



Tuomo Rantala

# Life Cycle Analysis of Mälkiä Canal Bridge



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Liikennevirasto

Helsinki 2010

*Kannen kuvat: Liikenneviraston kuva-arkisto*

Verkkojulkaisu pdf ([www.liikennevirasto.fi](http://www.liikennevirasto.fi))

ISBN            978-952-255-545-8

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## Abstract

The research was conducted to calculate the life cycle costs and environmental impacts of the new Mälkiä Canal Bridge over the Saimaa Canal. This research has also been a part of testing the tools for the Nordic Bridge Life Cycle Optimisation (ETSI) project. The ETSI project consists of bridge life cycle cost methodology (LCC), life cycle assessment of bridges (LCA) as well as bridge aesthetics and cultural effects evaluation. The tested tools are produced for LCC and LCA calculations in the ETSI project.

Mälkiä Canal Bridge is a continuous composite girder bridge which main bearing structures are steel girders and reinforced concrete deck. It consists of two motorway bridges, A and B, on the Main Road 6 near the city of Lappeenranta and will be completed in year 2010. There are seven spans in the bridge and the total length is 318.8 meters. The life cycle analysis focuses on bridge A. The bridge A has two lanes and one lane for bicycle and pedestrian traffic. The bridge is designed to withstand 100 years. Life cycle calculations were performed on bridge A.

Life cycle costs were calculated by three different interest rates, 2 %, 3 % and 4 %. In calculations were investment cost, maintenance costs, repair costs, traffic disturbances and demolition cost taken into account throughout the bridge life cycle. Present values were calculated at commissioning year. Present value is for 2 % 10 182 000 €, for 3 % 9 254 000 € and for 4 % 8 698 000€. Investment cost is same with every interest rate, 7 380 000 €.

Life cycle assessment calculations were performed using material quantities and transport distances. Moreover; repair, maintenance and demolition actions were taken into account throughout the bridge life cycle. Environmental impacts are divided as follows, total quantity and per bridge square meter: Abiotic depletion 43 045 kg Sb-equivalent (9.4 kg/m<sup>2</sup>), acidification 38 101 kg SO<sub>2</sub>-equivalent (8.3 kg/m<sup>2</sup>), eutrophication 7 931 kg PO<sub>4</sub>-equivalent (1.7 kg/m<sup>2</sup>), global warming potential 4 992 703 kg CO<sub>2</sub>-equivalent (1088 kg/m<sup>2</sup>), ozone layer depletion 0.7 kg CFC-11-equivalent (0.15 g/m<sup>2</sup>) and photochemical ozone creation 1 520 kg C<sub>2</sub>H<sub>4</sub>-equivalent (0.33 kg/m<sup>2</sup>).

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# 1 Introduction

This research was conducted to calculate Mälkiä Canal Bridge life cycle costs and environmental impacts. This research has also been a part of testing tools for ETSI project. ETSI project stands for Bridge Life Cycle Optimisation which consists of bridge life cycle cost methodology (LCC), life cycle assessment of bridges (LCA) as well as bridge aesthetics and cultural effects evaluation.[1] The tested tools are produced for LCC and LCA calculations in ETSI project.

LCC calculations were conducted by using the WebLCC tool. WebLCC is a web based program that can be utilized to calculate the discounted prices. It also takes in account traffic disturbances.

LCA was performed by utilizing BridgeLCA tool. BridgeLCA is Excel based tool which takes advantage of MATLAB in its calculations. Environmental impact calculations are performed by calculating emission of materials manufacturing, construction, transportation, repair and maintenance. Used values for emissions are from EcoInvent database [1].

Mälkiä Canal Bridge A itself is a remarkable bridge and it is one of the biggest bridge under construction in Finland at year 2009. The new Mälkiä Canal Bridge allows the old Saimaa Canal to be renovated and once again opened.

The life cycle thinking is coming increasingly important in civil and bridge engineering. The importance of life cycle assessment and overall life cycle costs are a part of "lifelong adapted bridge" thinking. Lifelong sustainable bridges are going to be adapted in bridge designing in order to obtain more cost-efficient bridges. This research was conducted as a part of Nordic ETSI project and was made by Tuomo Rantala from Finnish Transport Agency. The guidance of this research was conducted by Lic.Sc. Timo Tirkkonen and M.Sc. Minna Torkkeli from Finnish Transport Agency.

## 2 Mälkiä Canal bridge

### 2.1 General

Mälkiä Canal Bridge is located near Lappeenranta and will be completed in year 2010. Mälkiä Canal Bridge is a part of the Trunk Road 6 improvement as a four-lane road in Kärki-Muukko part. Mälkiä Canal Bridge consists of two bridges. This research was conducted over the Bridge A which has two lanes and one lane for bicycle and pedestrian traffic separated by concrete-glass noise cover. The bridge is a continuous composite bridge. The main bearing structures are continuous steel girders and concrete slab. Colour of the girders and bracings is dark red. New bridge in Mälkiä allows the old Saimaa Canal to be renovated and once again opened.

Total length of the bridge is 318.8 meters and the length of superstructure is 309.1 meters. Effective width is 14.4 meters. Span lengths are 40 + 62 + 42 + 42 + 42 + 42 + 38 meters and the biggest span is 62 meters. The bridge is direct (obliquity 0 gon) and it is designed for Lk-I, Ek-I and Tiel-99 loads. Bridge's design age is 100 years.

### 2.2 Life Cycle Cost inputs

Life cycle cost calculations were performed utilizing different interest rates. Chosen values were 2 %, 3 % and 4 %. The 2 % interest rate is recommended to be used for bridges with longer than 40 years life cycle periods [2]. Average daily traffic at the bridge site is 14 442 vehicles and amount of heavy traffic is 13.5 % [Appendix 1]. Traffic growth was estimated to be max 1 % due to increasing traffic between Russian along the new improved of Trunk Road 6. Especially the amount of heavy traffic will rise because more Russian directing lorry traffic is steered to drive Trunk Road 6 from Trunk Road 7 to reduce growing queue at the border.

The maximum speed limit of the Trunk Road 6 is 120 km/h and reduced speed during maintenance and repair actions was assumed to 50 km/h. Hourly traffic cost for cars is 16.09 €/h and for lorries 56.02 €/h [3]. Total investment cost is 7 380 000 €. Investment cost was calculated using the bill of quantities and unit prices. Moreover, the contractor was interviewed to evaluate the cost estimate.

The maintenance costs consist mainly of

- continuous inspections, 1 year interval
- general inspections, 5 years interval
- special inspections (repair designing included) circa 30-35 year intervals, before major repair designing,
- bridge cleaning, every year
- cleaning of dewatering system, every year
- maintenance of railing, includes repainting the railing in every 25 years
- maintenance of bearings, bridge seat, expansion joints, every year, and
- repainting the steel girders and stiffeners, 25 years interval

All of the predicted maintenance actions are not included in calculations due to uncertainty of prediction, and some due to low effect on costs.



The repair costs consist mainly of

- edge beam repairs, 25 years interval,
- bearings and hinges changes, 35 years interval,
- expansion joints reparations, 35 years interval,
- reparations of railing (both parapet, railing and noise cover, parapets and railings were predicted to be shift to new ones), 50 years interval,
- water proofing, 35 years interval and
- surfacing (asphalt layer renewal), 10 years interval

Like in maintenance prediction, all the repair actions were not included. Concrete quality and road salting was taken into account performing the WebLCC calculations. Weighting factor for concrete quality was 1.10 and for road salting 1.00.

In traffic disturbance calculations, the disturb length is the whole length where the speed is reduced. The disturbance length was approximated to be 1 km due bridge maintenance and repair actions.

## 2.3 Life Cycle Assessment inputs

The Life Cycle Assessment (LCA) calculations were executed utilizing the BridgeLCA program. LCA calculations were performed by calculating environmental impacts from building materials, material transportations, constructing and the transportation of workers. Moreover, the life cycle reparations and maintenance impacts were included to estimate the whole life cycle impacts.

All the material transportations to the work site are done by trucks. Transport distances to main materials are:

- concrete 9 km,
- construction steel 400 km,
- stainless steel 400 km
- reinforcement steel 300 km
- lower grade steel 400 km
- sawn timber for formworks and trestles 20 km and
- equipment and glass 300 km

Total amount of concrete during the whole life cycle is approximately 4 185 m<sup>3</sup>. The biggest amounts are used in foundations (925 m<sup>3</sup>), concrete piles (85 m<sup>3</sup>), abutments and piers (942 m<sup>3</sup>) as well as slab and deck (1 667 m<sup>3</sup>). In life cycle reparations are ca. 520 m<sup>3</sup> of concrete also used. Reinforcing steel is used totally ca. 537 tons. It divides in main parts as 79 tons in foundations, 6.8 tons in piles, 81,7 tons in abutments and piers as well as 370 tons in slab and deck. Sawn timber for formwork and trestles is used totally 10 054 m<sup>2</sup> in the whole life cycle. Utilized value is m<sup>2</sup> because of the used formwork area. It is used for foundations 461 m<sup>2</sup>, abutments and piers 2 100 m<sup>2</sup>, as well as slab and deck 5 123 m<sup>2</sup>.

The total amount of used construction steel is 651 tons. It is used mainly in steel pipe piles (44 tons) as well as main bearing girders and bracing members (602 tons). Stainless steel is mainly used in drainage system (1.5 tons) and in other bridge equipments. The total amount of stainless steel is 1.54 tons. Lower grade steel is used

approximately 56 tons during the life cycle. It is used 28 tons in railing and parapets and it is assumed to be replaced once in the life cycle.

The total amount of excavation on the work site is 118475 m<sup>3</sup>. Rubber is used totally approximately 1 100 kg. It divides for bearing (350 kg) and expansion joints (343 kg). Rest of the rubber is used in life cycle reparations for bearing and expansion joints. Glass is used totally 18 330 m<sup>2</sup>. It is used just for the noise cover in parapet and it assumed to be replaced once in the bridge life cycle.

The area of the pavement is 4 286 m<sup>2</sup>. Consumption layer is renewed every tenth year and every 35<sup>th</sup> year the whole layer is renewed during the replacement of the waterproofing. For waterproofing it is used mastic (1 410 m<sup>2</sup>) in the edge beam borders and asphalt membrane (12 858 m<sup>2</sup>) in the bridge life time. Waterproofing is renewed every 35<sup>th</sup> years.

Zinc coating area in steel girders and braces is 5 487 m<sup>2</sup> and polyurethane painted area is 5 872 m<sup>2</sup>. Repainting is done every 25<sup>th</sup> year. Zinc coated area in parapet and railing is 782 m<sup>2</sup>.

Total amount of used explosives is approximately 140 kg. It is used blasting the bedrock. Approximate amount of burned diesel in building machines on construction site is 360 m<sup>3</sup>.

In the end-of-life (EOL) management concrete is reused as a filling material. Using the facts from previous bridge demolishing, it is assumed that parts of the concrete structures are contaminated. In previous bridge, edge beams were too contaminated to be used as a filling material. Contaminated part of the concrete is calculated to be 300 m<sup>3</sup>. Reinforcing, construction and lower grade steels are recycled at the end of the bridge life. EOL transportation distances are assumed to be the same as in material transportation distances.

The total car transportation distance is approximately 239 000 km. It includes transportation of workers during the bridge life cycle and bridge inspection distances. The total truck transportation distance is approximately 585 000 km. It includes transportations of construction materials and elements and EOL transportations.

## 3 Results

### 3.1 Life Cycle Cost results

Total discounted value of Mälkiä Bridge A in 2 % interest rate is 10 182 000 €, 3 % interest rate 9 254 000 € and in 4 % interest rate 8 698 000 € (Figure 1). Present values are discounted to year "zero"; in the other words commissioning year. The difference between the total sums of 2 and 4 % interest rates is 1 484 000 €. Investment cost is at all rates 7 380 000 €.

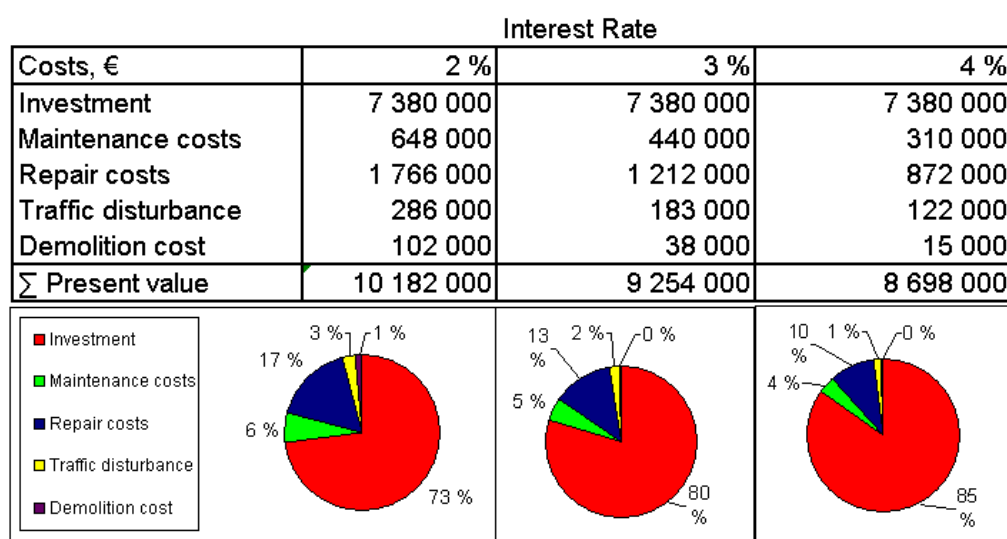


Figure 1: Mälkiä Canal Bridge A, LCC results

### 3.2 Life Cycle Assessment results

Mälkiä Canal Bridge A construction, maintenance, repairing and demolishing consumes Antimony equivalent (Sb-equivalent) 43 045 kg. Antimony stands for equivalent to abiotic depletion. The bridge Sulphur Dioxide equivalent (SO<sub>2</sub>-equivalent) emissions are 38 100 kg in its life time. Sulphur Dioxide is equivalent value for acidification. Photosphate equivalent (PO<sub>4</sub>-equivalent) is produced 7 931 kg. Photosphate is equivalent value for eutrophication. Carbon dioxide equivalent (CO<sub>2</sub>-equivalent) is produced 4 992 703 kg. Carbon dioxide is equivalent value for global warming potential. Trichlorofluoromethane equivalent (CFC-11-equivalent) is produced only 0.7 kg. It is used as an equivalent value for ozone layer depletion. Ethylene equivalent (C<sub>2</sub>H<sub>4</sub>-equivalent) is produced 1 520 kg. Ethylene is equivalent value for photochemical ozone creation.

Main sources of abiotic depletion are construction steel parts manufacturing (23.2 %, 8 150 kg Sb-equivalent), asphalt manufacturing (18.9 %, 9 970 kg Sb-equivalent), diesel burned in building machines (17.4 %, 7 480 kg Sb-equivalent), asphalt membrane manufacturing (16.5 %, 7 120 kg Sb-equivalent) and reinforcing steel bars manufacturing (10.1 %, 4 350 kg Sb-equivalent). Abiotic depletion divides for structural part and operations as follows: (Figure 2) superstructure 31.6 % (13 600 kg Sb-equivalent), operation, repair and maintenance 28.4 % (12 200 kg Sb-equivalent), construction 21.4 % (9 200 kg Sb-equivalent), bridge equipment 10.3 % (4 400 kg

Sb-equivalent), foundation 4.8 % (2 100 kg Sb-equivalent), substructure 2.8 % (1 200 kg Sb-equivalent) and end-of-life operations 0.7 % (300 kg Sb-equivalent).

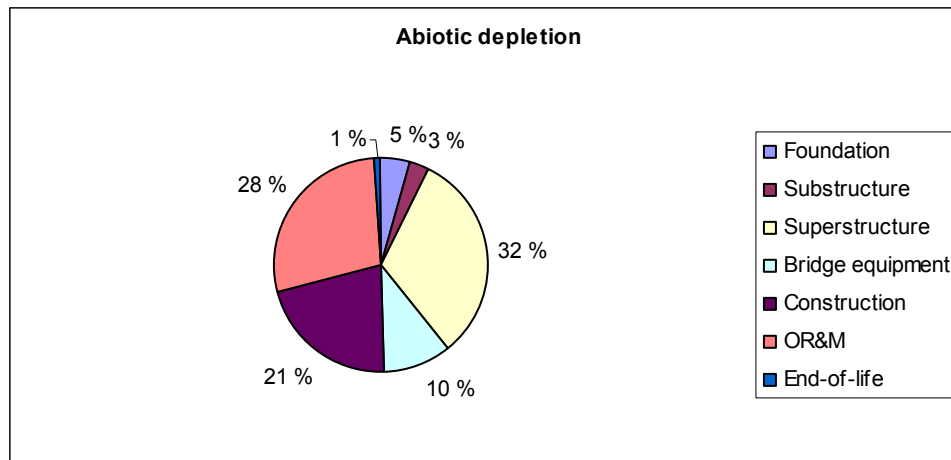


Figure 2: Mälkiä Canal Bridge A, abiotic depletion

Main sources of acidification are excavating and transporting stone and soil (43.0 %, 16 400 kg SO<sub>2</sub>-equivalent), diesel burned in building machines (23.5 %, 8 970 kg SO<sub>2</sub>-equivalent) and construction steel parts manufacturing (12.6 %, 4 790 kg SO<sub>2</sub>-equivalent). Acidification divides for structural parts and operations as follows: (Figure 3) construction 63.9 % (24 300 kg SO<sub>2</sub>-equivalent), superstructure 18.1 % (6 900 kg SO<sub>2</sub>-equivalent), operation, repair and maintenance 6.5 % (2 500 kg SO<sub>2</sub>-equivalent), foundation 6.5 % (2 500 kg SO<sub>2</sub>-equivalent), bridge equipment 2.9 % (1 100 kg SO<sub>2</sub>-equivalent), substructure 1.8 % (700 kg SO<sub>2</sub>-equivalent) and end-of-life operations 0.4 % (100 kg SO<sub>2</sub>-equivalent).

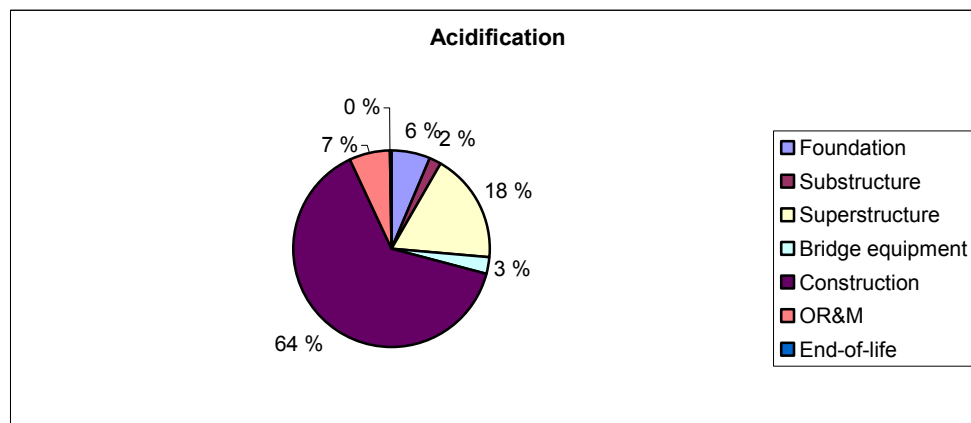


Figure 3: Mälkiä Canal Bridge A, acidification

Main sources of eutrophication are excavating and transporting stone and soil (49.9 %, 3 960 kg PO<sub>4</sub>-equivalent), diesel burned in building machines (24.3 %, 1 930 kg PO<sub>4</sub>-equivalent) and construction steel parts manufacturing (11.0 %, 870 kg PO<sub>4</sub>-equivalent). Eutrophication divides for structural parts and operations as follows: (Figure 4) construction 70.9 % (5 624 kg PO<sub>4</sub>-equivalent), superstructure 15.1 % (1 200 kg PO<sub>4</sub>-equivalent), foundation 6.5 % (500 kg PO<sub>4</sub>-equivalent), operation, repair and maintenance 4.1 % (300 kg PO<sub>4</sub>-equivalent), bridge equipment 1.6 % (100 kg PO<sub>4</sub>-equivalent), substructure 1.4 % (100 kg PO<sub>4</sub>-equivalent) and end-of-life operations 0.3 % (25 kg PO<sub>4</sub>-equivalent).

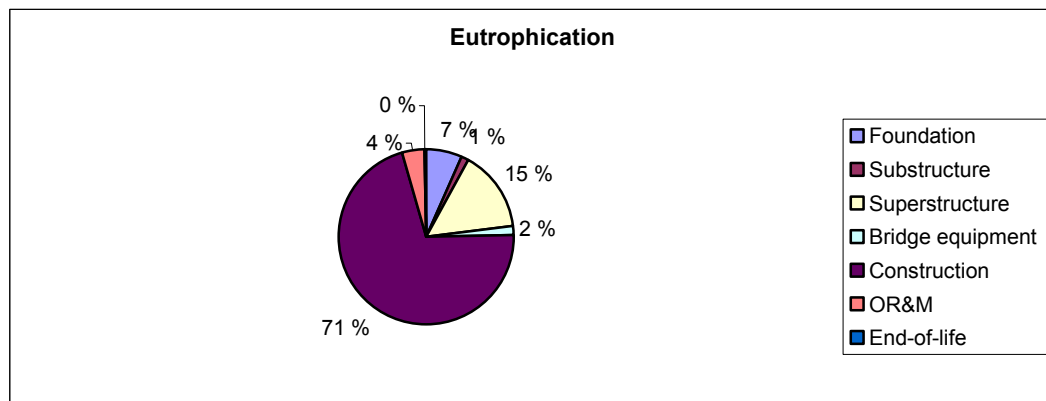


Figure 4: Mälkiä Canal Bridge A, eutrophication

Main sources of global warming potential are construction steel parts manufacturing (23.3 %, 1 162 800 kg CO<sub>2</sub>-equivalent), diesel burned in building machines (21.5 %, 1 136 400 kg CO<sub>2</sub>-equivalent) and concrete manufacturing (21.8 %, 1 090 000 kg CO<sub>2</sub>-equivalent). Global warming potential divides for structural parts and operations as follows: (Figure 5) superstructure 38.4 % (1 917 000 kg CO<sub>2</sub>-equivalent), construction 29.1 % (1 452 000 kg CO<sub>2</sub>-equivalent), operation, repair and maintenance 11.8 % (588 000 kg CO<sub>2</sub>-equivalent), foundation 9.0 % (451 000 kg CO<sub>2</sub>-equivalent), substructure 6.5 % (323 000 kg CO<sub>2</sub>-equivalent), bridge equipment 4.3 % (213 000 kg CO<sub>2</sub>-equivalent) and end-of-life operations 1.0 % (49 000 %).

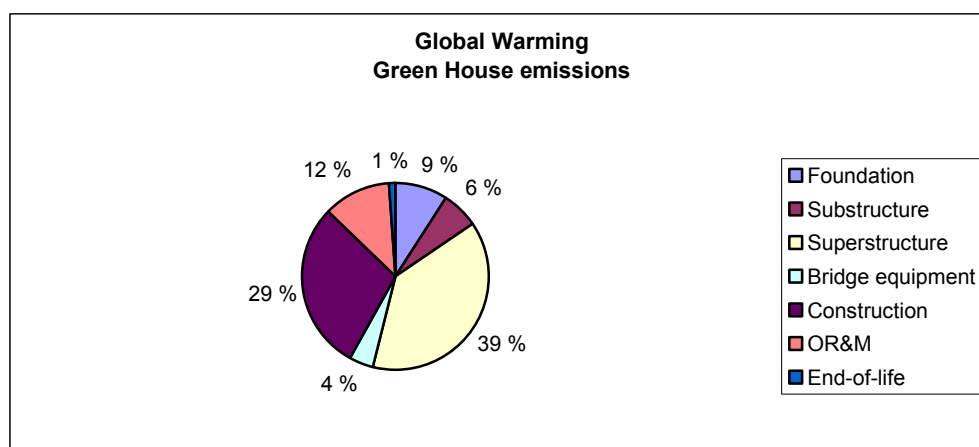


Figure 5: Mälkiä Canal Bridge A, global warming

Main sources of Ozone layer depletion are asphalt manufacturing (35.6 %, 0.24 kg CFC-11-equivalent), diesel burned in building machines (21.5 %, 0.14 kg CFC-11-equivalent) as well as asphalt membrane manufacturing and installation (17.4 %, 0.12 kg CFC-11-equivalent). Ozone layer depletion divides for structural parts and operations as follows: (Figure 6) operation, repair and maintenance 42.0 % (0.28 kg CFC-11-equivalent), construction 26.3 % (0.18 kg CFC-11-equivalent), bridge equipment 13.2 % (0.09 kg CFC-11-equivalent), superstructure 12.8 % (0.09 kg CFC-11-equivalent), foundation 2.7 % (0.02 kg CFC-11-equivalent), substructure 1.9 % (0.01 kg CFC-11-equivalent) and end-of-life operations 1.1 % (0.007 kg CFC-11-equivalent).

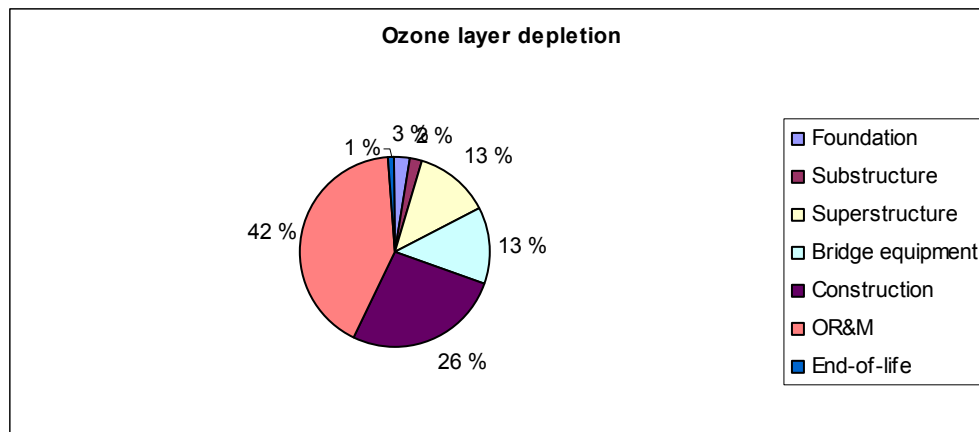


Figure 6: Mälkiä Canal Bridge A, ozone layer depletion

Main sources of photochemical ozone creation are construction steel parts manufacturing (38.3 %, 580 kg C<sub>2</sub>H<sub>4</sub>-equivalent), reinforcing steel bars manufacturing (14.8 %, 220 kg C<sub>2</sub>H<sub>4</sub>-equivalent), diesel burned in building machines (14.3 %, 220 kg C<sub>2</sub>H<sub>4</sub>-equivalent) as well as excavating and transporting stone and soil (10.6 %, 161 kg C<sub>2</sub>H<sub>4</sub>-equivalent). Photochemical ozone creation divides for structural parts and operations as follows: (Figure 7) superstructure 48.5 % (740 kg C<sub>2</sub>H<sub>4</sub>-equivalent), construction 25.3 % (390 kg C<sub>2</sub>H<sub>4</sub>-equivalent), operation, repair and maintenance 10.8 % (160 kg C<sub>2</sub>H<sub>4</sub>-equivalent), foundation 7.0 % (100 kg C<sub>2</sub>H<sub>4</sub>-equivalent), bridge equipment 4.9 % (80 kg C<sub>2</sub>H<sub>4</sub>), substructure 3.2 % (50 kg C<sub>2</sub>H<sub>4</sub>-equivalent) and end-of-life operations 0.3 % (10 kg C<sub>2</sub>H<sub>4</sub>-equivalent).

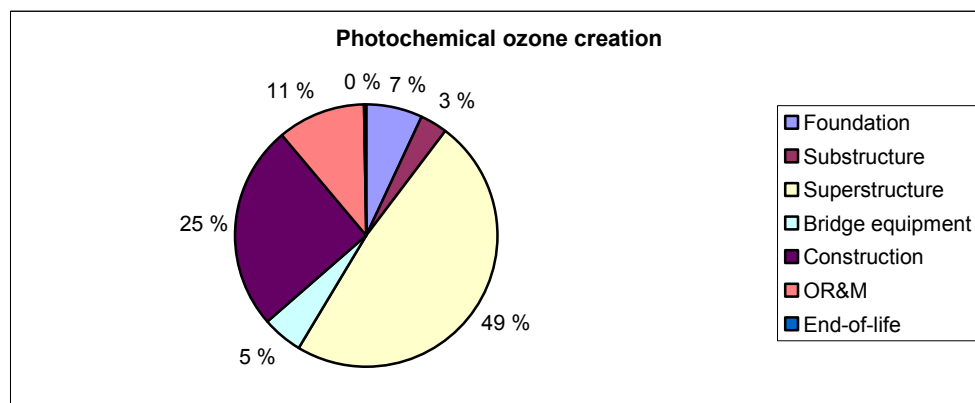


Figure 7: Mälkiä Canal Bridge A, photochemical ozone creation

## 4 Conclusions

In life cycle cost (LCC) calculations, program WebLCC does not take into account of the return value of steel recycling and the benefit of other sold materials. Repair and maintenance costs are too low because the repair and maintenance actions are very hard to predict. Moreover, all the maintenance and repair actions were not taken in account due to difficult prediction and low cost effect. Any accidents and risks were not also taken in account. In WebLCC, traffic disturbance input could have a field where average waiting time could be added to count the cost of traffic disturbance. Traffic disturbance is difficult value to define precise due to difficult repair and maintenance action predictions. It is though important to minimize the disadvantage of traffic and in many cases repair and maintenance expenses are lower if the repair time is shorter. WebLCC program is although a handy tool to calculate the discounted LCC values.

Life cycle assessment (LCA) calculations had same type of problems than LCC. BridgeLCA program utilization is though easy to approach. However, it is difficult to predict repair and maintenance action intervals and repair quantities. Environmental impacts are not precise enough due to used international standard values for manufacturing and construction impacts. National values for environmental impacts should be determined in order to calculate actual environmental impacts. During the calculations, it was noticed that the BridgeLCA does not include yet all the important material or different material strengths, such as different concretes. Moreover, it was considered that the program does not take in account asphalt recycling in manufacturing.

A very precise comparison between different bridge types could not be made in the LCC and LCA calculations. Calculations require quite precise data to input to the programs in order to get sufficient data to compare. The bill of quantities and cost estimate is at least required to perform the calculations. Moreover, prediction of structural parts life spans is needed as well as repair and maintenance unit prices. Environmental impacts monetary value is also hard to define without precise unit prices for environmental emissions. Transportation of materials and workers is although difficult to predict.

Environmental impacts have been calculated little so far for bridges. That is why; it is difficult to compare Mälkiä Canal Bridge A to other bridge type solutions. Only sketch design was made of other bridge types and rough cost estimates for Mälkiä Canal Bridge. These sketches were not precise enough to evaluate the life cycle costs and assessments because no structural design of these bridge types were made.

## 5 Summary

Mälkiä Canal Bridge A is a large continuous steel girder composite bridge located in Lappeenranta. The new bridge allows the old Saimaa Canal to be renovated and once again opened. Its environmental impact is still difficult to compare to other bridges because there is not enough life cycle assessment data yet. Besides, national values for environmental impacts are not yet determined to get more precise data. Precise monetary values for environmental impacts must be also determined in order to get the best optimized bridge solutions. Environmental impact costs could also have own weighting factors in order to make those significant.

Programs developed for ETSI project are easy to use but the input data gathering proved to be arduous. Comparing different solutions precisely is quite difficult if structural design is not readymade. Moreover, estimating of different structural solutions must be made to be able to define reliably life spans of different type of structural solutions. For example, concrete cover thickness, protection, maintenance and strength effects to structural life spans must be determined.

BridgeLCA and WebLCC could be handy tools for designers to find out the optimum solutions for bridges. It is important to remember that minimum investment cost is not always the most economical or the most environmentally friendly solution. Life cycle optimisation is a difficult task and without proper tools it is very difficult to compare the results. ETSI Project is a new innovative project to develop these bridge life cycle optimisation tools.



## 6 List of sources

[1] ETSI Project (Stage 2), Bridge Life Cycle Optimisation. Ed. Lauri Salokangas TKK-R-BE3- 140 s.

[2] Siltojen elinkaarikustannukset. Tiehallinto 2009, 27 s.

[3] Tieliikenteen ajokustannusten laskenta. Tiehallinto 2005, 37 s.



# Average daily traffic in measuring point 523 Lappeenranta



LAM  
Uusimaa

## Vuoden keskimääräinen vuorokausiliikenne (KVL)

Mittauspiste: 523 LAPPEENRANTA

Vuosi: 2008

Ajoneuvoluokka: Kaikki ajoneuvoluokat

Suunta: S1 = Imatra, S2 = Lappeenranta

10.7.2009

Sivu 1 (1)

	2008
	246 / 386
11 HA-PA	12 182
12 KAIP	396
13 Linja-autot	78
14 KAPP	475
15 KATP	994
16 HA + PK	280
17 HA + AV	37
Kevyet	12 499
Raskaat	1 943
Yhteensä	14 442



## Mälkiä Canal Bridge A environmental impacts

Material	Sb	SO <sub>2</sub>	PO <sub>4</sub>	CO <sub>2</sub>	CFC-11	C <sub>2</sub> H <sub>4</sub>
Concrete	2369,4	1777,2	281,0	1089975,3	0,0359	65,6
Steel construction	9974,3	4789,9	871,3	1162800,4	0,0464	582,2
Stainless Steel	59,8	41,3	4,8	8009,8	0,0003	2,6
Reinforcing Steel	4347,7	1896,4	336,1	512536,4	0,0302	224,4
Steel , lower grade	575,3	240,2	46,2	67397,2	0,0032	33,9
Sawn Timber, Formwork	96,5	80,4	19,0	13443,9	0,0015	3,9
Stone	1091,2	16395,3	3958,4	214755,0	0,0167	161,4
Rubber	42,7	11,7	0,9	2914,7	0,0007	0,6
Glass	104,7	154,3	11,8	9813,2	0,0015	5,2
Asphalt	8151,9	933,5	134,5	219961,4	0,2392	78,2
Mastic	13,5	3,2	0,3	316,2	0,0003	0,2
Asphalt Membrane	7117,4	1784,3	185,7	323018,5	0,1166	98,8
Epoxy Paint	88,1	58,0	7,5	8342,2	0,0010	2,2
Polyurethane paint	180,7	102,8	23,4	15105,0	0,0031	5,0
Zinc Coating	299,0	371,6	28,1	40847,9	0,0063	14,0
Blasting	1,6	37,2	9,0	360,0	0,0000	0,3
Diesel	7478,0	8966,1	1930,5	1136428,5	0,1444	216,7
Car Transportation	302,4	136,7	22,5	48111,5	0,0067	15,0
Truck Transportation	745,7	314,9	59,0	117786,7	0,0176	9,6
Concrete deposit	5,2	5,8	1,2	779,2	0,0001	0,2

Percentage	Sb	SO <sub>2</sub>	PO <sub>4</sub>	CO <sub>2</sub>	CFC-11	C <sub>2</sub> H <sub>4</sub>
Concrete	5,50 %	4,66 %	3,54 %	21,83 %	5,35 %	4,32 %
Steel construction	23,17%	12,57 %	10,98 %	23,29 %	6,91 %	38,30 %
Stainless Steel	0,14 %	0,11 %	0,06 %	0,16 %	0,05 %	0,17 %
Reinforcing Steel	10,10%	4,98 %	4,24 %	10,27 %	4,49 %	14,76 %
Steel , lower grade	1,34 %	0,63 %	0,58 %	1,35 %	0,47 %	2,23 %
Sawn Timber, Formwork	0,22 %	0,21 %	0,24 %	0,27 %	0,23 %	0,26 %
Stone	2,54 %	43,03 %	49,91 %	4,30 %	2,49 %	10,62 %
Rubber	0,10 %	0,03 %	0,01 %	0,06 %	0,11 %	0,04 %
Glass	0,24 %	0,40 %	0,15 %	0,20 %	0,22 %	0,34 %
Asphalt	18,94%	2,45 %	1,70 %	4,41 %	35,62 %	5,14 %
Mastic	0,03 %	0,01 %	0,00 %	0,01 %	0,04 %	0,01 %
Asphalt Membrane	16,53%	4,68 %	2,34 %	6,47 %	17,36 %	6,50 %
Epoxy Paint	0,20 %	0,15 %	0,09 %	0,17 %	0,15 %	0,14 %
Polyurethane paint	0,42 %	0,27 %	0,30 %	0,30 %	0,46 %	0,33 %
Zinc Coating	0,69 %	0,98 %	0,35 %	0,82 %	0,93 %	0,92 %
Blasting	0,00 %	0,10 %	0,11 %	0,01 %	0,00 %	0,02 %
Diesel	17,37%	23,53 %	24,34 %	22,76 %	21,50 %	14,25 %
Car Transportation	0,70 %	0,36 %	0,28 %	0,96 %	1,00 %	0,99 %
Truck Transportation	1,73 %	0,83 %	0,74 %	2,36 %	2,63 %	0,63 %
Concrete deposit	0,01 %	0,02 %	0,02 %	0,02 %	0,01 %	0,01 %

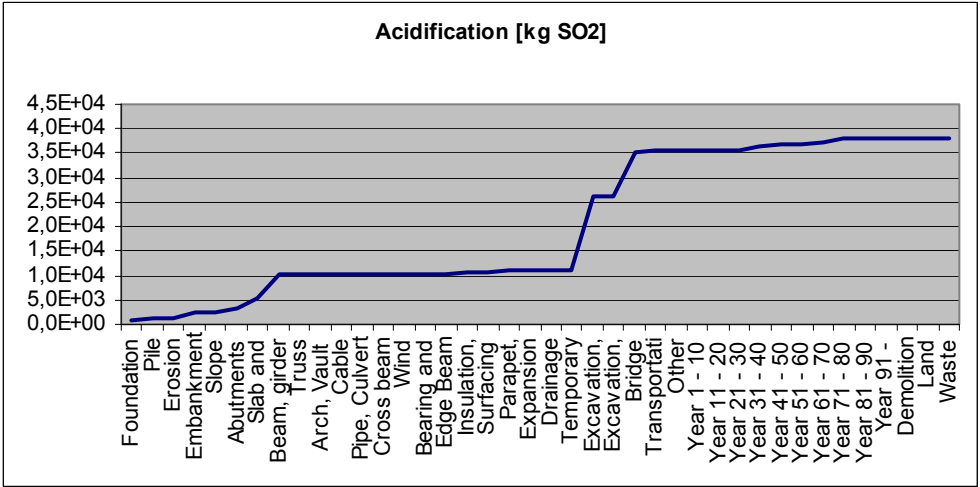
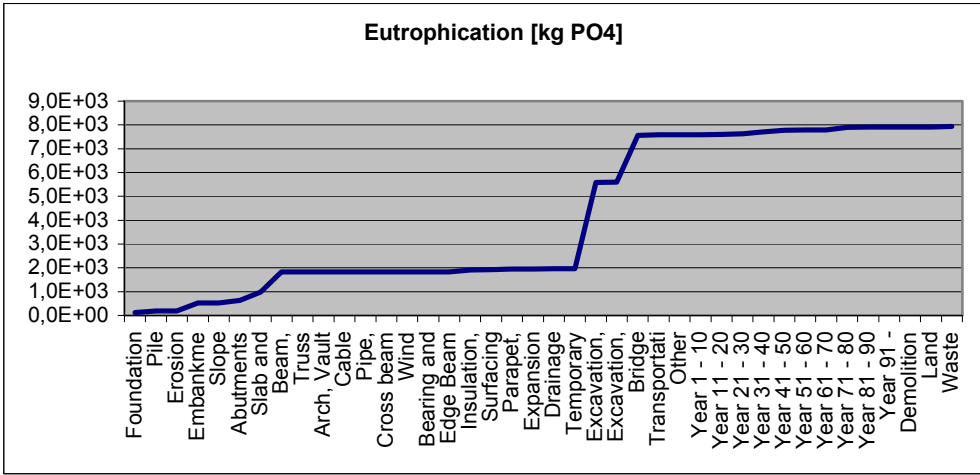
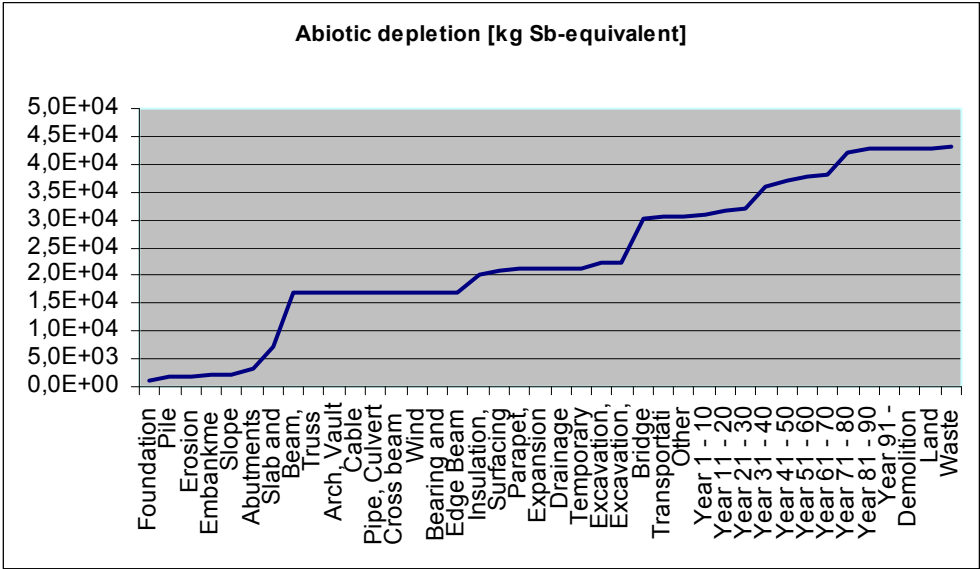
## Mälkiä Canal Bridge A environmental impacts per structural parts and operations

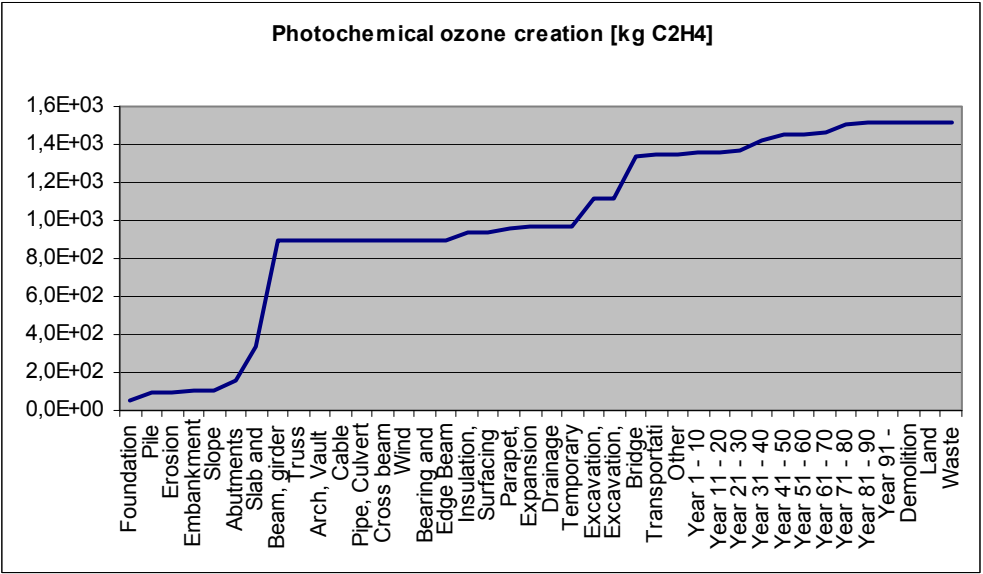
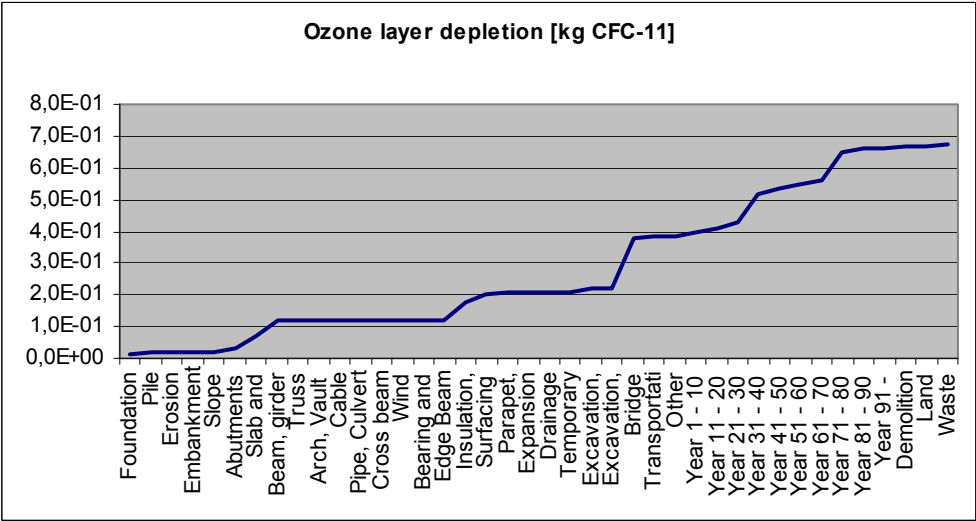
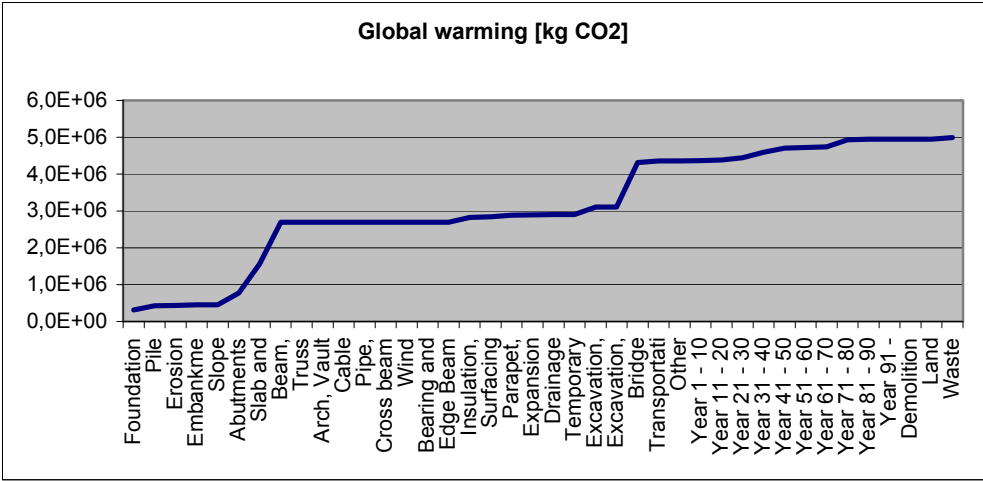
Absolute kg	Sb	SO <sub>2</sub>	PO <sub>4</sub>	CO <sub>2</sub>	CFC-11	C <sub>2</sub> H <sub>4</sub>
<b>Foundation</b>	2 060	2 460	518	450 907	0,0184	106
<b>Substructure</b>	1 194	688	114	323 184	0,0127	49
<b>Superstructure</b>	13 608	6 896	1 197	1 917 419	0,0860	737
<b>Bridge equipment</b>	4 439	1 092	130	212 630	0,0885	75
<b>Construction</b>	9 228	24 345	5 624	1 451 614	0,1769	385
<b>OR&amp;M</b>	12 207	2 484	322	587 935	0,2819	164
<b>End-of-life</b>	310	135	25	49 013	0,0073	5
Percentage	Sb	SO <sub>2</sub>	PO <sub>4</sub>	CO <sub>2</sub>	CFC-11	C <sub>2</sub> H <sub>4</sub>
<b>Foundation</b>	4,8 %	6,5 %	6,5 %	9,0 %	2,7 %	7,0 %
<b>Substructure</b>	2,8 %	1,8 %	1,4 %	6,5 %	1,9 %	3,2 %
<b>Superstructure</b>	31,6 %	18,1 %	15,1 %	38,4 %	12,8 %	48,5 %
<b>Bridge equipment</b>	10,3 %	2,9 %	1,6 %	4,3 %	13,2 %	4,9 %
<b>Construction</b>	21,4 %	63,9 %	70,9 %	29,1 %	26,3 %	25,3 %
<b>OR&amp;M</b>	28,4 %	6,5 %	4,1 %	11,8 %	42,0 %	10,8 %
<b>End-of-life</b>	0,7 %	0,4 %	0,3 %	1,0 %	1,1 %	0,3 %

## Mälkiä Canal Bridge A total environmental impacts and impacts per bridge square meter

	<b>ADP</b>	<b>AP</b>	<b>EP</b>	<b>GWP</b>	<b>ODP</b>	<b>POCP</b>
Total emissions	Sb	SO <sub>2</sub>	PO <sub>4</sub>	CO <sub>2</sub>	CFC-11	C <sub>2</sub> H <sub>4</sub>
kg	43045,0	38100,7	7931,4	4992703,1	0,7	1520,2
Emissions/Bridge area	Sb	SO <sub>2</sub>	PO <sub>4</sub>	CO <sub>2</sub>	CFC-11	C <sub>2</sub> H <sub>4</sub>
kg/m2	9,376524	8,29951	1,7277	1087,5643	0,000146	0,331142

# Mälkiä Canal Bridge A total environmental impact diagrams







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ISBN 978-952-255-545-8

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