Institute of Transport Economics
Norwegian Centre for Transport Research

Summary

The external costs of transport

Marginal damage cost estimates for passenger and freight transport in Norway

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As groundwork for the National Transport Plan 2022-2033, the Norwegian transport agencies commissioned the Institute of Transport Economics, Sintef Ocean and the Swedish National Road and Transport Research Institute to estimate marginal damage costs of road, rail, and maritime transports. This report emphasises costs due to air pollution, accidents, noise, congestion, accidental spills and infrastructure wear, and comprises damage costs of the marginal vehicle-kilometer for a wide range of vehicles used in passenger and freight transports. This report documents how the damage costs are estimated and presents the main results.

Context

It is well-known that transport activities cause harm and inconveniences to the society at large, which we refer to as "damage costs". They may for example come in the form of sleep deprivation, detriment to human health and loss of recreation opportunities. We will consistently use "damage costs" instead of "external costs" to avoid ambiguity: That is, while damage costs from transport are taxed in a more or less precise way, implying some level of internalization, we want to account for the overall damages caused and their valuation.

The National Transport Plan (NTP) 2022-2033 aims for a transport system that is safe, promotes value creation and contributes to the transition to a low-emission society and fulfilment of Norwegian emissions reduction targets. Given the magnitude of project appraisals that will be undertaken for the NTP, there is a need for a knowledge update with regards to the social costs of transport. The idea is that better, more up-to-date cost-benefit analysis (CBA) will lead to a Transport Plan with a better project portfolio. This report has been commissioned by the Ministry of Transport and the Norwegian transport agencies; the National Public Roads Authority, the Norwegian Railway Directorate, the Norwegian Coastal Administration, along with the government owned companies Avinor (responsible for airports) and Nye Veier (responsible for some major main roads). Hereafter, we will refer to them as "the transport agencies".

A team consisting of researchers from the Institute of Transport Economics (TØI), Sintef Ocean and the Swedish National Road and Transport Research Institute (VTI) has been commissioned to estimate marginal damage costs stemming from transport by road, rail and sea. It has resulted in an analysis of damage costs (in some instances, approximated by avoidance costs) stemming from:

- Greenhouse gas emissions
- Local air pollution
- Accidents
- Noise

- Congestion
- Accidental spills
- Infrastructure cost (wear and tear)

Internal and external damage costs

The basic textbook description of external costs in the transport sector is the situation where the transport user only cares about his or her own costs and benefits, and ignores the costs that his or her transport activites impose on others. Consequently, the user costs are lower than the society's total costs of transport; i.e., the difference between the user costs and the society's costs of transport is due to the damage costs. When the user fails to take into account the damage costs, they are typically referred to as *external* costs. Because the users face a cost that is lower than the overall societal costs, the amount of transport consumed will be higher than what is economically optimal. This is an example of a market failure.

There are many possible measures to correct market failures. A well-known instrument is the Pigouvian tax. In the transport sector, such a tax could be designed so that the transport user at all times faces a tax that is proportional to the marginal damage costs he or she is imposing. In this case, the damage costs are *internalised*.

To assign one instrument per environmental problem would be the basic environmental economics textbook description of a first-best approach for dealing with environmental problems. In reality, transport users today face a combination of measures, ranging from parking restrictions to fuel taxes and tolls. Many of these instruments are implemented for fiscal considerations, and some are designed to correct market failures in the transport market. Only a few of the instruments used purposefully seek to internalise the damage costs.

In the case of road transport, a *road price* differentiated according to real damage costs (which depend on vehicle type, driving style and time and place of the trips) would, from a point of view of economic efficency, be the best form of pricing of negative externalities in the transport sector. This means using geographical positioning systems to map where and when trips take place, so that environmental taxes can be adjusted to give the correct incentives at any place and time. This report can be seen as an input to the design of such taxes, in addition to providing parameters for CBA.

Main results

This report is mainly a documentation of the methods used and main results. The project has focused on detailed decompositions of damage costs according to geographical areas (large urban areas, small urban areas, rural areas), time of day (peak hours, off-peak hours, daily average) and a wide range of vehicle types. For accidents and emissions we also provide trend projections. Because of this, key deliverables of this project are large Excel-files containing detailed results that have been handed over to the transport agencies.

Concerning road transport, we distinguish between the damage costs for an average 24-hour period and the damage caused during peak and off-peak periods. The following three tables summarise the main marginal damage cost estimates for road transport for the average 24-hour period.

Table S1: Marginal damage costs for heavy vehicles (NOK per km).

Vehicle weight	Area	CO_2	Local emission	Noise	Con-gestion	Accident	Infra-structure	SUM
<=7,5t	Rural	0,17	0,05	0,24	0,00	0,55	0,00	1,01
<=7,5t	Small urban area (Pop. 15 000 - 100 000)	0,16	0,39	1,63	0,21	0,55	0,00	2,94
<=7,5t	Large urban area (Pop. >100 000 innb.)	0,16	2,68	2,39	1,48	0,55	0,00	7,26
>7,5-14t	Rural	0,24	0,06	0,24	0,00	0,55	0,03	1,12
>7,5-14t	Small urban area (Pop. 15 000 - 100 000)	0,24	0,47	1,63	0,21	0,55	0,03	3,13
>7,5-14t	Large urban area (Pop. >100 000 innb.)	0,24	3,05	2,39	1,48	0,55	0,03	7,75
>14-20t	Rural	0,29	0,06	0,24	0,00	0,55	0,09	1,23
>14-20t	Small urban area (Pop. 15 000 - 100 000)	0,31	0,53	1,63	0,21	0,55	0,09	3,32
>14-20t	Large urban area (Pop. >100 000 innb.)	0,31	3,30	2,39	1,48	0,55	0,09	8,12
>20-28t	Rural	0,39	0,07	0,24	0,00	0,55	0,07	1,32
>20-28t	Small urban area (Pop. 15 000 - 100 000)	0,42	0,56	1,63	0,21	0,55	0,07	3,44
>20-28t	Large urban area (Pop. >100 000 innb.)	0,42	3,46	2,39	1,48	0,55	0,07	8,37
>28-40t	Rural	0,46	0,07	0,24	0,00	0,37	0,03	1,17
>28-40t	Small urban area (Pop. 15 000 - 100 000)	0,50	0,54	1,63	0,21	0,37	0,03	3,28
>28-40t	Large urban area (Pop. >100 000 innb.)	0,50	3,36	2,39	1,48	0,37	0,03	8,12
>40-50t	Rural	0,50	0,07	0,24	0,00	0,40	0,15	1,35
>40-50t	Small urban area (Pop. 15 000 - 100 000)	0,54	0,56	1,63	0,21	0,40	0,15	3,49
>40-50t	Large urban area (Pop. >100 000 innb.)	0,54	3,43	2,39	1,48	0,40	0,15	8,39
>50-60t	Rural	0,60	0,10	0,24	0,00	0,40	0,23	1,57
>50-60t	Small urban area (Pop. 15 000 - 100 000)	0,66	0,69	1,63	0,21	0,40	0,23	3,81
>50-60t	Large urban area (Pop. >100 000 innb.)	0,66	4,06	2,39	1,48	0,40	0,23	9,22
Gasoline, all types	Rural	0,24	0,11	0,24	0,00	0,55	0,03	1,17
Gasoline, all types	Small urban area (Pop. 15 000 - 100 000)	0,25	0,57	1,63	0,21	0,55	0,03	3,23
Gasoline, all types	Large urban area (Pop. >100 000 innb.)	0,25	3,38	2,39	1,48	0,55	0,03	8,08
El or hydrogen	Rural	0,00	0,00	0,24	0,00	0,55	0,03	0,82
El or hydrogen	Small urban area (Pop. 15 000 - 100 000)	0,00	0,18	1,63	0,21	0,55	0,03	2,60
El or hydrogen	Large urban area (Pop. >100 000 innb.)	0,00	1,63	2,39	1,48	0,55	0,03	6,08

Table S2: Marginal damage costs for passenger vehicles (NOK per km).

Energy	Area	CO_2	Local emission	Noise	Congestion	Accident	Infra-structure	SUM
Diesel	Rural	0,06	0,01	0,04	0,00	0,12	0,03	0,26
Diesel	Small urban area (Pop. 15 000 - 100 000)	0,07	0,09	0,30	0,21	0,12	0,03	0,82
Diesel	Large urban area (Pop. >100 000 innb.)	0,07	0,53	0,33	1,48	0,12	0,03	2,56
Hybrid	Rural	0,04	0,00	0,04	0,00	0,12	0,03	0,23
Hybrid	Small urban area (Pop. 15 000 - 100 000)	0,05	0,03	0,30	0,21	0,12	0,03	0,73
Hybrid	Large urban area (Pop. >100 000 innb.)	0,05	0,24	0,33	1,48	0,12	0,03	2,25
LPG	Rural	0,06	0,00	0,04	0,00	0,12	0,03	0,25
LPG	Small urban area (Pop. 15 000 - 100 000)	0,07	0,03	0,30	0,21	0,12	0,03	0,76
LPG	Large urban area (Pop. >100 000 innb.)	0,07	0,26	0,33	1,48	0,12	0,03	2,29
Gasoline	Rural	0,07	0,00	0,04	0,00	0,12	0,03	0,26
Gasoline	Small urban area (Pop. 15 000 - 100 000)	0,08	0,04	0,30	0,21	0,12	0,03	0,78
Gasoline	Large urban area (Pop. >100 000 innb.)	0,08	0,30	0,33	1,48	0,12	0,03	2,34
All ICE	Rural	0,07	0,01	0,04	0,00	0,12	0,03	0,26
All ICE	Small urban area (Pop. 15 000 - 100 000)	0,08	0,07	0,30	0,21	0,12	0,03	0,80
All ICE	Large urban area (Pop. >100 000 innb.)	0,08	0,44	0,33	1,48	0,12	0,03	2,48
Zero em. veh.	Rural	0,00	0,00	0,04	0,00	0,12	0,03	0,19
Zero em. veh.	Small urban area (Pop. 15 000 - 100 000)	0,00	0,03	0,30	0,21	0,12	0,03	0,68
Zero em. veh.	Large urban area (Pop. >100 000 innb.)	0,00	0,24	0,33	1,48	0,12	0,03	2,19

Table S3: Marginal damage costs for light commercial vehicles (LCE), motor cycles (MC) and buses (NOK per km).

Vehicle type	Fuel	Area	CO_2	Local emission	Noise	Congestion	Accident	Infra-structure	SUM
LCE	D	Rural	0,09	0,02	0,04	0,00	0,05	0,03	0,23
LCE	D	Small urban area (Pop. 15 000 - 100 000)	0,10	0,09	0,30	0,21	0,05	0,03	0,78
LCE	D	Large urban area (Pop. >100 000 innb.)	0,10	0,59	0,33	1,48	0,05	0,03	2,58
LCE	P	Rural	0,08	0,01	0,04	0,00	0,05	0,03	0,21
LCE	P	Small urban area (Pop. 15 000 - 100 000)	0,09	0,06	0,30	0,21	0,05	0,03	0,74
LCE	P	Large urban area (Pop. >100 000 innb.)	0,09	0,41	0,33	1,48	0,05	0,03	2,39
MC	P	Rural	0,04	0,00	0,04	0,00	0,43	0,00	0,51
MC	P	Small urban area (Pop. 15 000 - 100 000)	0,04	0,01	0,30	0,21	0,43	0,00	0,99
MC	P	Large urban area (Pop. >100 000 innb.)	0,04	0,07	0,33	1,48	0,43	0,00	2,36
Tour bus	D	Rural	0,40	0,07	0,24	0,00	0,36	0,03	1,09
Tour bus	D	Small urban area (Pop. 15 000 - 100 000)	0,47	0,62	1,63	0,21	0,36	0,03	3,31
Tour bus	D	Large urban area (Pop. >100 000 innb.)	0,47	3,69	2,39	1,48	0,36	0,03	8,42
City bus	CNG	Small urban area (Pop. 15 000 - 100 000)	0,53	0,46	1,63	0,21	0,36	0,03	3,22
City bys	CNG	Large urban area (Pop. >100 000 innb.)	0,53	2,91	2,39	1,48	0,36	0,03	7,69
City bus	D	Small urban area (Pop. 15 000 - 100 000)	0,44	0,52	1,63	0,21	0,36	0,03	3,18
City bus	D	Large urban area (Pop. >100 000 innb.)	0,44	3,21	2,39	1,48	0,36	0,03	7,90

We distinguish between marginal damage costs caused by rail transport during the day and at night, because of substainal differences in railway noise costs. The following table summarizes the main findings for rail transport taking place during the day. Note that marginal infrastructure costs vary substantially across regions. The table presents a weighted average of the estimated costs per region.

Table S4: Marginal damage costs of railway transport (NOK per km).

Train type	Energy	Area	CO_2	Local emission	Noise	Accident	Maintenance	Reinvestment	SUM
Freight train	Diesel	Rural	10,48	7,37	2,63	1,36	18,08	32,74	72,64
Freight train	Diesel	Small urban area (Pop. 15 000 - 100 000)	10,48	35,63	8,81	1,36	18,08	32,74	107,09
Freight train	Diesel	Large urban area (Pop. >100 000 innb.)	10,48	199,81	9,23	1,36	18,08	32,74	271,69
Freight train	Electricity	Rural	0,00	0,00	2,63	1,36	18,08	32,74	54,80
Freight train	Electricity	Small urban area (Pop. 15 000 - 100 000)	0,00	0,00	8,81	1,36	18,08	32,74	60,98
Freight train	Electricity	Large urban area (Pop. >100 000 innb.)	0,00	0,00	9,23	1,36	18,08	32,74	61,40
Passenger train	Diesel	Rural	1,95	1,37	0,45	1,04	18,08	32,74	55,63
Passenger train	Diesel	Small urban area (Pop. 15 000 - 100 000)	1,95	6,63	1,21	1,04	18,08	32,74	61,64
Passenger train	Diesel	Large urban area (Pop. >100 000 innb.)	1,95	37,15	1,20	1,04	18,08	32,74	92,16
Passenger train	Electricity	Rural	0,00	0,00	0,45	1,04	18,08	32,74	52,31
Passenger train	Electricity	Small urban area (Pop. 15 000 - 100 000)	0,00	0,00	1,21	1,04	18,08	32,74	53,07
Passenger train	Electricity	Large urban area (Pop. >100 000 innb.)	0,00	0,00	1,20	1,04	18,08	32,74	53,06

Because the marginal damage costs of maritime transport are reported for a wide range of ship types and according to deadweight (DWT) and length overall, we present the sum of the individual damage costs to avoid extensive tables. The sum comprises marginal damage costs due to emissions to air, fatalities and injuries and accidental oil spills, where the air pollution cost estimates vary according to type of area.

Table S5: Marginal damage costs of maritime transports in rural areas (NOK per km).

Ship type/DWT	<1'	1'-5'	5'-15'	15'-25'	25'-35'	35'-45'	45'-55'	>55'
Breakbulk	19,6	46,7	91,8	166,2	220,4	211,7	226,5	268,3
Container Lo/Lo		69,4	131,7	205,0	236,8	286,8	332,6	389,5
Cruise	80,8	258,9	520,2					
Express boat	24,8	173,1						
RoPax	42,1	92,9						
Product tanker	58,2	92,9	139,1	212,1	261,7	242,6	258,5	358,0
Reefer	35,5	82,8	142,5	224,4				
Coastal route	175,1	208,9						
LPG/LNG	63,8	87,7	159,1	230,5	240,1	275,9	305,3	405,3
Offshore ship	62,5	149,1	147,8					
Ro-Ro ship	26,7	89,8	146,0	229,6	278,2			
Crude tanker	57,5	98,3	153,3	301,9	256,7	311,5	255,2	390,7
Dry bulk	35,5	74,1	102,0	158,1	199,9	205,1	211,6	249,6
Ferry	261,7	283,4	447,3					

Table S6: Marginal damage costs of maritime transports in small urban areas (NOK per km).

Ship type/DWT	<1'	1'-5'	5'-15'	15'-25'	25'-35'	35'-45'	45'-55'	>55'
Breakbulk	34,1	82,5	165,3	352,1	499,6	449,9	510,6	606,7
Container Lo/Lo		132,8	257,9	456,8	538,9	649,3	767,7	911,5
Cruise	145,8	609,3	1289,4					
Express boat	51,4	353,2						
RoPax	80,3	186,9						
Product tanker	88,9	145,1	241,4	430,7	554,1	500,5	539,2	774,5
Reefer	57,9	141,7	255,5	505,0				
Coastal route	399,5	490,9						
LPG/LNG	120,3	152,6	326,6	502,3	529,7	628,3	695,8	942,3
Offshore ship	115,8	305,6	305,2					
Ro-Ro ship	49,8	188,9	308,2	515,6	621,3			
Crude tanker	80,2	157,7	247,8	636,4	502,8	603,0	491,4	828,7
Dry bulk	55,8	122,5	185,7	350,3	444,1	454,1	465,6	575,1
Ferry	578,1	674,3	1090,1					

Table S7: Marginal damage costs of maritime transports in large urban areas (NOK per km).

Ship type/DWT	<1'	1'-5'	5'-15'	15'-25'	25'-35'	35'-45'	45'-55'	>55'
Breakbulk	104,7	256,2	520,0	1241,1	1826,1	1581,3	1851,7	2205,8
Container Lo/Lo		439,5	865,5	1645,0	1964,8	2360,4	2820,9	3375,4
Cruise	461,9	2267,4	4888,1					
Express boat	181,1	1221,3						
RoPax	266,1	641,3						
Product tanker	238,7	397,6	733,8	1467,1	1934,6	1718,3	1865,8	2745,8
Reefer	166,4	427,0	804,0	1831,0				
Coastal route	1463,2	1824,4						
LPG/LNG	394,0	466,9	1128,2	1791,5	1901,1	2295,0	2544,5	3461,6
Offshore ship	375,4	1068,2	1071,1					
Ro-Ro ship	162,1	663,8	1079,0	1877,2	2255,2			
Crude tanker	191,1	445,1	703,2	2213,9	1667,5	1989,0	1607,8	2883,3
Dry bulk	154,8	356,9	589,9	1257,7	1597,3	1631,3	1666,7	2101,8
Ferry	2112,8	2546,1	4161,2					

Table S8: Samletabell skadekostnader, kr per skipkm, etter skipstype og dwt-kategori, Spredt bebyggelse (2019-kr).

Ship type/DWT	<1'	1'-5'	5'-15'	15'-25'	25'-35'	35'-45'	45'-55'	>55'
Breakbulk	19,6	46,7	91,8	166,2	220,4	211,7	226,5	268,3
Container Lo/Lo		69,4	131,7	205,0	236,8	286,8	332,6	389,5
Cruise	80,8	258,9	520,2					
Hurtigbåt	24,8	173,1						
Innenlands_ropax	42,1	92,9						
Kjemi/Produkt tanker	58,2	92,9	139,1	212,1	261,7	242,6	258,5	358,0
Kjøle/fryseskip	35,5	82,8	142,5	224,4				
Kystrute	175,1	208,9						
LPG/LNG	63,8	87,7	159,1	230,5	240,1	275,9	305,3	405,3
Offshore skip	62,5	149,1	147,8					
Ro-Ro cargo	26,7	89,8	146,0	229,6	278,2			
Tanker	57,5	98,3	153,3	301,9	256,7	311,5	255,2	390,7
Tørrbulk	35,5	74,1	102,0	158,1	199,9	205,1	211,6	249,6
Utenlandsferge	261,7	283,4	447,3					

Table S9: Samletabell skadekostnader, kr per skipkm, etter skipstype og dwt-kategori, Tettsted (15 000 - 100 000 innb.) (2019-kr).

Ship type/DWT	<1'	1'-5'	5'-15'	15'-25'	25'-35'	35'-45'	45'-55'	>55'
Breakbulk	34,1	82,5	165,3	352,1	499,6	449,9	510,6	606,7
Container Lo/Lo		132,8	257,9	456,8	538,9	649,3	767,7	911,5
Cruise	145,8	609,3	1289,4					
Hurtigbåt	51,4	353,2						
Innenlands_ropax	80,3	186,9						
Kjemi/Produkt tanker	88,9	145,1	241,4	430,7	554,1	500,5	539,2	774,5
Kjøle/fryseskip	57,9	141,7	255,5	505,0				
Kystrute	399,5	490,9						
LPG/LNG	120,3	152,6	326,6	502,3	529,7	628,3	695,8	942,3
Offshore skip	115,8	305,6	305,2					
Ro-Ro cargo	49,8	188,9	308,2	515,6	621,3			
Tanker	80,2	157,7	247,8	636,4	502,8	603,0	491,4	828,7
Tørrbulk	55,8	122,5	185,7	350,3	444,1	454,1	465,6	575,1
Utenlandsferge	578,1	674,3	1090,1					

Table S10: Samletabell skadekostnader, kr per skipkm, etter skipstype og dwt-kategori, Tettsted (> 100 000 innb.) (2019-kr).

Ship type/DWT	<1'	1'-5'	5'-15'	15'-25'	25'-35'	35'-45'	45'-55'	>55'
Breakbulk	104,7	256,2	520,0	1241,1	1826,1	1581,3	1851,7	2205,8
Container Lo/Lo		439,5	865,5	1645,0	1964,8	2360,4	2820,9	3375,4
Cruise	461,9	2267,4	4888,1					
Hurtigbåt	181,1	1221,3						
Innenlands_ropax	266,1	641,3						
Kjemi/Produkt tanker	238,7	397,6	733,8	1467,1	1934,6	1718,3	1865,8	2745,8
Kjøle/fryseskip	166,4	427,0	804,0	1831,0				
Kystrute	1463,2	1824,4						
LPG/LNG	394,0	466,9	1128,2	1791,5	1901,1	2295,0	2544,5	3461,6
Offshore skip	375,4	1068,2	1071,1					
Ro-Ro cargo	162,1	663,8	1079,0	1877,2	2255,2			
Tanker	191,1	445,1	703,2	2213,9	1667,5	1989,0	1607,8	2883,3
Tørrbulk	154,8	356,9	589,9	1257,7	1597,3	1631,3	1666,7	2101,8
Utenlandsferge	2112,8	2546,1	4161,2					

The report is mainly a documentation of a large number of parameter estimates for damage costs stemming from transport that can be used in Norwegian CBAs. The report can be used as a reference book for the application of these estimates.

We want to underline that many of these cost estimates can be considered fairly uncertain. There is uncertainty in all parts of the calculation, from the magnitude of physical damages, to how they should be valued. We recommend that CBAs do sensitivity tests with both higher and lower values for damage costs, in order to ensure that conclusions and recommendations are robust against this uncertainty.