how traffic is distributed in the road network. The differentiated marginal costs for rural and urban areas have been weighted together by assuming given weights for traffic in different environments. Thus, it is assumed that 66 percent of total traffic by cars and light trucks, 68 percent of total traffic by trucks without a trailer, and 80 percent of total traffic by trucks with a trailer is in rural areas.

Average marginal costs for emissions of CO_2 from rail transport are shown in Table B.3.13. Since the marginal cost is expressed as Eurocents per liter diesel, it does not capture the variation in fuel use between different vehicles and in different traffic situations. The damages caused by emissions of CO_2 do not vary depending on the geographical location of the emissions since it causes a global externality. The marginal cost of emissions per liter diesel are therefore the same regardless of the geographical location of the emissions.

Table B.3.13: Marginal costs and a prognosis for 2040 of the valuation of CO_2 emissions from rail transport. (EUR) cent per liter diesel, 2019 price level.

Source: Swedish Transport Administration (2020).

Vehicle	2017	Prognosis 2040
Motor carriages, average	173.59	173.59
Locomotive, average	173.59	173.59

Average marginal cost of fuel use for maritime transport is shown in Table B.3.14. The fuels for which the costs have been reported for are those that are used within the sulfur-control area SECA. The marginal cost of CO_2 represents an average with respect to different types of ships and sizes of ships that are used today. The source of the emission factors is a report by consultancy M4Traffic (2019).

Table B.3.14: The cost of emissions per kilogram per kilogram fuel and the marginal cost of emissions per kilogram fuel from maritime transports.

Source: Swedish Transport Administration (2020).

Fuel	Emissions in kg/kg fuel	MC of emissions, (eur) cents per kg fuel
Marine diesel, marine gas	31.24	211.17

Emissions from flight are to be counted up by a high-altitude factor of 1.9 for international flight at an altitude of about 10 000 meters, and a factor of 1.4 for domestic flight at lower altitudes. The valuation should take into account whether the flight is included in the European Union Emissions Trading System. For this reason, only the high-altitude effect (factors 0.9 and 0.4) give a net effect on emissions. Emissions from aviation should be valued at their ASEK-value of 7 SEK per kg CO_2-ekv, not at the price of the Emission Allowances (Swedish transport Administration, 2020).

B.3.5 Methodology used for integrating effects without a monetary value

Problems with vibrations of the ground are related to noise. Vibrations usually arise when the infrastructure is built in areas with clay, water-resistant soil, and thick soil layers with similar material. Heavy vehicles in close sequence are the main cause of vibrations. In ASEK (2018) there are no valuations of vibrations and infrasound. However, the extent of the problem has been estimated with regard to vibrations from railroads; for vibrations arising from road transport not even the extent of the problem is known.

B.3.6 Considerations regarding the use of limited environmental goods

B.3.6.1 Impact of extreme weather events

ASEK (2018) contains instructions to how future economic costs due to extreme weather events and other catastrophes on transport infrastructure can be assessed. Four effects are identified, three of which are direct effects: direct accident costs in conjunction with the damage, costs for rebuilding and repairing infrastructure, and traffic disturbance costs during the damaging event and until the infrastructure has been restored. The fourth effect is indirect: secondary damages on other markets and/or on different type of infrastructure and assets that are caused by the primary damages to the transport infrastructure. This could be, for example, damages on water pipes and drains, electricity power lines, or IT.

B.3.6.2 Land use

Encroachment of the physical environment and visual intrusion in the landscape are difficult to value according to ASEK (2018). These impacts are included in the CBA through a verbal description, which adds to the calculation.

ASEK (2018) notes further that when the saving of travel time is the greatest positive impact, and the physical intrusion the largest negative one, it would be possible to do a study where the value of the intrusion to the residents is weighed against travel time savings (for a proposal of methodology, see Ivehammar (2008)). It would not be possible to include the results in the main calculation, however, since there is no manual for standardized use. Instead, they could be used for a sensitivity analysis.

For encroachment where winners and losers are separate groups, where the encroachment is to an area of national interest, encroachment which is not in conflict with savings of travel time etc., ASEK (2018) concludes that there is today no method for valuing them in monetary terms. In these cases, expert assessment or an environmental consequences assessment should constitute the basis for an evaluation of the impact.

If a transport investment leads to the release of attractive and usable land, e.g., when a road or a railroad is made to pass a tunnel, ASEK (2018) recommends that the economic value of the released land should not be included in the main calculation but only in the sensitivity analysis. In the main analysis, the impact could be included in the non-valued (difficult to value and/or non-priced) impacts. The reason for this recommendation is that the risk for double-counting is great and that there are great unknowns in the methodology that has been developed for this types of analyses (Transek, 2005; 2006; WSP, 2007a; 2007b).

B.4 Comparisons Finland – Sweden

Comparing the valuation of noise between Finland and Sweden does not seem meaningful since the Finnish values are transferred from Sweden. Table B.4.1 makes a comparison of the values of different air pollutants and greenhouse gases (including CO_2) in the two countries based on the figures shown in, Table B.2.3, Table B.3.8, and Table B.3.11. The differences in valuation are considerable both with regard to the compounds having been valued, and to the values themselves. Nitrogen oxides, particulate matter and carbon dioxide are the three compounds included in both countries. Besides these three, Sweden includes sulphur dioxide (SO_2) and volatile organic compounds (VOC), while Finland includes hydrocarbons (HC) for both road and rail transport. For the rail mode, Finland also includes SO_2 from electricity generation, methane, and nitrous oxide.

Table B.4.1: Comparison of the valuation of air pollution and greenhouse gas emissions between Finland and Sweden. Emissions are valued at EUR/kg (EUR/exposure unit for the local effects in Sweden) in 2019 price terms.

Emissions, euro/ton	Finland						Sweden	
	Road transport, EUR/kg			Rail transport, EUR/kg			EUR/ exposure unit	EUR/ kg
	Urban areas	Countryside	Average	Electric	Diesel		Local effects	Regional effects
					Cities with a station	Other areas		
NO_X	1.49	0.32	0.90	0.60	0.60	0.30	0.21	8.66
PM	143.66	8.94	76.30	0.49	86.00	5.98	59.12	0
HC	0.033	0.033	0.033	0.033	0.033	0.033		
SO_2				0.39	0	0	1.73	2.92
CH_4				0.87	0.87	0.87		
N_2O				12.85	12.85	12.85		
VOC							0.35	4.33
CO_2	0.042	0.042	0.042	0.042	0.042	0.042	0.12	0.12

Also, differences in valuations are large. Sweden (ASEK 6.1) values carbon dioxide at almost three times higher than Finland. On the other hand, methane and nitrous oxide included in the emissions from the rail sector in Finland are also greenhouse gases; the Swedish recommendation is to convert these to CO_2 equivalents and value them at the value of CO_2. Not having translated these unit values to CO_2-equivalents and not knowing the amounts emitted, it is difficult to say whether the valuation of greenhouse gases from the rail sector in Finland is higher or lower than in Sweden. Regardless, it is noteworthy that the valuations in Finland differ between road and rail modes, with rail having a larger climate impact when measured in euros per kilogram emissions.

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Attachment C:

Treatment of climate and environmental effects in cost benefit analysis in transport. The case of Norway

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C.1 Introduction

Cost-benefit analysis (CBA) is central in Norwegian infrastructure planning. Most transport projects undergo a thorough assessment of the positive and negative impacts for transport users as well as for the wider economy, society and the environment.

The relevant transport infrastructure agencies propose projects to be included in the national transport plan (NTP) after internal discussion and consultations with local and regional authorities. Large projects (>NOK 1000 mill = €103 mill) are put through a two-stage quality assessment.

CBA guidelines are embodied in an official document, Rundskriv R-109/14 (Finansdepartementet, 2014), which describes how to measure the costs and benefits of a project. This includes assumptions about future GDP growth, lifetimes of projects, discount rates, the value of work and leisure time and health and mortality impacts. The guidelines also require an analysis of the environmental impact.

All costs with a market price are calculated at full cost including VAT. For public expenses without a competing private sector, costs are calculated based on actual costs including social benefits and taxes aimed at correcting external effects but excluding VAT and import duties.

Guidelines for the assessment of environmental costs are mentioned briefly and state that a value of a statistical life (VSL) at 30 million NOK (2012) should be used when relevant. Environmental costs based on VSL and dose-response between emissions, concentration levels and health effects must be adjusted according to the expected growth in GDP per capita in the latest version of Perspektivmeldingen (Meld. St. 14, 2020–2021) from the Ministry of Finance and changes in dose-response ratios over time.

Non-monetary environmental effects should be investigated and the effects on the socio-economic profitability considered.

C.2 The assessment of monetary values of environmental and climate effects

Most transport infrastructure projects in Norway involve one of the 5 large transport agencies;

- Avinor AS (The main airport operator);
- Statens vegvesen, SVV (Norwegian Public Roads Administration);
- Jernbanedirektoratet, JBV (Norwegian Railway Directorate);
- Kystverket, KV (Norwegian Coastal Administration); and
- Nye Veier AS (A government owned company in charge of building roads))

Each transport agency has a user manual for CBA and while both the methods and actual monetary assessments have to some extent varied from agency to agency, the basis for the assessments has been values worked out by the Institute of Transport Economics (TØI) and other contractors over the years.

An early report from TØI (Eriksen and Hovi, 1995) calculated the marginal environmental cost per passenger- and ton km related to emissions, including CO_2, road dust and noise for road traffic, train, boat traffic and aviation. The values were later revised in for instance:

- Eriksen, Markussen and Pütz (1999)
- Econ (2003)
- Magnussen et al. (2010d)
- Magnussen et al. (2010e)
- Foss el al (2010) for heavy (road) vehicles
- Thune-Larsen et al. (2014, revised in 2016) for road traffic
- Magnussen et al. (2015) for freight transport by rail and sea.

With the aim of updating all assessments and ensuring consistent values, the transport agencies hired TØI to update most of the monetary assessments of marginal external effects in transport for use in CBA in transport in 2018. The results are published in Kenneth Rødseth et al. (2019). Results from the report are mostly implemented in the method toolbox of each agency and the TØI-report is for this reason the prime source for the Norwegian part of the project, except in the case of CO_2-emissions.

On July 3rd 2020, the Ministry of Transport sent a letter to the transport agencies with a recommendation for the valuation of CO_2-emissions in CBA in the National Transport Plan (2022–2033).

The following chapters are divided by:

- effects of noise
- environmental effects of air pollution
- climate effects

C.2.1 Noise

Noise can be defined as the unwanted sound of duration, intensity or other quality that causes physical or psychological harm to humans. Noise will as a rule cause increasing annoyance with increasing noise levels. Noise above a certain level may also cause health damages such as increased risk of cardiovascular diseases and nervous stress reactions.

Traditionally the value of noise used in CBA in Norwegian transport has been measured based on studies of willingness to pay (to avoid annoyance from noise), often based on conjoint analysis.

The recommended values that are presently to be implemented in CBA in Norway have been calculated in Rødseth et al. (2019). They are an aggregate of the values of:

- Annoyance
- Health effects from severe annoyance
- Health effects of disturbed sleep
- Increased risk of ischemic heart (cardiovascular) disease

The value of annoyance

The most obvious effect of noise is *annoyance*. As the noise levels increase, the level of annoyance increases, and an increasing amount of people are affected by the noise. The value of this annoyance is estimated in studies of willingness to pay (to avoid noise). The estimated value of annoyance per person bothered by noise per year was NOK_{2009} 2750. The equivalent value in 2019, based on the present exchange rate and increase in BNP, is $€_{2019}$ 408.3.

Based on effect curves from Miedema & Oudshoorn (2001), the recommended value of noise annoyance per dB per person has been updated in Rødseth et al. (2019). The cost of outdoor noise levels under 50/53 dB for road/railroad noise has been set at zero. Above this level, the cost of increased road/railroad noise per person is valued at $€_{2019}$ 5.15/6.8 per dB respectively.

The value of health effects caused by severe annoyance

Severe noise annoyance also affects health. The value of health effects from severe noise are related to the value of Disability Adjusted Life Years (DALY). 1 DALY is estimated at a value of NOK_{2019} 1611 000.

One extra person affected by severe annoyance is valued at 0.02 DALY= NOK_{2019} 32 220 based on international studies. Effect curves from Miedema & Oudshoorn (2001) predict the share of people that are affected by a certain noise level.

Based on the estimated relation between noise levels and the number of affected persons, the marginal health cost per dB per person per year related to severe noise annoyance from road traffic has been calculated at $€_{2019}$ 34.4 (52–65 dB) and $€_{2019}$ 77.6 (65–80 dB).

For rail the estimate is €$_{2019}$ 21.9 (53–65 dB) and NOK$_{2019}$ 61.6 (65–80 dB).

The value of health effects caused by disturbed sleep

According to WHO, the health effect of *disturbed sleep* is valued at 0.07 DALY.

Effect curves from Basner et al. (2018) predict the likelihood of disturbed sleep given the level of noise during the period of sleep.

Based on these estimates the cost per dB per person per year at noise levels in the night (L_{night}) above 50 dB is calculated at €$_{2019}$ 67.1 for road traffic and €$_{2019}$ 174.8 for train traffic.

Increased risk of ischemic heart disease

The value of the increased risk of ischemic heart disease has been calculated based on:

- The overall death rate related to ischemic heart disease;
- The increased risk related to increased noise stated in (van Kempen, Casas, Pershagen, & Foraster [2018]);
- The baseline (the death rate without deaths caused by noise);
- Average number of DALY lost because of death related to ischemic heart disease (Estimated at 11.376 in the project Global Burden of Disease).

The result for road traffic is €$_{2019}$ 12.4 per person per dB per year.

Recommended values

Recommended values are presented in € in tables C.2.1 – C.2.4.

The values in euros are calculated using a conversion rate of 9.72 NOK/€.

Table C.2.1: Unit prices for noise related to road traffic (€$_{2019}$/dB/person/year). Source: Rødseth et al. (2019).

	52	53–55	56–64	65–
Annoyance	5.1	5.1	5.1	5.1
Cardiovascular		12.4	12.4	12.4
Disturbance of sleep			73.8	73.8
Severe annoyance	34.4	34.4	34.4	77.6
Total cost road traffic	39.5	52.0	125.7	168.9

Table C.2.2: Unit prices for noise related to train traffic (€$_{2019}$/dB/person/year). Source: Rødseth et al. (2019).

	53–56	57–64	64–
Annoyance	6.8	6.8	6.8
Disturbance of sleep		192.3	192.3
Severe annoyance	21.9	21.9	61.6
Enhetspris bane	28.7	221.0	260.7

Table C.2.3: Average noise cost of an additional vehicle kilometer by category (€$_{2019}$/km). Source: Rødseth et al. (2019)

	Marginal cost Light vehicles	Marginal cost Heavy vehicles
Rural areas	0.004	0.025
Urban area < 100 000 persons	0.031	0.168
Urban area > 100 000 persons	0.034	0.246

Table C.2.4: Average noise cost of an additional train kilometer by category (€$_{2019}$/km). Source: Rødseth et al. (2019)

MC by area	Passenger train day	Passenger train night	Freight train day	Freight train night
Urban area > 100 000 persons	0.12	1.23	0.95	9.19
Urban area < 100 000 persons	0.12	1.24	0.91	8.73
Rural areas	0.05	0.45	0.27	2.52

C.2.2 Global emissions – effects of greenhouse gases

Global warming (or greenhouse gas) emissions affect the climate in the same way regardless of time and place. It therefore makes sense to use global evaluations of the effect. The most important greenhouse gases are carbon dioxide (CO_2), methane and nitrous oxide. They have different degrees of effect on the climate and are commonly measured in CO_2-eqivalents (CO_2-eq).

The recommended pricing of CO_2-eq in CBA in transport in Norway has so far been related to estimates of future prices of CO_2 in the EU Emission Trading System (EU ETS) in Klimakur 2020 (2009). The result was a price per ton CO_2-eq of €40 in 2020 and €100 in 2030.

The new recommendations in Rødseth et al. (2019) look at the recommendations in Hagen-utvalget (NOU 2012:16). The basic recommendation in Hagen-utvalget is to price climate effects based on the marginal cost of emissions required to reach certain emission targets. In 2012 the global emission target was related to a goal of a maximum 2 degrees increase in global temperature compared to preindustrial levels.

The estimates in Rødseth et al. (2019) relate to the Paris agreement, where global warming emissions should be limited to 1.5 degrees above preindustrial levels. The Paris agreement was sanctioned by the Norwegian parliament and government in June 2016.

The marginal cost of limiting emissions enough to keep the Paris accord is uncertain, but the IPCC (2018) presents estimates of the necessary price of CO_2 to meet the emission target. Rødseth et al. (2019) recommend the use of the mean IPPC estimate. Converted to Norwegian prices the recommendation is a price for CO_2-eq of NOK_{2019} 2 159/ton CO_2-eq in 2030 increasing to NOK_{2019} 34 455 in 2100.

For 2019 the recommended price in Rødseth et al. is identical to the present CO_2-tax of NOK 508/ton and for intermediate years a gradual increase to the IPCC-price in 2030.

The recommendations in Rødseth et al. (2019) converted to euro are presented in table C.2.5.

Table C.2.5: Recommended pricing of climate effects by year in Rødseth et al. (2019).

	2019	2030	2050	2070	2100
$€_{2019}$/ton CO_2-eq.	52.3	222	823	1 242	3 545
Source	CO_2-tax	IPCC (2018)	IPCC (2018)	IPCC (2018)	IPCC (2018)

Hoel, Moss, and Vennemo, H. (2020) recommend a CO_2 price of approximately 1000 NOK/ton for emissions not included in EU ETS in 2020, increasing with the discount rate in the future.

The latest recommendation was issued on July 3rd 2020 by the Ministry of Transport in a letter to the transport agencies. The letter recommends a value of NOK 1500/ton ($€_{2019}$ 152/ton) CO_2 in 2020 with a future annual adjustments equal to the discount rate. For the purpose of sensitivity analysis, values of both 500 and 2500 NOK/ton should be applied, at least in cases where the valuation is important for the result and/or the reduction of CO_2-emissions is the main purpose of the project.

Unlike other modes of transport, domestic aviation is included in EU ETS. Increased (reduced) emissions from aviation will, at least in theory, be balanced by reduced (increased) emissions in other sectors covered by EU ETS through the total emission cap leading to changes in the carbon price. Additional pricing of emissions from aviation is therefore not recommended by Rødseth et al. Because of the additional greenhouse effects from contrails from aviation performed over 26 000 feet, Rødseth et al. instead recommend a pricing of emissions from aviation over 26 000 feet equivalent to 80 percent of the prices in table C.2.5. Since turboprop aircrafts never exceed 26 000 feet this only applies to jet airplanes.

C.2.3 Local emissions to air

Evaluations of local emissions are valued based on the damage costs due to health effects from air pollution.

The emissions taken into consideration are:

- Particulate emissions (PM)
- Nitrogen oxides (NO_x)
- Sulfur dioxide (SO_2)

Evaluations of damage costs from local emissions in Norway have been done in 5 steps:

1. Calculation of emission factors for transport by transport mode.

Exhaust emission factors for road transport are based on the HBEFA model (Swedish Transport Administration [2019b], Holmgren and Fedoryshyn [2015]), see table C.2.6. Emission factors in Norway include particulate matter from road dust, brakes and tire wear as well as from exhaust. For rail transport the emission factors for diesel trains have been calculated based on reported emissions and fuel consumption from Statistics Norway.

Table C.2.6: Available combinations of road category and speed in HBEFA.

Source: Holmgren and Fedoryshyn (2015).

			Speed Limit (km/h)											
Area	Road type	Levels of service	30	40	50	60	70	80	90	100	110	120	130	>130
Rural	Motorway -Nat.	4 levels of service						Motorway	Motorway	Motorway	Motorway	Motorway	Motorway	Motorway
	Semi-Motorway	4 levels of service							Motorway		Motorway			
	Trunk Road/ Primary -Nat.	4 levels of service				Urban	Rural	Rural	Rural	Rural	Rural			
	Distributor/ Secondary	4 levels of service			Urban	Urban	Rural	Rural	Rural	Rural				
	Distributor/ Secondary (sinuous)	4 levels of service			Urban	Urban	Rural	Rural	Rural	Rural				
	Local/ Collector	4 levels of service			Urban	Urban	Rural	Rural						
	Local/ Collector (sinuous)	4 levels of service			Urban	Urban	Rural	Rural						
	Access-residental	4 levels of service	Urban	Urban	Urban									
Urban	Motorway -Nat.	4 levels of service						Motorway	Motorway	Motorway	Motorway	Motorway	Motorway	
	Motorway -NCity	4 levels of service				Motorway	Motorway	Motorway	Motorway	Motorway	Motorway			
	Trunk Road/ Primary -Nat.	4 levels of service					Urban	Rural	Rural	Rural	Rural			
	Trunk Road/ Primary -City	4 levels of service			Urban	Urban	Urban	Rural	Rural					
	Distributor/ Secondary	4 levels of service			Urban	Urban	Urban	Rural						
	Local/ Collector	4 levels of service			Urban	Urban								
	Access-residental	4 levels of service	Urban	Urban	Urban									

Assigned Fleet compositions:

= Motorway

= Rural

= Urban

2. Modelling dispersion of pollutants.

Models for dispersion of pollutants are used to calculate the change in pollution levels in different geographical areas.

3. Modelling the resulting exposure/concentration levels of pollution according to geographical area

For instance, 1 extra ton of PM released from emissions in Oslo will increase the concentration of PM by 0.0075 mg/m^3 as described in table C.2.7 below.

Table C.2.7: Contribution to concentration of emissions/dust (mg/m3/ton). Source: Rødseth et al. (2019)

	PM from exhaust	PM from road dust	NO_2 fra road trafific
Oslo	0.0075	0.0172	0.0039
Bergen	0.0147	0.0275	0.0082
Trondheim	0.0247	0.0829	0.0162
Drammen	0.0279	0.0460	0.0183

4. Modelling exposure-response functions between concentration levels and health incidents.

Functions are mainly based on dose-response functions recommended by WHO (2013), see table C.2.8 and C.2.9.

Table C.2.8: If 1000 persons are exposed to an annual average increase of the concentration of 1 µg/m3 PM10 we expect this increase of (Source: Rødseth et al. [2019]).

Long-term effects	Number of cases
Persons who after 5 years die 8 years before expected lifetime because og cardio-vascular or lung disease (other than lung cancer)	0.01
Persons who after 30 years die 11 years before expected lifetime because of lung cancer.	0.002
Infant mortalities before the age of 1 year.	0.0002
Cases of bronchitis among children	0.05
Persons developing COPD	0.03
Days in hospital because of COPD	0.18
Annual amount of lost work hours because of unfitness for work because of COPD	6.35
Short-term effects:	
Persons who die 1 year earlier than expected lifetime	0.01
Days in hospital due to respiratory disorder	0.17
Days in hospital because of heart disease (including stroke)	0.08
Children with upper respiratory disorder	0.005
Children with lower respiratory disorder	0.0003
Lost work hours because of illness	235
Persons severely bothered by PM emissions	8.07

Table C.2.9: If 1000 persons are exposed to an annual average increase of the concentration of 1 µg/m3 NO_2 we expect this increase of (Source: Rødseth et al. 2019).

Long-term effects:	Number of cases
Persons who after 5 years die 8 years before expected lifetime because og cardio-vascular or lung disease (reduced by 17% because of cases included for effects of PM10)	0.01
Cases of bronchitis among children	0.014
Short-term effects:	
Persons who die 1 year earlier than expected lifetime	0.002
Days in hospital due to respiratory disorder	0.16
Persons severely bothered by NO2-emissions	1.79

5. Monetary evaluation of damage.

Because pollution generates many different health effects, the monetary evaluation is based on several methods. Health incidents resulting in death are calculated based on VSL (Value of Statistical Life) or DALY.

Most of the costs are related to increased mortality because of heart and lung diseases, effects on bronchitis among children and COPD, increased absence from work and increased levels of annoyance.

The values are stated below in tables C.2.10 and C.2.11 and are calculated at 9.72 NOK/€.

Table C.2.10: The cost of exposing 1000 persons to an increased annual concentration of µg/m^3 PM_{10}: (€$_{2019}$):

Long-term effects:	**1000 €/1000 persons exposed**
DALY for people who die too early because of cardiovascular and/or lung diseases	16.0
VSL for infant deaths	1.5
Costs related to bronchitis among children	15.3
Costs related to people that develope COPD	19.2
Other factors	0.05
Short-term effects:	
Absence from work because of illness	9.6
Value of increased number of severe cases of annoyance	13.4
Other factors	0.8
Total marginal cost related to PM10	**75.9**

Table C.2.11: The cost of exposing 1000 persons to an increased annual concentration of µg/m^3 NO_2: (€$_{2019}$):

Long-term effects:	**1000 NOK/1000 persons exposed**
DALY for people who die too early because of cardiovascular and/or lung diseases (minus 17% for cases covered by the effect of PM10)	8.6
Bronchitis among children	4.0
Short-term effects:	**1000 NOK/1000 persons exposed**
Value of increased number of severe cases of annoyance	3.0
Other factors	0.9
Total marginal cost related to NO_2	16.5

No damage cost has been calculated for rural areas. Norway has, however, signed the Gothenburg Protocol of 1999 that limits total permitted emissions of SO_2, NO_X, NH_3 and NMVOC by 2020. The common practice has been to value NO_X based on abatement costs and estimate the abatement cost at the same level as the present tax on NO_X emissions of NOK 22.27 in 2019.

For SO_2 the damage cost has been estimated based on damage to nature and buildings at 11 NOK/kg in small urban areas and twice of that in large urban areas.

The results per unit of emission are divided by 3 levels of urbanization in table C.2.12:

Table C.2.12: Marginal damage cost from PM_{10}, NO_x and SO_2 (€$_{2019}$). Source: Rødseth et al. (2019).

	Rural areas	Small urban area (pop 15.000- 100.000)	Large urban area (pop >100.000)
€/kg PM10 – emissions	0	37	330
€/kg PM10 – road dust	0	88	796*
€/kg PM10 – weighted average	0	63	566
€/kg NO_x	2.3	9.1	40.5
€/kg SO_2	0	1.1	22.3

*Road dust has a higher value than emissions because the contribution to concentration is higher according to table C.2.7.

C.3 Emission costs per vehicle km

The recommended values per km for road, diesel trains, domestic aviation and maritime transport are introduced in tables C.3.1 – C.3.8.

C.3.1 Road transport

Table C.3.1: Emission costs for trucks. National average. €-cents$_{2019}$. Source: Rødseth et al. (2019).

Wiight	€/km CO_2	€/km NO_X	€/km PM from exhaust	€/km SO_2	€/km PM from road dust	SUM local
<=7.5t	1.7	2.4	0.4	0.0	3.4	6.2
>7.5-14t	2.5	3.2	0.4	0.0	3.4	7.1
>14-20t	3.1	3.8	0.4	0.0	3.4	7.7
>20-28t	4.1	4.2	0.4	0.0	3.4	8.1
>28-40t	4.9	4.0	0.4	0.0	3.4	7.8
>40-50t	5.2	4.2	0.4	0.0	3.4	8.0
>50-60t	6.5	5.6	0.6	0.0	3.4	9.7
Petrol	2.5	4.7	0	0.0	3.4	8.2
All trucks	5.2	4.7	0.5	0.0	3.4	8.7
El/hydrogen	0.0	0.0	0.0	0.0	3.4	3.4

Table C.3.2: Emission costs for cars. National average. €-cents$_{2019}$. Source: Rødseth et al. (2019).

Fuel	€/km CO_2	€/km NO_X	€/km PM from exhaust	€/km SO_2	€/km PM from road dust	SUM local
Diesel	0.7	0.8	0.1	0.0	0.6	1.6
Hybrid	0.5	0.0	0.0	0.0	0.6	0.6
LPG	0.7	0.1	0.0	0.0	0.6	0.7
Petrol	0.8	0.2	0.0	0.0	0.6	0.8
All with ICE	0.7	0.6	0.1	0.0	0.6	1.3
El/hydrogen	0.0	0.0	0.0	0.0	0.6	0.6

Table C.3.3: Emission costs for vans, MC and bus. National average. €-cents$_{2019}$. Source: Rødseth et al. (2019).

Category	Fuel	€/km CO_2	€/km NO_X	€/km PM from exhaust	€/km SO_2	€/km PM from road dust	SUM local
Van	Diesel	1.0	0.8	0.2	0.0	0.7	1.7
Van	Petrol	0.9	0.5	0.0	0.0	0.7	1.2
MC	Petrol	0.4	0.1	0.0	0.0	0.1	0.2
Tour bus	Diesel	4.5	6.0	0.6	0.0	4.4	11.0
City bus	CNG	5.5	7.1	0.2	0.0	8.2	15.4
City bus	Diesel	4.5	8.2	0.6	0.0	8.2	17.1

C.3.2 Rail transport

Table C.3.4: Emission costs for diesel trains. €-cents$_{2019}$. Source: Rødseth et al. (2019).

Category	Area	€/km CO_2	€/km NO_X	€/km PM from exhaust	€/km SO_2	SUM local
Freight	Rural	108	70	6	0.07	76
Freight	Urban (15'-100' inh.)	108	276	90	0.07	367
Freight	Urban >100' inh.	108	1241	815	0.07	2056
Passenger	Rural	20	13	1	0.01	14
Passenger	Urban (15'-100' inh.)	20	51	17	0.01	68
Passenger	Urban >100' inh.	20	231	152	0.01	382

C.3.3 Air transport

Table C.3.5: Emission costs for domestic aviation. €-cents$_{2019}$. Source: Rødseth et al. (2019)

	Climate*	Other emissions
Turboprop	0.0	8.9
Jet	34.1	14.9
All domestic	21.2	10.7

*based on 80% of emissions > 26 000 feet

C.3.4 Maritime transport

Table C.3.6: Recommended emission costs for maritime transport. Rural areas. €$_{2019}$/vkm.

Source: Rødseth et al. (2019).

Category/ dwt	<1'	1'-5'	5'-15'	15'-25'	25'-35'	35'-45'	45'-55'	>55'
Breakbulk	1.26	3.06	5.96	12.53	18.11	17.06	18.59	22.89
Container Lo/ Lo		5.40	9.89	16.37	19.64	23.57	28.29	33.94
Cruise	5.62	23.68	49.87					
Coaster	2.31	14.16						
Domestic_ropax	3.25	7.61						
Chem/ Product tanker	2.67	4.44	8.09	15.03	19.16	17.06	18.68	28.62
Cool/ Freezeship	1.91	5.03	10.09	18.52				
Coastal voyage	15.24	18.71						
LPG/LNG	4.81	5.53	12.71	19.15	19.99	23.66	26.69	35.76
Offshore ship	4.62	13.46	13.29					
Ro-Ro cargo	1.99	7.43	11.31	18.91	22.69			
Tanker	1.98	5.07	7.59	21.60	16.79	21.58	15.78	29.13
Dry bulk	1.76	4.13	6.83	12.55	16.00	16.53	17.06	20.96
International ferry	24.99	26.39	42.49					

Table C.3.7: Recommended emission costs for maritime transport. Urban<100' inh. €$_{2019}$/vkm.

Source: Rødseth et al. (2019).

Category/ dwt	<1'	1'-5'	5'-15'	15'-25'	25'-35'	35'-45'	45'-55'	>55'
Breakbulk	2.75	6.75	13.52	31.66	46.83	41.57	47.81	57.71
Container Lo/ Lo		11.91	22.87	42.27	50.73	60.87	73.05	87.65
Cruise	12.30	59.73	128.99					
Coaster	5.05	32.69						
Domestic_ropax	7.18	17.28						
Chem/ Product tanker	5.83	9.81	18.61	37.51	49.24	43.59	47.57	71.47
Cool/ Freezeship	4.22	11.09	21.72	47.39				
Coastal voyage	38.33	47.74						
LPG/LNG	10.64	12.21	29.94	47.11	49.78	59.92	66.87	91.01
Offshore ship	10.10	29.55	29.48					
Ro-Ro cargo	4.36	17.62	27.98	48.32	57.99	0.00	0.00	0.00
Tanker	4.32	11.17	17.31	56.01	42.11	51.57	40.09	74.19
Dry bulk	3.85	9.10	15.44	32.33	41.12	42.15	43.18	54.44
International ferry	57.53	66.59	108.62					

Table C.3.8: Recommended emission costs for maritime transport. Urban>100' inh. $€_{2019}$/vkm.

Source: Rødseth et al. (2019).

Category/ dwt	<1'	1'-5'	5'-15'	15'-25'	25'-35'	35'-45'	45'-55'	>55'
Breakbulk	10.01	24.62	50.00	123.12	183.30	157.97	185.78	222.22
Container Lo/ Lo		43.48	85.38	164.52	197.42	236.90	284.28	341.14
Cruise	44.83	230.32	499.24					
Coaster	18.38	122.00						
Domestic_ropax	26.30	64.03						
Chem/ Product tanker	21.24	35.79	69.27	144.14	191.26	168.88	184.05	274.28
Cool/ Freezeship	15.38	40.44	78.15	183.81				
Coastal voyage	147.76	184.93						
LPG/LNG	38.79	44.54	112.41	179.75	190.87	231.39	257.06	350.20
Offshore ship	36.81	108.01	108.28					
Ro-Ro cargo	15.92	66.48	107.28	188.41	226.09			
Tanker	15.73	40.74	64.17	218.31	161.93	194.17	154.94	285.57
Dry bulk	14.03	33.22	57.03	125.68	159.76	163.26	166.76	211.51
International ferry	215.42	259.17	424.58					

C.4 The methods used to integrate environmental effects without a monetary value

C.4.1 Assessment of non-monetary environmental effects

The recommended method used for integration of environmental effects without a monetary value is described in Veileder i samfunnsøkonomiske analyser i jernbanesektoren (Jernbanedirektoratet, 2018) and in detail in Håndbok V712 Konsekvensanalyser (Vegdirektoratet, 2018).

The non-monetary effects to be considered are all related to a specific affected area. The effects are divided into 5 main categories:

- Landscape picture: "The spatial and visual landscape"
- Outdoor urban/rural life: "The landscape in terms of how people perceive and use it"
- Nature diversity: "The ecological landscape"
- Cultural heritage: "The cultural-historical landscape"
- Natural resources: "The production landscape"

Handbook V712 mentions three key concepts for assessing and analyzing non-monetary effects:

- Value: An assessment of the importance of the affected area from a national perspective;
- Impact: An assessment of how the area is affected compared to the reference situation (reference alternative); and
- Consequence: A compilation of value and impact.

The overall assessments for each category are collected in an overall assessment table with an overall total ranking for each alternative as in table C.4.1.

Table C.4.1: Overall assessment of non-monetary effect.

	Reference	Alt.1	Alt.2	Alt.3
Landscape picture	0			
Outdoor urban/ rural life	0			
Nature diversity	0			
Cultural heritage	0			
Natural resources	0			
Overall assessment	0	Negative	Extremely negative	Very negative
Ranking	**1**	**2**	**4**	**3**
Reason for ranking				

C.4.2 Integration of assessments of non-monetary environmental effects

A preliminary ranking combines rankings from monetary and non-monetary effects as in table C.4.2.

Table C.4.2: Preliminary ranking based on monetary and non-monetary effects

		Reference	Alt 1	Alt 2	Alt 3
Results from CBA	Net benefit Net benefit/ investment	0 0	-2000 -0.31	-2200 -0.24	-1600 -0.18
	Ranking	1	3	4	2
Non-monetary evaluation	Overall effect	0	Negative	Extremely negative	Very negative
	Ranking	1	2	4	3
	Preliminary overall ranking	**1**	**2 or 3**	**4**	**2 or 3**

The next step is the break-even analysis. In the current example alternative 3 returns 400 more in money terms than alternative 1, but at the same time the non-monetary effects are more negative in alternative 3 than alternative 1. This means that the cost of choosing the less negative alternative is 400. The final recommendations take into consideration the actual extra negative effects of choosing alternative 1 instead of alternative 2, compared to the extra cost of choosing this alternative.

C.5 Considerations regarding the use of limited environmental goods

We have not been able to find specific recommendations for considerations regarding the effects on limited environmental goods of transport projects in Norway.

However, considerations regarding limited environmental goods are to a large extent integrated in the described assessments of environmental effects without a specific recommended monetary value, since all aspects regarding the area affected by a transport project are supposed to be considered.

An irreversible change in the landscape will in many cases result in "using up" some part of the environment in that area and may sometimes limit the possibilities and quality of outdoor activities. If an animal or plant species is threatened by extinction or some cultural heritage is threatened because of a new project this will be an important consideration with respect to natural diversity and cultural heritage.

Finally, the possible limitation of the production potential of an area is an important consideration as regards non-monetary effects. This is especially important where the possible encroachment of farm land is involved, even though the actual value of the lost production may be small. Norway had limited available areas for farming and enforces rather strict policies when it comes to the irreversible encroachment of farm land.

Another classic example of considerations regarding production potentials is related to the considerations regarding the building of Oslo Airport Gardermoen on top of the largest groundwater reservoir in Norway. Possible leakage from de-icing fluids into the reservoir was one of many major considerations in the decision process leading up to the final decision to build the new airport.

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Attachment D:

Update of values for Finland and Sweden

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This is a supplement to the Attachment B Finland and Sweden (Hammes, 2020).

D.1 Updating values

The methods and monetary values for assessing environmental effects in the Nordic countries are presented in this report. An appendix to the report (Attachment B), containing Finnish and Swedish values (Hammes, 2020) was written in 2019/2020, but both the Swedish and Finnish road administrations released updated values at the end of 2020.

The Finnish Transport Infrastructure Agency released new monetary unit values for noise and air pollution (Finnish Transport Infrastructure Agency, 2020), and the Swedish Transport Administration published a new guideline, ASEK 7.0 (Swedish Transport Administration, 2020), during the year 2020. This meant that some of the values in the appendix (Hammes, 2020) needed to be updated, and these updated values are presented in this supplementary attachment.

If the computation method has been changed or revised in comparison to what is reported in Attachment B, this is specifically mentioned.

D.2 Updated Finnish values

The new report with the updated unit values in Finland (Finnish Transport Infrastructure Agency, 2020) presents all values in 2018-terms. The new report replaces the previous report from 2015, which had monetary values in 2013-terms (Tervonen & Metsäranta, 2015).

All values presented in this chapter are updated from 2018- to 2019-terms based on a CPI-increase of 1.1% and an increase in GDP per capita of 1.0% (OECD, 2020), resulting in a total increase of 2.1%.

D.2.1 Noise

The unit value of noise in Finland is set according to Swedish empirical studies, and is computed based on outside noise during the day between 7 a.m. and 10 p.m. (7-22). The unit value is presented as a function of the noise level measured in decibels.

Table D.2.1 shows the unit value of noise for road transport and rail transport. This table replaces Table B.2.1 in Attachment B (Hammes, 2020).

Table D.2.1: Value of road and rail transport noise, Euro/person-year. 2019 price level. (Finnish Transport Infrastructure Agency, 2020)

DB(A)	Road transport	Rail transport
55-60	133	51
60-65	735	286
65-70	1879	766
70-75	3594	1501
75-	6157	2614

Comparing methods used in previous studies (Hammes, 2020) with the newest update (Finnish Transport Infrastructure Agency, 2020), there is no evident change in the methodology for computing these values, despite the fact that some of the updated values are far higher than before.

D.2.2 Air pollution

The emission costs from road transport are updated in the new Finnish report (Finnish Transport Infrastructure Agency, 2020). The values are computed using the Impact Pathway Approach and are based on international and national research results. They are presented in Table D.2.2, which replaces Table B.2.3 in Attachment B (Hammes, 2020).

Table D.2.2: Valuation of air pollution, effects in urban areas and the countryside, Euro/kg of emissions. 2019 price level. (Finnish Transport Infrastructure Agency, 2020)

Emissions of	Road transport, EUR/kg emissions			Rail transport, EUR/kg emissions		
	Urban areas	Countryside	Average	Electric	Diesel	
					Cities with a station	Other areas
NO_X (Nitrogen oxides)	1.53	0.33	0.92	0.61	0.61	0.30
Particulate matter (primary, $PM_{2.5}$)	142.94	9.09	77.60	0.50	87.14	6.06
HC (Hydrocarbons)	0.03	0.03	0.03	0.03	0.03	0.03
CO_2 (Carbon dioxide)	0.08	0.08	0.08	0.08	0.08	0.08
SO_2 (Sulphur dioxide)	-	-	-	0.39	0.00	0.00
CH_4 (Methane)	-	-	-	0.88	0.88	0.88
N_2O (Nitrous oxide)	-	-	-	13.02	13.02	13.02

The Finnish report is more of a handbook and does not cite specific sources. The underlying methodologies are described in detail in a methodology report that was not yet published at the time of writing this update. The values are in this case almost exactly the same as the values in Attachment B (apart from the value of CO_2).

D.2.3 Carbon dioxide

The value of CO_2 and CO_2 equivalents is set to 77 Euro per ton (2018) and CPI-adjusting it to 2019 terms results in 79 Euro/ton, which is the value presented in Table D.2.2.

D.3 Updated Swedish values

The Swedish Transport Administration recommends new values in ASEK 7.0 (Swedish Transport Administration, 2020). All values in ASEK 7.0 are updated to the base year 2017. Another update with relevance to this report is the societal cost of emissions to air. A new valuation study is the foundation of the updated values.

All values in the report are updated with an increase in CPI of 3.8% between 2017 to 2019 (Statistikmyndigheten SCB, 2020). The ASEK 7.0 report (Swedish Transport Administration, 2020) recommends updating values both with respect to CPI and GDP per capita. The GDP per capita increase was 1.1% in Sweden between 2017 and 2019 (OECD, 2020). Combining CPI and GDP per capita increase results in a total increase of 5%, which is used to update all 2017-values in the tables in this report. In some tables a prognosis value for 2040 is also presented. This prognosis is updated from 2017 terms to 2019 terms with the CPI increase.

All values in this chapter are given in Euro, computed from Swedish kroner with a conversion rate of 1 € = 10.52 kr.

D.3.1 Noise

There is no evident change in methodology when compared to previous Swedish values, but some of the values for railroad noise have increased significantly compared to the values in Attachment B.

The Swedish values for noise costs are presented in Tables D.3.1 and D.3.2 below. Both road and railroad noise costs are presented for the base year 2017 and for the future scenario 2040 (all in 2019 price terms).

Tables D.3.1 and D.3.2 replace Table B.3.5 in Hammes (2020).

Table D.3.1: Value of noise for road traffic in 2017 and a prognosis for 2040. Euro/person-year, 2019 price terms. The 2040 value is a prognosis in 2019 price terms.

Noise equivalent outdoors (DB)	Disturbance	Health effects	Total cost, Euro	
	2017	2017	2017	2040
50	8.41	0.00	8.41	11.72
51	26.20	0.00	26.20	36.52
52	53.43	0.00	53.43	74.48
53	90.05	0.00	90.05	125.52
54	136.05	0.00	136.05	189.64
55	191.44	0.00	191.44	266.84
56	256.21	0.00	256.21	357.12
57	330.42	0.00	330.42	460.56
58	414.01	3.69	417.70	582.23
59	506.99	6.67	513.66	715.99
60	609.35	11.12	620.47	864.87
61	721.16	16.33	737.48	1027.97
62	842.34	23.00	865.34	1206.19
63	972.91	31.14	1004.05	1399.53
64	1112.87	40.09	1152.96	1607.09
65	1262.21	49.69	1311.90	1828.64
66	1420.99	60.86	1481.86	2065.54
67	1589.16	73.45	1662.61	2317.48
68	1766.71	87.55	1854.26	2584.63
69	1953.64	102.58	2056.22	2866.14
70	2150.01	119.94	2269.95	3164.05
71	2355.77	138.11	2493.88	3476.19
72	2570.91	157.70	2728.61	3803.37
73	2795.44	178.80	2974.24	4145.75
74	3029.35	201.42	3230.77	4503.32
75	3272.70	226.21	3498.91	4877.08

Table D.3.2: Value of noise for railroad traffic in 2017 and a prognosis for 2040. Euro/person-year, 2019 price terms. The 2040 value is a prognosis in 2019 price terms.

Noise equivalent outdoors (DB)	Disturbance	Health effects	Total cost, Euro	
	2017	2017	2017	2040
50	6.73	0.00	6.73	9.38
51	20.83	0.00	20.83	29.04
52	42.20	0.00	42.20	58.83
53	70.85	0.00	70.85	98.75
54	106.87	0.00	106.87	148.96
55	150.05	0.00	150.05	209.15
56	200.60	0.00	200.60	279.62
57	258.54	0.00	258.54	360.37
58	323.64	7.38	331.01	461.39
59	396.11	13.34	409.45	570.73
60	475.85	22.24	498.09	694.28
61	562.86	32.66	595.52	830.09
62	657.14	46.00	703.15	980.10
63	758.80	62.28	821.08	1144.49
64	867.73	80.18	947.91	1321.27
65	983.93	99.38	1083.31	1510.00
66	1107.50	121.73	1229.23	1713.41
67	1238.23	146.90	1385.13	1930.72
68	1376.35	175.11	1551.45	2162.55
69	1521.73	205.16	1726.89	2407.09
70	1674.49	239.88	1914.37	2668.41
71	1834.51	276.22	2110.74	2942.13
72	2001.70	315.39	2317.09	3229.76
73	2176.38	357.59	2533.97	3532.07
74	2358.21	402.84	2761.05	3848.58
75	2547.42	452.42	2999.84	4181.44

Noise from air traffic and maritime noise should be valued as noise from road traffic multiplied by a factor of 1.4.

The values of marginal costs for road traffic stem from the Samkost-project at VTI. The marginal cost of road traffic in urban areas, differentiated by population density, is shown in Table D.3.3. The marginal costs for rural areas are zero.

Table D.3.3: Marginal costs for noise from road traffic. prices in 2019 terms. Euro-cent/vehicle-km.

From Tables 10.6 and 10.7 in ASEK 7.0 (Swedish Transport Administration, 2020).

			Urban areas		
Vehicle	Other urban area[21]	Low population density[22]	Medium population density[23]	High population density[24]	Average
2017					
Car all fuels	0.06	0.26	1.08	1.78	1.16
Bus	0.34	1.25	5.03	8.27	5.41
Heavy truck (> 3.5 ton) without trailer	0.34	1.25	5.03	8.27	5.41
Heavy truck (> 3.5 ton) with trailer	0.87	3.26	13.23	20.59	13.62
2040					
Car all fuels	0.08	0.37	1.52	2.51	1.64
Bus	0.48	1.76	7.10	11.67	7.63
Heavy truck (> 3.5 ton) without trailer	0.48	1.76	7.10	11.67	7.63
Heavy truck (> 3.5 ton) with trailer	1.23	4.60	18.66	29.03	19.21

21 22 23 24

The marginal cost of noise from trains is presented in Table D.3.4. The method for computing these costs has not changed since the previous update ASEK 6.1 (Swedish Transport Administration., 2018).

21. Population density between 131 and 400 persons/ km^2
22. Population density between 400 and 1000 persons/ km^2
23. Population density between 1000 and 2000 persons/ km^2
24. Population density over 2000 persons/ km^2

Table D.3.4: Marginal cost of noise from train traffic. 2019 terms. Euro-cent/vehicle-km.

From Table 10.8 in ASEK 7.0 (Swedish Transport Administration, 2020).

Train type	2017	Prognosis 2040
X60	5.64	7.95
Y31s	0.43	0.61
X50-54	4.77	6.73
X31	8.02	11.32
X2	19.09	26.92
X40	12.48	17.60
X10-14	3.14	4.43
RC pass	39.92	56.29
Freight. electrically operated	50.99	71.90
Freight. diesel	37.21	52.46
All passenger trains	9.76	13.76
All freight trains	50.01	70.53

D.3.2 Air pollution

The effects of air pollution are in ASEK 7.0 divided into three categories: local, regional and global effects (Swedish Transport Administration, 2020). The first two of these are presented in this section, while global effects are categorized as climate effects and are not discussed in this section.

Previous values in the Swedish framework (ASEK 6.1 and earlier) are based on values from 1990 and have been updated according to economic growth. In the new ASEK 7.0 report the methodology is revised, and the foundation of the new recommendations is that the damage cost (skadekostnad) is derived from the actual harm and damage that emissions to air have on human health and on the environment. The findings are reported in the final report from the project REVSEK (Tore Söderqvist, 2019). These values differ from previous values. The health effect from wear from tires is calculated, while VOC- and SO_2-emissions are not valued since the emissions from these have less impact (Swedish Transport Administration, 2020).

In Table D.3.5 and Table D.3.6 the local and regional cost of air pollution is presented as Euro per kg emission in 2019 prices. Health effects are valued as particulate emission from exhaust and wear and tear from tires, while the environmental and cultural effects are based on particulates from wear and tear. Compared to the values presented in Attachment B, values of particulate matter have increased and values of NOx have reduced significantly.

Table D.3.5: Cost of air pollution. local effects in the base year 2017 and a prognosis for 2040. Euro/kg emission, 2019 terms.

From table 11.1 in ASEK 7.0 *(Swedish Transport Administration, 2020)*

Effects	2017	Prognosis 2040
Health effects Particulates PM2.5 – Exhaust particles	688.69	959.77
Particulates PM10 – Wear and tear	139.73	194.74
Cultural and environmental effects Particulates PM10 – Wear and tear	31.84	44.37

Table D.3.6: Cost of air pollution. regional effects in the base year 2017 and a prognosis for 2040. Euro/kg emission, 2019 terms.

From table 11.1 in ASEK 7.0 *(Swedish Transport Administration, 2020)*

Effects	2017	Prognosis 2040
NH_3 (Ammonia) – Natural environment - Eutrophication	0.80	1.11
NO_X (Nitrogen oxides) – Natural environment - Eutrophication	0.20	0.28
NO_X (Nitrogen oxides) – Tropospheric ozone. average	0.10	0.14
NO_X (Nitrogen oxides) – Tropospheric ozone. Norrland Sweden	0.05	0.07
NO_X (Nitrogen oxides) – Tropospheric ozone. Svealand Sweden	0.10	0.14
NO_X (Nitrogen oxides) – Tropospheric ozone. Götaland Sweden	0.15	0.21

The valuation of air pollution, presented in Table D.3.5 and Table D.3.6, is updated from the previous Swedish values and the new values are regarded as better estimates. Even though these values are improved, the authors of ASEK 7.0 (Swedish Transport Administration, 2020) point out that they underestimate the actual cost, since all effects from emissions to air could not be included.

The marginal costs of air pollution have been revised in ASEK 7.0 (Swedish Transport Administration, 2020). The marginal costs are presented in Table D.3.7, Table D.3.8 and Table D.3.9 in terms of Euro-cent per vehicle-kilometer.

Table D.3.7: Marginal costs of air pollution in 2017. Euro-cent/vehicle-kilometer. 2019 terms.

From Table 11.3 in ASEK 7.0 (Swedish Transport Administration, 2020).

Vehicle	Coutryside	Urban areas	Average all transport environments
Car. all fuels	0.010	3.693	1.298
Car gasoline	0.003	3.493	1.198
Car diesel	0.020	3.893	1.298
Light truck (<3.5 ton) all fuels	0.020	4.891	1.697
Truck without trailer (LBU)	0.050	6.587	2.096
Truck with trailer (LBS)	0.050	6.587	1.397

In Table D.3.8 and Table D.3.9 the marginal costs of emissions from road transport in 2040 are presented in 2019 terms. There are two different future scenarios, where prognosis A is based on already decided policy with the same fuel mix as today, while prognosis B is based on cars being 70% fossil fuel free, using biofuels and an increase in electric vehicles (Swedish Transport Administration, 2020).

Table D.3.8 shows the future marginal costs for different fuels and vehicle types and regional attributes (countryside/urban areas).

Table D.3.8: Prognosis for marginal costs of emissions from road transport in 2040. Euro-cent/vehicle-kilometer, 2019 terms.

From Table 11.4 in ASEK 7.0 (Swedish Transport Administration, 2020).

	Prognosis A			Prognosis B		
Vehicle	Coutryside	Urban areas	Average	Coutryside	Urban areas	Average
Car. all fuels	0.001	4.933	1.677	0.001	4.835	1.677
Car gasoline	0.001	4.933	1.677	0.001	4.933	1.677
Car diesel	0.004	5.032	1.677	0.004	5.032	1.677
Light truck (<3.5 ton) all fuels	0.004	4.933	1.677	0.002	4.835	1.677
Truck without trailer (LBU)	0.006	5.131	1.677	0.004	5.032	1.579
Truck with trailer (LBS)	0.011	5.328	1.085	0.009	5.229	1.085

Table D.3.9 shows the marginal costs differentiated over truck types.

Table D.3.9: Prognosis for marginal costs of emissions from road transport in 2040. Average for all transport environments. Euro-cent/vehicle-kilometer, 2019 terms.

From Table 11.5 in ASEK 7.0 (Swedish Transport Administration, 2020)**.**

Vehicle	Prognosis A	Prognosis B
Light truck. < 3.5 tonnes	1.697	1.697
Heavy truck 3.5 – 16 tonnes	1.597	1.597
Heavy truck 16 – 24 tonnes	1.597	1.597
Heavy truck 25 – 40 tonnes	0.998	0.998
Heavy truck 25 – 60 tonnes	1.098	1.098

Marginal costs from train traffic are presented in Table D.3.10 below.

Table D.3.10: Marginal costs for air emissions from train traffic. Euro-cent/liter diesel, 2019 terms.

From Table 11.7 and Table 11.8 in ASEK 7.0 (Swedish Transport Administration, 2020)**.**

	Countryside (only regional impacts)		Urban areas (local and regional impacts)		Average	
	2017	2040	2017	2040	2017	2040
Motor carriage unregulated	1.597	2.269	84.739	118.107		
Motor carriage stage IIIA	0.699	0.987	55.295	77.061		
Motor carriage stage IIIB/V	0.399	0.592	7.286	10.163		
Locomotive unregulated	1.497	2.072	134.444	187.471		
Locomotive stage IIIA	0.399	0.592	52.400	73.114		
Locomotive stage IIIB	0.200	0.296	6.687	9.374		
Locomotive stage V	0.200	0.296	4.092	5.723		
Motor carriage in average					5.190	1.381
Locomotive in average					6.987	0.789

D.3.3 Carbon dioxide

The values of carbon dioxide and CO_2 equivalents were updated according to ASEK 7.0 in Hammes (2020).

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