Towards Sustainable Construction:
Life Cycle Assessment of Railway Bridges

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Outlines:

- An Excel-Based LCA tool for Railway Bridge
- Two case studies of the Banafjäl Bridge

Based on three Journal Papers:

•Thiebault Vincent, Du Guangli, Karoumi Raid, Design of railway bridges considering LCA, accepted by the journal of ICE Bridge Engineering.

•Du Guangli, Karoumi Raid, LCA of Railway Bridge: a comparison between two superstructure designs, published by the Journal of Structure and Infrastructure Engineering.

•Du Guangli, Karoumi Raid, Life cycle assessment of bridges: a literature survey and critical issues, submitted to the Journal of Structure and Infrastructure Engineering.

A challenge from the environmental issues

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The main environmental issues from the construction

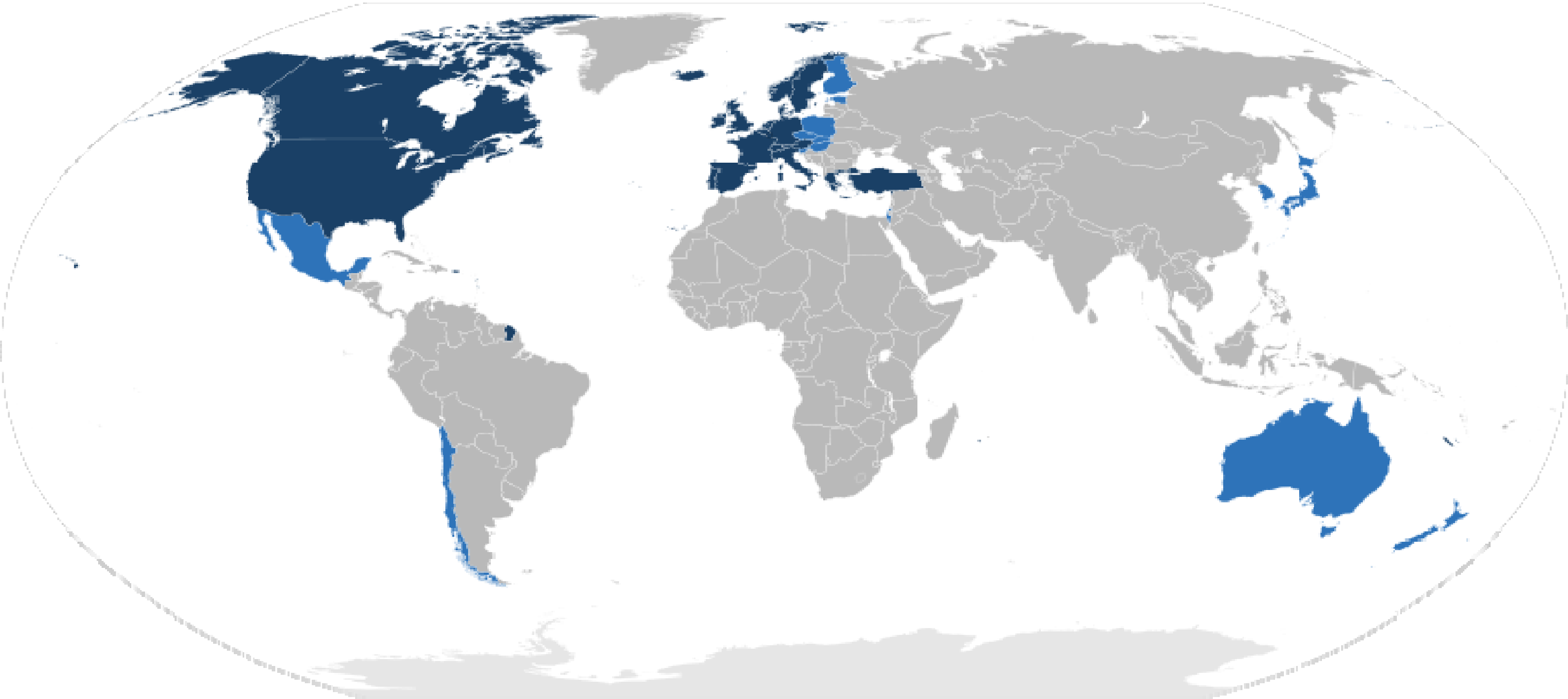


Figure 1: Environmental allocation due to construction in *OECD countries*

(Building and climate change, 2007)

25%-40% Energy Use	30% Raw material Use	30%-40% Global warming emissions	30%-40% Solid waste generation

Strategy for a sustainable transport from European White Paper 2011

- By 2030, 30% of road freight over 300km should shift to other modes, such as rail or waterborne transport
- By 2050, should be more than 50%

Life Cycle Assessment (LCA) of Railway Bridges

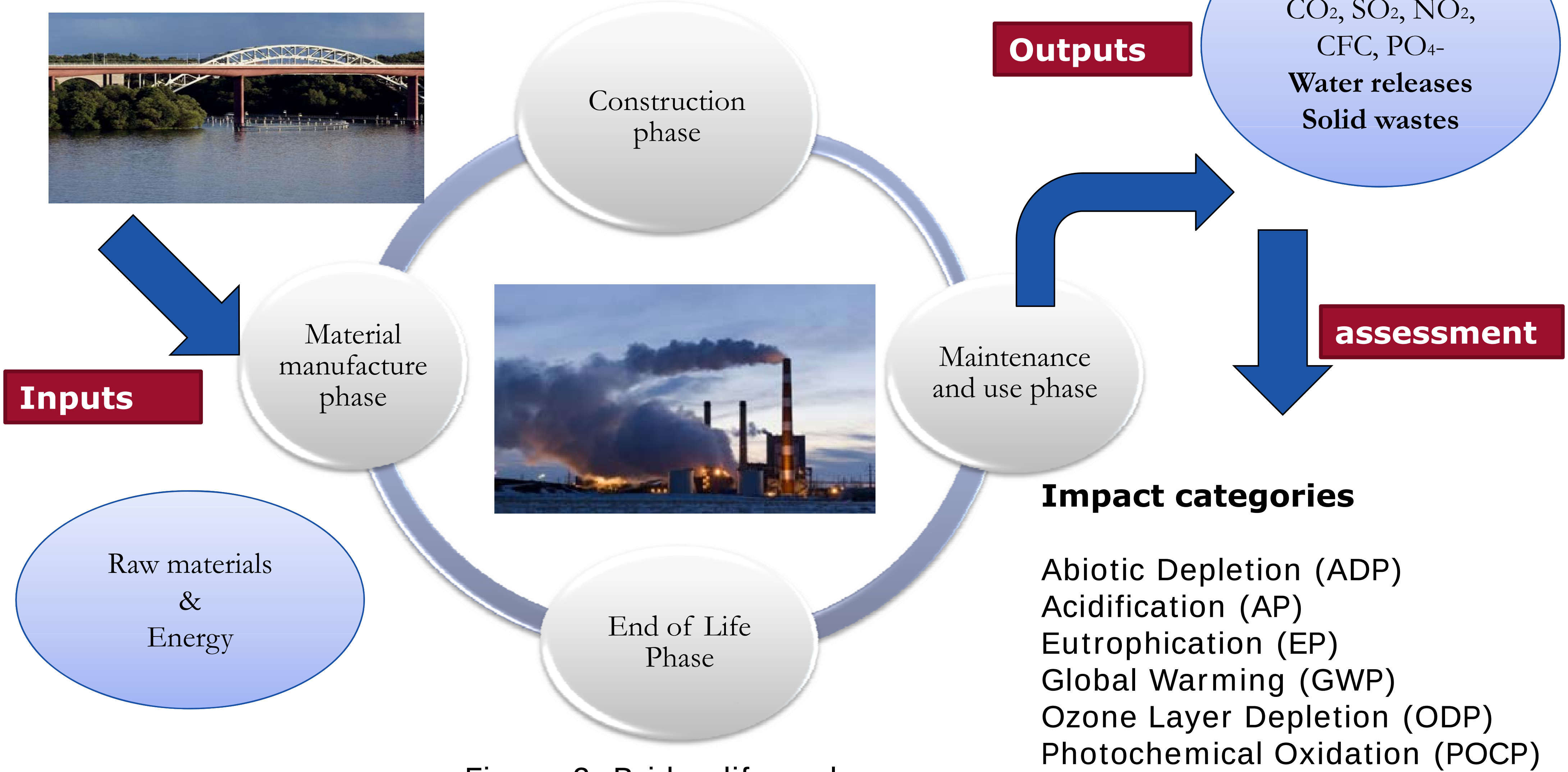


Figure 2 Bridge life cycle

Main Aim:

estigate the key operational issues

ablish a generalized framework

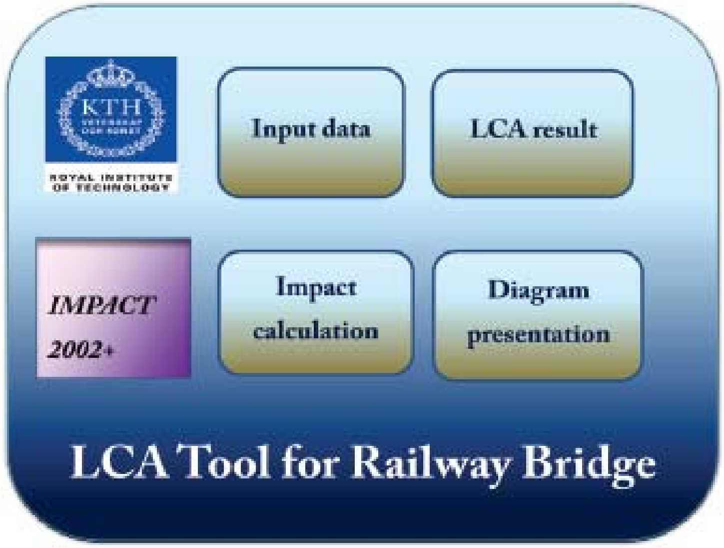
plement LCA into practical studies

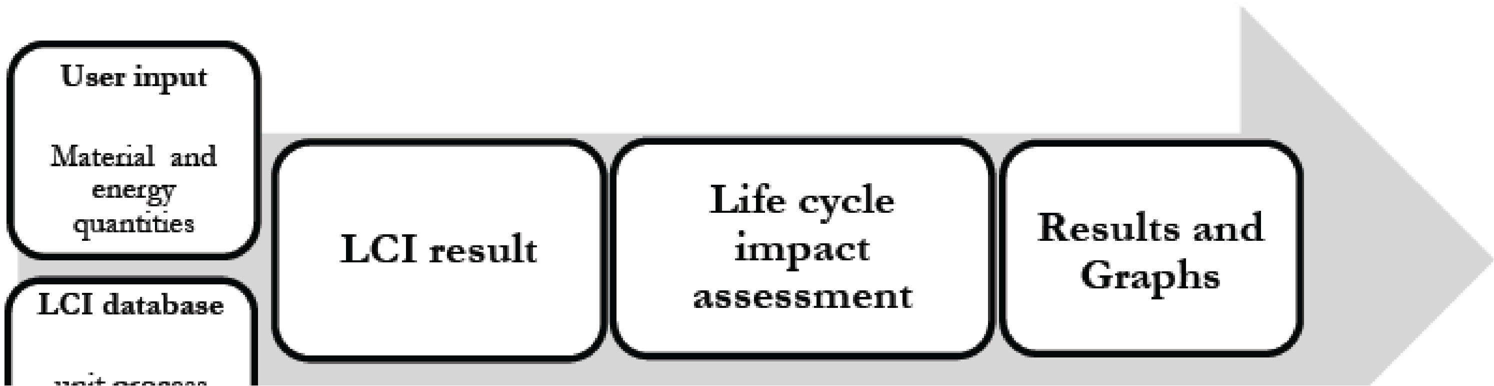
ect

a new design criterion

imize the bridge life cycle scenarios

The Excel-based LCA tool



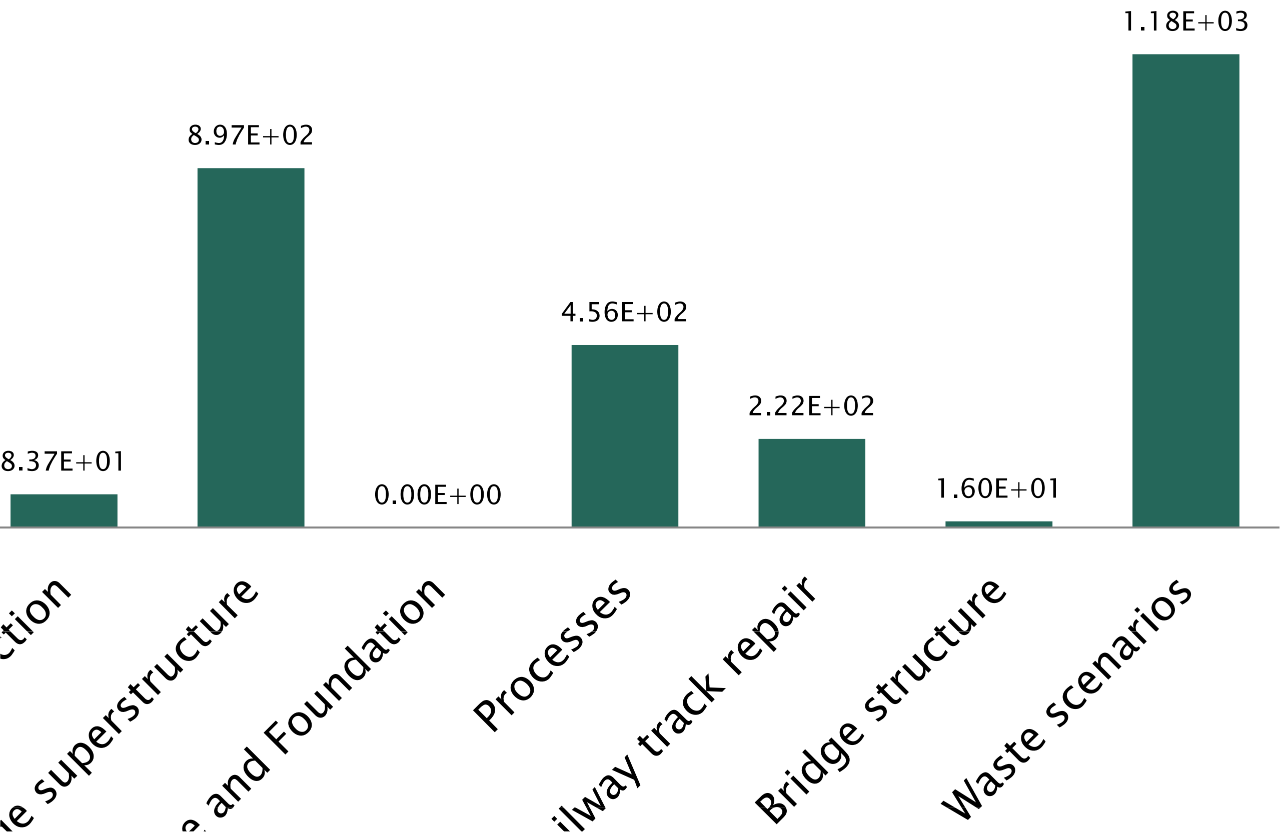


The Excel-based LCA tool

Table 1: The life cycle covered by the tool

<table>
<tr><td>Material manufacture phase</td><td>Structural components
Railway track system
Superstructure
Substructure
→
Material and Energy
Concrete, steel, painting, timber, rubber, aggregate, electricity, reinforcement, fuel</td></tr>
<tr><td>Construction phase</td><td>Energy consumption of construction machines</td></tr>
<tr><td>Maintenance phase</td><td>Maintenance schedules with related traffic disturbances and transportation
<table>
<tr><th>Structural</th><th>Maintenance activity</th><th>Ballast track</th><th>Fixed-slab track</th></tr>
<tr><td></td><td>Track direction</td><td>0.5 year</td><td>no repair</td></tr>
<tr><td></td><td>Rail replacement</td><td>25 years</td><td>25 years</td></tr>
<tr><td></td><td>Sleeper renewal</td><td>50 years</td><td>no repair</td></tr>
<tr><td></td><td>Fastener renewal</td><td>25 years</td><td>25 years</td></tr>
<tr><td></td><td>Rubber pad renewal</td><td>25 years</td><td>25 years</td></tr>
<tr><td></td><td>Ballast renewal</td><td>20 years</td><td>no repair</td></tr>
<tr><td>Superstructure</td><td>Repainting</td><td>30 years</td><td>30 years</td></tr>
</table>
</td></tr>
</table>

The Excel-based LCA tool



ammonia,

benzene,

carbon monoxide,

nitrogen oxides,

sulphur oxides,

hydrogen chloride,

hydrogen fluoride,

hydrogen sulphide,

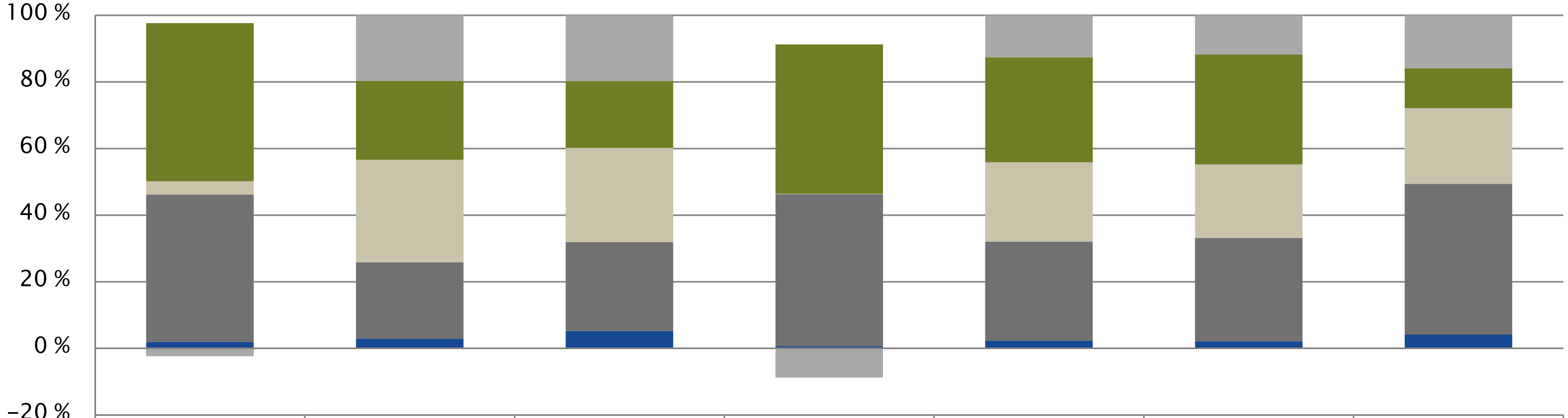
carbon dioxide,

dinitrogen onoxide,

methane, NMVOC

The Excel-based LCA tool

Characterization result

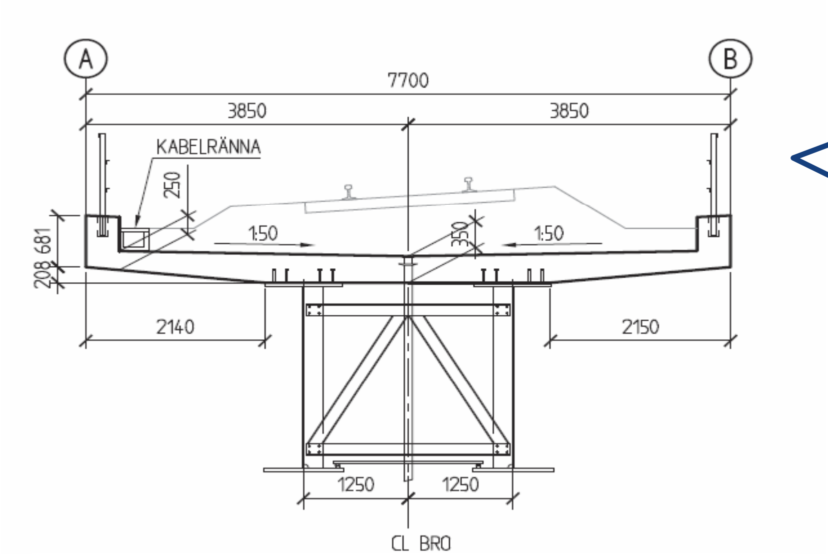


	Total Human toxicity	Respiratory effects on human health	Photochemical oxidation	Aquatic ecotoxicity (E,1) and Terrestrial ecotoxicity (E,2)	Terrestrial acidification and nutrification (E,3)	Aquatic acidification (E,4)	Global warming (C,1)
enarios	-4.42E-03	3.96E-01	5.34E-02	-1.17E+00	1.41E+01	1.81E+00	3.20E+02
	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	9.04E-02	4.78E-01	5.39E-02	5.99E+00	3.53E+01	5.06E+00	2.40E+02
on	1.53E-07	7.23E-06	1.98E-06	5.30E-06	3.10E-04	3.94E-05	7.38E-03
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Case study 1:
LCA of the Banafjäl Bridge

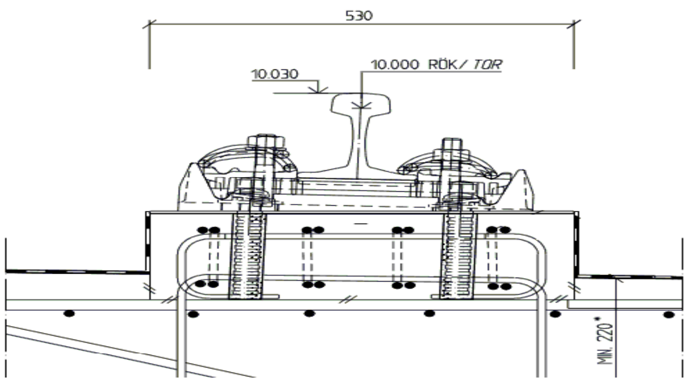
- Steel-concrete composite bridge
- Single ballasted railway track
- 42 m span, 7.2 m width
- Located on the Bothnia Line, Sweden

Two design alternatives:

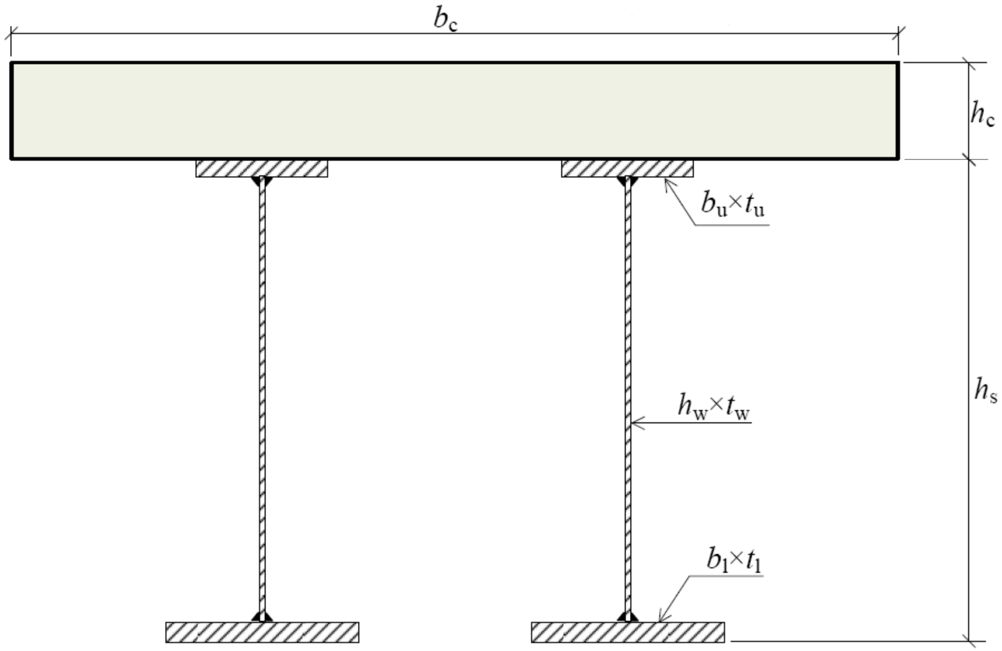


Original design:
Ballast track

Redesign



Alternative design:
Fixed slab track



-Δ15% Steel Quantities

	t_u (mm)	b_u (mm)	h_w (mm)	t_w (mm)	t_1 (mm)	b_1 (mm)
t design option	48	900	2397	17	55	950

Study scope of the Banafjäl Bridge

Life cycle of the Banafjäl Bridge				
Ballast track design option	Fixed slab design option			
Material manufacture stage	Railway track	Bridge deck	Steel I-girder	
	Ballast Fastening clips Sleeper Rails Rubber pad	Concrete slab Reinforcement	Cross stringers Steel I-girder Painting	
Construction stage	Energy consumption in the construction machine			Tansportation process
Maintenance stage	Railway track	Steel I-girder	Traffic disturbance	
	Ballast Fastening clips Sleeper Rails	Painting	Truck transportation Private cars	

Result

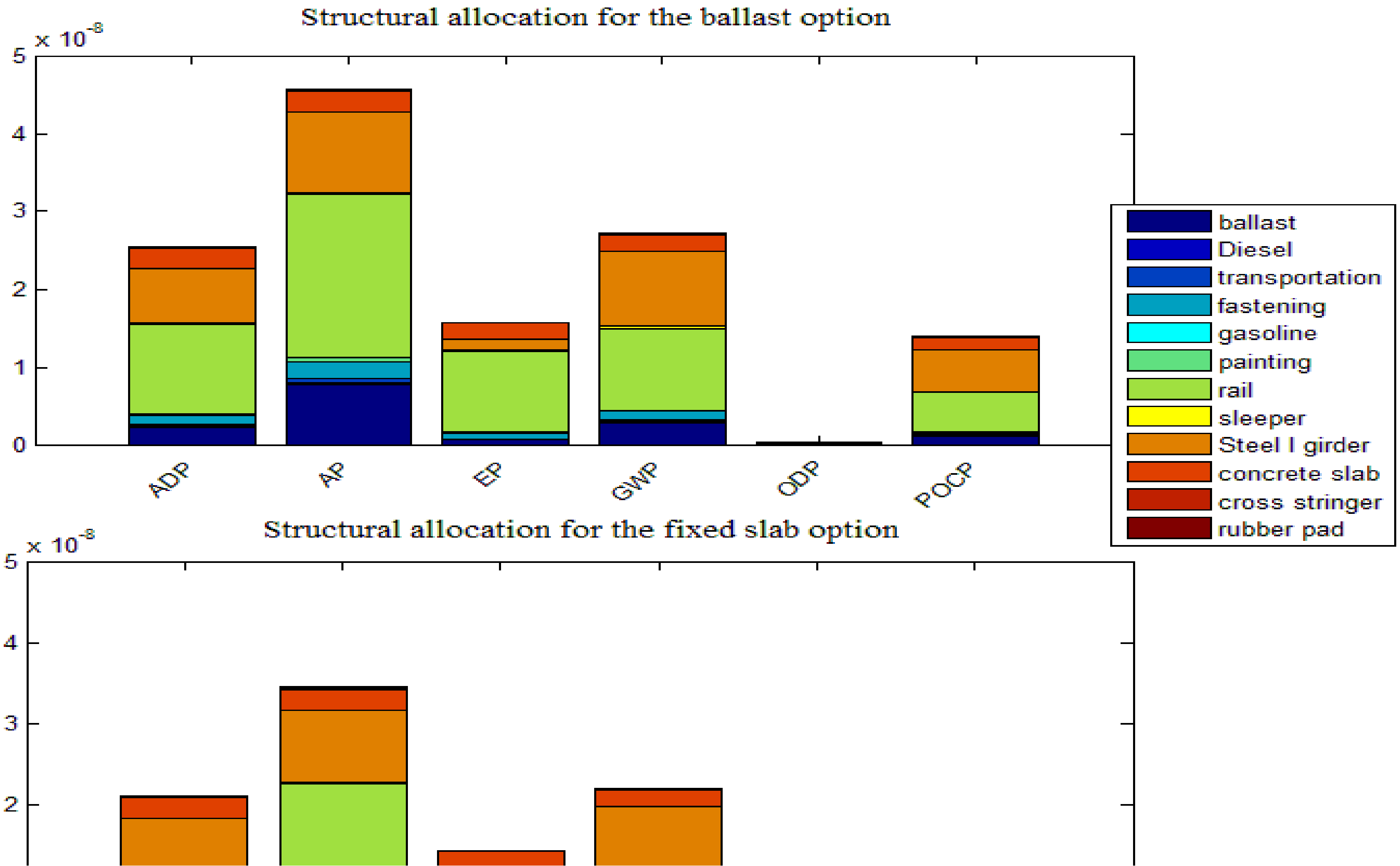
s

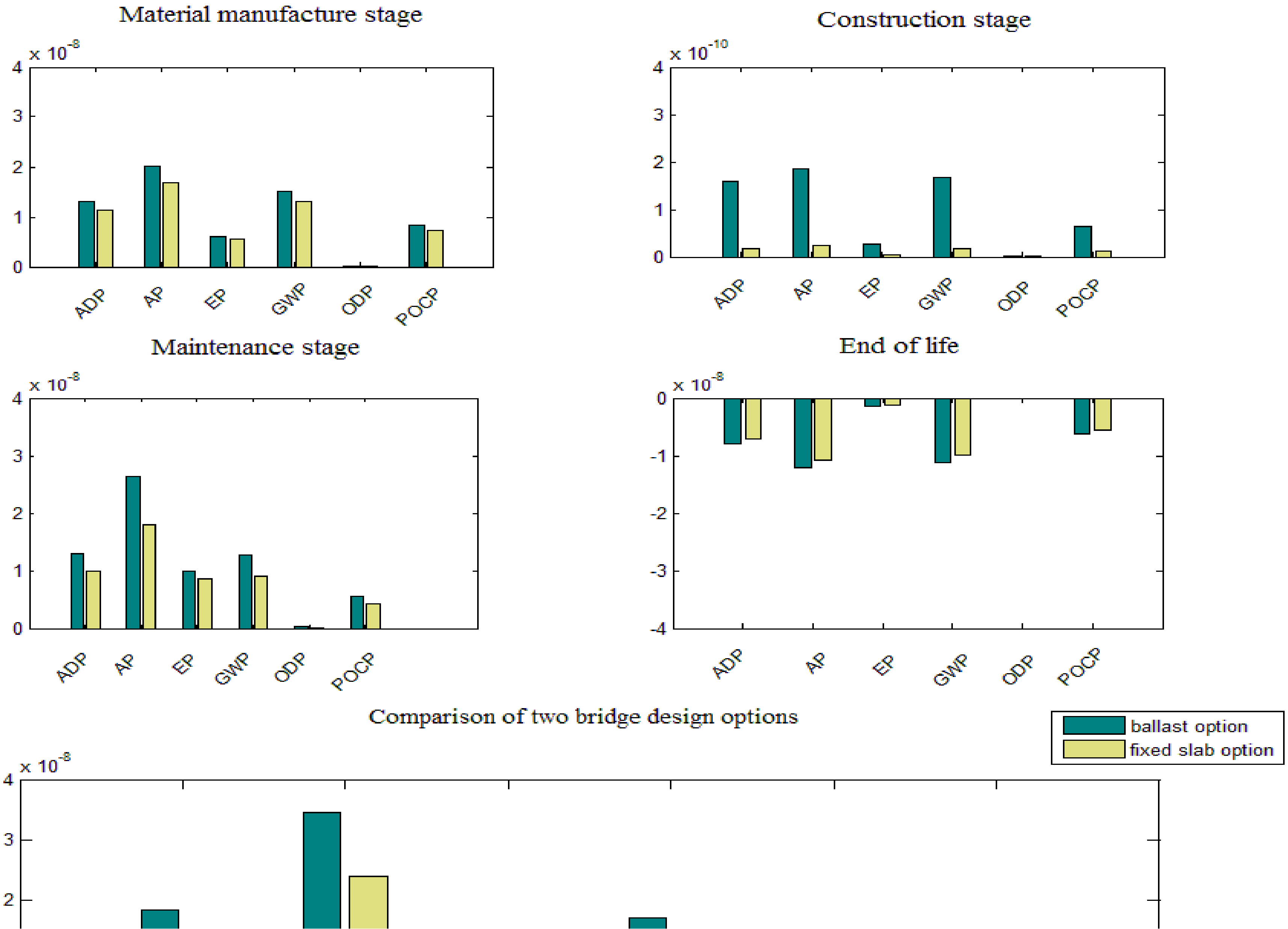
ADP)

WP)

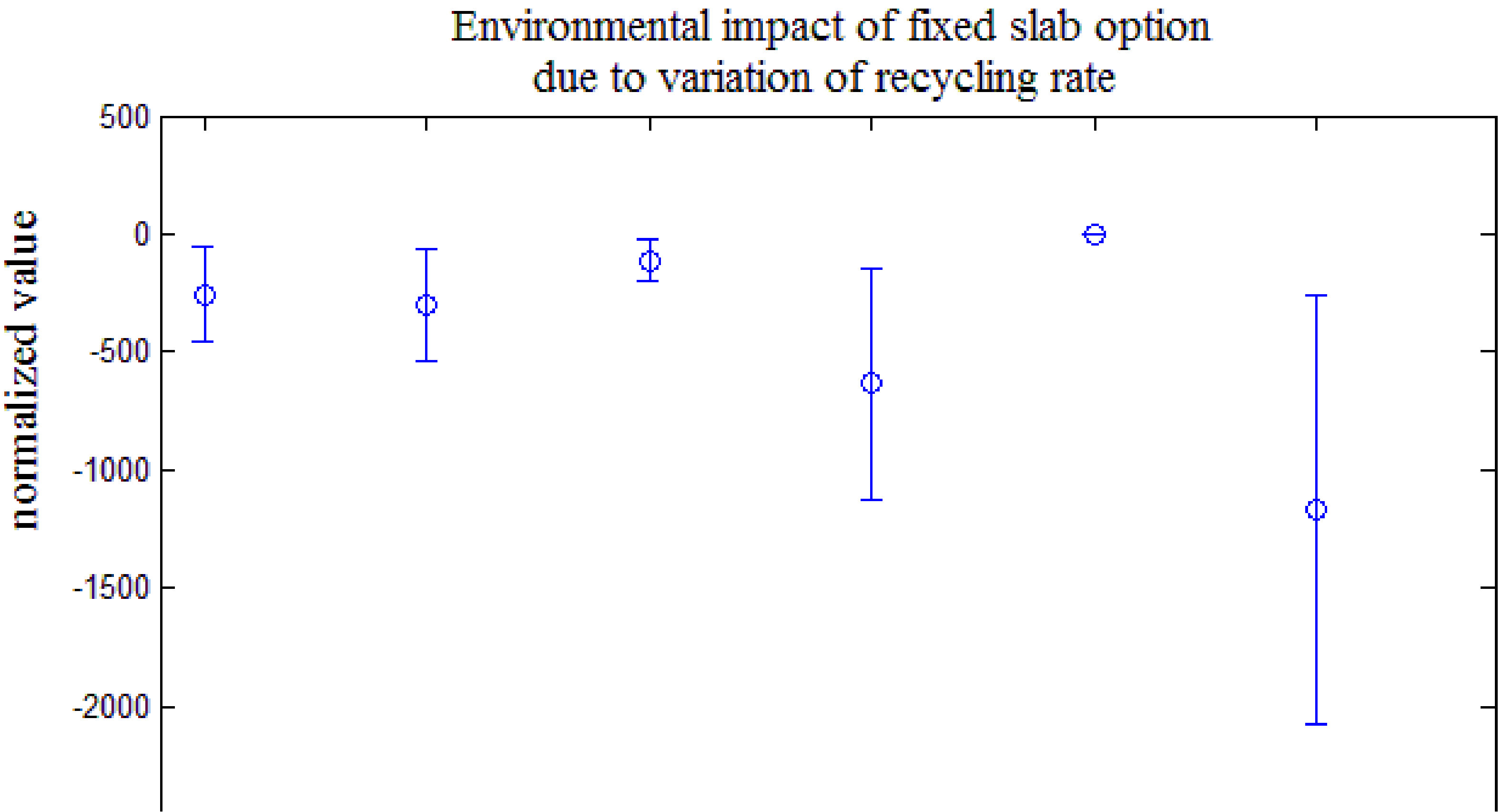
tion (ODP)

lation




Material manufacture stage
x 10^-8
0
1
2
3
4
ADP
AP
EP
GWP
ODP
POCP
Construction stage
x 10^-10
0
1
2
3
4
ADP
AP
EP
GWP
ODP
POCP
Maintenance stage
x 10^-8
0
1
2
3
4
ADP
AP
EP
GWP
ODP
POCP
End of life
x 10^-8
0
-1
-2
-3
-4
ADP
AP
EP
GWP
ODP
POCP
Comparison of two bridge design options
ballast option
fixed slab option
x 10^-8
2
3
4

Sensitivity analysis: Steel recycling rate varies from 20% to 95%



Sensitivity analysis: Rail replacement interval every 25 years to 20 years

Impact category	Abbreviation	Ballast option + Δ %	Fixed-slab option + Δ %
Abiotic depletion	ADP	13%	16%
Acidification	AP	12%	17%
Eutrophication	EP	14%	16%
Global warming	GWP100	13%	17%
Ozone layer depletion	ODP	7%	13%
Photochemical	POCP	13%	16%

Sensitivity analysis: consider traffic disturbance or not

Impact category	Abbreviation	Ballast option + Δ %	Fixed-slab option + Δ %
Abiotic depletion	ADP	0.43%	0.16%
Acidification	AP	0.31%	0.13%
Eutrophication	EP	0.29%	0.09%
Global warming	GWP100	0.42%	0.17%
Ozone layer depletion	ODP	0.83%	0.61%
Photochemical oxidation	POCP	0.28%	0.10%

Case Study 2: Banafjäl Bridge

	Case study 1	Case study 2

Life span & functional unit: 120 years for 1 m bridge in the longitudinal direction
60 years for the whole bridge

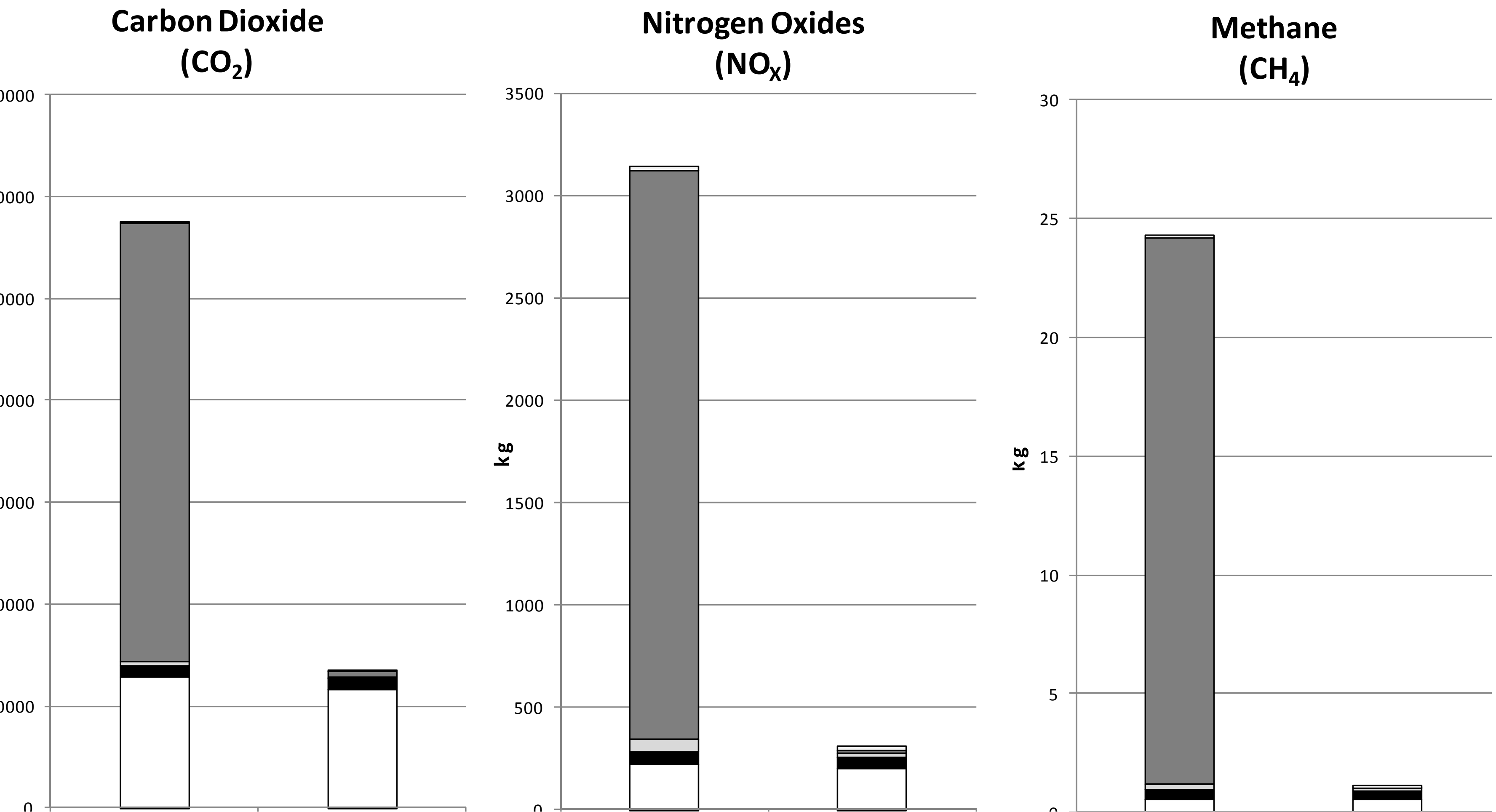
Included structure components

Included maintenance and EOL scenarios

Methodology and LCI databases:
CML 2001 method,
Eco-indicator 99' method

Considered parameters in the sensitivity analysis:
Recycling rate, maintenance scenarios, traffic disturbances
Increase all the parameters by 10%

Case Study 2: Banafjäl Bridge



Conclusions

k of uniformed LCA guideline and criterion is recognized as a main tacle. Currently, various LCIA methods and LCI databases are developed are available. However, the results are usually limited to the selected A methodology, the applied LCI data and different goal and scope nitions.

k of good LCI data and related information is another problem when forming LCA.

el of arbitrary, it has been found that the environmental profile varies e by case even for the same bridge type.

structural type affects the life cycle scenarios, thus further influencing

Thank you!