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DEMONSTRATION OF ETSI LCC AND LCA TOOLS

COWI

CONTENTS

APPENDICES

1 Preface

The present report comprises an actual application of the ETSI tools on life cycle costs (LCC) and life cycle assessment (LCA).

The study has been made on the Danish Road Directorates initiative with a twofold objective:

1) Showing how the ETSI tools can be applied in relation to an actual bridge project

2) Gaining knowledge and sharing ideas on the perspectives on using the tools for applications within the Danish Road Directorate.

We would like to thank the following persons from the Danish Road Directorate, the contractor Jorton and COWI for supporting the project and for participating in a constructive dialogue on applications, perspectives and visions:

Danish Road Directorate: Erik Stoklund Larsen, Iben Maag, Barbara Boesen Pedersen, Vibeke Wegan, Jeanne Rosenberg, Jørn Raaberg
Jorton: Bo Vestergaard
COWI: Henrik Elgaard Jensen, Jens Sandager Jensen, Ejnar Sibbesen

The report has been written with input from:

Anders Hasse Petersen, Anders Ole Stubbe Solgaard, Jens Thorup Laursen, Kirsten Eriksen, Kristian Kruse-Birch, Linda Høibye and Birit Buhr Jensen - all from COWI.

It has been a pleasure working with all parties within the ETSI project. On behalf of the ETSI working group: Linda Høibye, Kirsten Eriksen and Birit Buhr Jensen

Lyngby, 3 May, 2012

Birit Buhr Jensen

2 Introduction

The present report concerns tools which were developed as part of the ETSI-project for Life Cycle Cost (LCC) and Life Cycle Assessment (LCA) for bridges. This report is ordered by The Danish Road Directorate (Vejdirektoratet, VD).

Simulations of LCC and LCA have gained momentum in recent years and it seems natural also to include such calculations within the construction business. Calculations of LCC and LCA can be used within the design phase for new structures to compare alternative solutions. Moreover, such tools concerning the actual full cost as well as the environmental footprint of a new structure are valuable for the optimisation of the preliminary design. The tools are also efficient for planning and preparation of the operation and maintenance (O&M) of the structure since they allow for direct comparison of O&M strategies.

The LCC tool covers the total cost for the bridge during its entire service life, including direct costs for construction and operation, maintenance (O&M) and repair as well as indirect costs such as user costs associated to delays and disturbance of the usual traffic.

The LCA tool concerns calculations of the total energy consumption, the emission of CO_2, the ozone depletion, the acidification, etc. during the entire service life of the bridge, including the construction phase, the O&M of the bridge and the end of life (demolition) of the bridge.

The scope of the work presented in this report is three-fold:

› Description of LCC and LCA tools

› Test of LCA and LCC tools in relation to a completed project

› Recommendations for VD concerning the tools and their implementation at VD

› The actual bridge considered in this project is a new bridge across M11, Holbækmotorvejen, bridge no. 72.10, Overpass of Vindingevej. A bridge already existed at that location. Demolition and disposal of that bridge are included in the LCC but not in the LCA calculations.

Input for the calculations of LCC and LCA during the construction phase has been retrieved from the bill of quantities. The quantities of construction materials and the associated costs might not be the same as the real costs and a comparison with the actual quantities and costs were carried out. Based on this comparison it was seen that this difference was negligible.

The input for the O&M plan used for the LCC and LCA i.e. quantities, frequency and O&M extend, service life of structural components etc. are based on engineering judgements and recommendations from the Road Directorates inspection manuals and the bridge management system DANBRO, developed by the Road Directorate.

Calculations concerning the user costs, i.e. the costs associated with delays and/or diversions of traffic were based on annual daily traffic (ADT) on the bridge and under the bridge, i.e. on the motorway, gathered from the bridge owner (Roskilde Municipality) and the owner of the motorway (VD), respectively. Input concerning the actual cost of delays and diversions of traffic are based on standard numbers provided by the Danish Road Directorate. The costs related to traffic, apart from delays associated with O&M of the bridge, cover also costs for the diversion of the traffic while the old bridge is demolished.

Input for the LCA calculations, such as the CO_2 emission per unit of construction material etc. are based on tabular values from Ecoinvent which is an integrated part of the LCA tool.

2.1 Possible applications of the ETSI tools

There are different possible applications for the ETSI tools in relation to the different bridge design phases.

- Feasibility study - different possible alignments and links (different bridge types and design).

- Tender - architects - comparison of bids, which often include evaluation of aesthetical values.

- **Tender - consultant tender design - optimization, minimizing life cycle costs and environmental impact.**

- Tender - construct and built and maybe operate - optimization, minimizing life cycle costs and environmental impact.

- Construction - monitoring, declaring and documenting costs and impacts in relation to actual suppliers, etc.

Applying the ETSI tools using Vindingevej as an example is based on a consultants (COWI) tender documents.

2.2 Objective

The objective of the present study is

- Apply the tools to a real case, gaining experience in what the tools can be used for

- Provide suggestions to adjustments to the tools to match the needs with the Danish Road Directorate

- To serve as basis for a discussion on possible implementation with the Danish Road Directorate.

A joint brainstorming meeting between the Danish Road Directorate, the Contractor Jorton and COWI (design and supervision team) has been held on May 1, 2012. The objective was to discuss the input parameters in the program and the possible implementation perspectives.

3 Conclusion and recommendations in relation to tools

3.1 Conclusion

Conclusions in relation to results are described under LCC and LCA headings separately in the report.

It has been a good learning process to implement the ETSI tools on an existing bridge project. Also the process on including the Danish Road Directorate, the Contractor and the designer in the evaluation process has shown to be of great value.

The process has given valuable information in relation to

› The tools themselves, impact of different input parameters and the ways the tools work. Details are included throughout the report.

› Possible improvements to the tools. Items and suggested actions are included in list under recommendations.

› The possible differences in how the tools are constructed and how the Danish Road Directorate system works. Items and suggested actions are included in list under recommendations.

› How the tools can be used in connection with a tender design process.

› Ideas to how the tools can be applied also for feasibility studies, detailed design and during the construction phase.

3.2 Recommendations for tools

The recommendations have been grouped under separate headings and are shown in the Table below. Elaboration on selected items in the recommendations is given below the Table.

Table 1 Recommendations for tools

Items of general interest				
Tool	**Sheet**	**Recommendation**	**Timeframe, short, mid, long term**	**Comment**
LCC	General condition	Traffic below bridge should be included as supplement to traffic on bridge	Short	
		Weighing factors could be replaced with service lifes on different elements combined with deterioration models	MId	included in amended calculations and reflected in separate O&M manual, weighing factors can be set as 1 as a starting point
	Investment costs	A more detailed price list is wishes for linking to the different structural elements	Mid	Weighted prices can be included, the price on formwork for instance relate however highly to location and extend in labor cost. Therefore it would be beneficial to provide more flexibility
	Operation & Inspection costs	Splitting of traffic costs into on bridge and under the bridge	Short	
		Repair should be combined with operation and maintenance as is the case with LCA	Short	
		Developed into more flexible tool, where it is possible to have a starting action year and intervals from there	Short	
		Repair should be % of surface area, so that separate calculations can be avoided	Short	
		Include annual increase in traffic in model	Short	
	Repair costs	Splitting of traffic costs into on bridge and under the bridge	Short	
	Result	Graphic presentation should be uniformed with LCA	Short	
		Graphs should show net present values or actual costs not both in same graph	Short	
LCA		Modelling end of life	Short	
		Revise traffic impact in relation to operation, maintenance and repair, subtracting daily traffic from additional impact or include traffic impact in general throughout the life	Short	
		Analyse the data to assess the significance of using generic data from Ecoinvent especially in relation to the use of energy (amount and type of fuel/energy carrier)	Short	
LCC and LCA		Inclusion of tunnels and roads	Long	For possible evaluation of alignments and possible options in feasibility stage
		A web based tool could be considered	Long	Allowing for flexibility and uniform approach within nordic countries
Items of danish road directorate interest				
LCC		Incorporation of Danish road directorate traffic model in LCC	Short	To match what is done within existing bridges. First stage could be calculation of impact using ETSI traffic model and VD model
		Elaborate on prices for operation, maintenance and repair	Short	
LCA		Develop and incorporate specific Danish emission factors for the materials which contribute to the largest potential environmental impacts.	Short	
		Development of weighting factors	Mid	
		Include more materials in the tool (stainless steel, gravel etc.)	Mid	
		Incorporate the possibility to insert daily traffic in Bridge LCA - especially for the use in the feasibility stage	Mid	
LCC and LCA		A web based tool could be considered	Long	

› The output from the results should be presented in net present value only. Existing figures in the LCC tool show costs calculated in net present value along with costs which are not calculated in net present value in the same figure, which makes the interpretation of the results difficult. It is suggested to change such figures to show results either calculated in net present value or not.

- The *results*- sheet in the LCC tool automatically generates six graphs showing the costs (user costs, repair costs, etc.). However, it is not possible to identify cost-drivers within those sub-categories, which is a major motivation for carrying out LCC calculations. Thus it is recommended to modify the LCC tool slightly in order to illustrate the contributions to each sub-category. In the result sheet it would be helpful to show the cost drivers in the construction phase also, which will ease the optimisation process.

- The LCC tool can in its present form calculate input parameters from traffic on the road. To make the tool more user friendly it could be supplemented by including traffic for over as well as underpass. Moreover it is recommended to implement the traffic models provided by the Danish Road directorate (VD). The reasoning for this recommendation is:

  - The VD models account for the typical scenarios, i.e. maintaining the traffic by reduced speed or regulations with traffic lights or diversions of the traffic.

  - The VD models are capable of extrapolating the amount of traffic, which is not the case in the existing LCC tool.

- Operation & Inspection costs and Repair costs sheets should be converted into one, as they jointly comprise the O&M manual. The possibility to give frequency for operation and maintenance is limited to either interval year with automatic start in year 1 or three separate years. This provides some limitations for instance if one wishes to have input on repair first time in year 40 followed by maintenance every 20 years. Therefore it is recommended to alter input to interval year and a starting year or extend the number of action years to 5 or 10. The latter solution may compromise the overview of the sheet.

- Extend in repairs should be included in percentage instead of amounts, which require separate calculations. This will in addition ease the input.

- The LCC tool may be expanded to also calculate material quantities used in the O&M phase, as these are a major input factor in the LCA tools.

- The LCA calculations concerning the impact of traffic showed, that the influence of the traffic on the total emission (calculated in CO_2 and SO_2 equivalents) is negligible compared to the emission from the remainder parameters. It is recommended to investigate this further as it may not be relevant to optimize the tool for usage with regard to traffic.

4 Perspectives and recommendations

4.1 Perspectives

It is the opinion of the authors that there is a great potential for the Nordic road authorities in applying the updated ETSI tools to meet the actual needs.

4.1.1 Feasibility studies

The earlier in the bridge design process the tools are applied the larger is the potential influence and impact. In the feasibility study phase, the road authority can use the tools to evaluate the cost optimum solution on links as well as the environmental optimum solution. At present the tools include bridges which will limit the use from comparing with tunnels, alternate routes etc.

Also alternative bridge solutions can be compared, concrete, steel, timber etc., where the possible effect of different investment and maintenance schemes can be compared.

4.1.2 Tender design phase

The tools can be used for different optimisation processes in the design process as a basis for a rational decision process compared to other decision process. This will provide a good basis for gaining knowledge on a rational basis for the benefit of future projects.

Also optimising material, durability and maintenance issues can be provided, for instance as basis for setting the standard for requirements to suppliers of materials for certification and optimising the productions.

4.1.3 Construction phase

The tools can be used to document the actual costs but even more important the actual environmental impact. The costs in a new bridge design phase will from a tender design and actual built situation from experience not differ significantly.

The environmental impact can however be highly dependent on actual suppliers, and will be an important source for evaluation.

4.2 Recommendation

It is recommended that a strategy and an action plan are developed for inclusion of the tools within the Nordic road authorities. This can comprise a series of pilot projects before implementing the tools as found useful.

The possible actions could comprise some or all of the above recommendations together with recommendation on supplementing the tools as described in chapter 3:

4.2.1 Feasibility phase

- The tools are further developed to include tunnels and connecting roads.
- An option to include daily traffic is included in the LCA to provide input on effect on alternative alignments/routes

4.2.2 Tender phase and construction phase

- National values for prices and emissions are further collected and data base maintained for same.
- In order for the contractors and suppliers to provide tenders on the same basis a uniformed operation and maintenance plan has to be developed
- An evaluation of emission factors and corresponding weighing factors should be developed when knowledge and experience have been further gathered from pilot testing the LCA tool in conjunction with the LCC tool.

5 Background

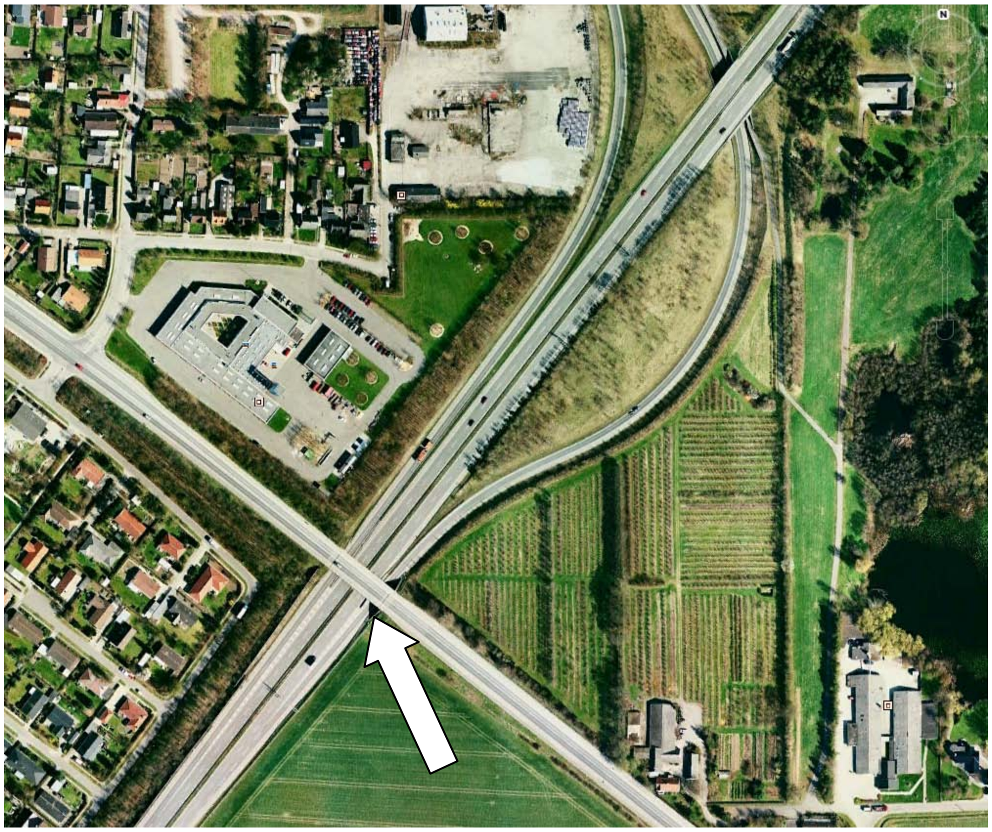
This section provides background information on the bridge project which is used in this report for the demonstration of the applicability of the developed LCC and LCA tools.

5.1 Bridge at Vindingevej

The traffic on motorway M11, Holbækmotorvejen, near Roskilde has increased over the years. To match the future traffic needs, it was decided to widen the motorway from 4 lanes to 6 lanes at the bridge location, where Vindingevej passes over the motorway.

The existing bridge had to be removed. It was replaced with a new standard 2-span concrete bridge. The bridge was cast on site and reinforced with pre-stressed reinforcement..

Photo showing the bridge viewed from the motorway, shortly before the new bridge was finished.



Aerial photo with the old bridge marked by an arrow.

The bridge, owned by VD, was erected by the contractor Jorton A/S.

In the design phase of the project, several parameters were investigated and optimized.

The first parameter was the cost of the bridge itself. In order to minimize the cost of the bridge, an optimized design solution was used - based on VD's specific aesthetic-, bridge type- and material demands.

The second parameter was the thickness of the bridge deck (the construction height). By reducing the thickness of the deck, more reinforcement steel has to be used than normal. But on the other hand, a reduced construction height leads to a reduced amount of earth works, which overall reduces the total cost of the whole project.

The third parameter was the traffic disturbances in which two alternative construction scenarios were considered:

The first scenario was to construct the new bridge next to the end locations of the old bridge, and then - after demolishing the old bridge - push the new bridge into place. This would lead to a closure of Vindingevej for a very short period of time.

The second scenario was to construct the bridge in several construction phases (using 2 parallel pieces of bridge deck) hereby reducing the traffic disturbance of the traffic on Vindingevej. This would lead to a prolonged construction period.

For both the above mentioned scenarios, the added construction cost was significant, and the overall reduction of traffic disturbances was considered too small. Therefore, it was decided to construct the bridge as a whole, while diverting the traffic on Vindingevej by using an interim road.

It took Jorton A/S approximately a year to construct the new bridge..

6 Input for LCC and LCA models

The main input for the LCC and LCA calculations consists of three separate items:

- Construction of the bridge,
- O & M during service life, and
- The impact from traffic

All of the above items, as will be seen in a separate section, are implemented in the LCC and LCA calculations.

6.1 Construction of the bridge

Input quantities and prices of the materials, used for the calculations of the LCC and LCA during the construction phase have been retrieved from the bill of quantities. The bill of quantities is attached in Appendix A of this report.

The unit price of the main materials as concrete and steel has been calculated as a weighted average, based on the different prices and quantities of the materials in the bill of quantities. There is for instance a difference in price on formwork in relation to where it is used due to differences in work load for setting form on deck and abutment.

The division into bridge elements in the LCC tool is also based on the **bill of quantities**. There are some differences between nomenclature in the LCC program and nomenclature used by the Danish Road Directorate. The program has for this application been adjusted to match the Danish Road Directorate nomenclature.

In the "Construction cost" sheet, in the section called "Road project" an estimate of the quantities, has been made. The bill of quantities for this part of the project contains the sum of quantities for roads leading up to two bridges. Based on project drawings it is estimated that 75% of the quantities are used as part of the "Vindingevej" project. This estimate contains some level of uncertainty.

6.2 Operation and maintenance of the bridge

The input for the O&M plan used for the service life of structural components are based on engineering judgements and recommendations from "Eftersyn af Bygværker" [1].

Quantities of materials contained in the different repairs are calculated separately, as they are needed as input in the LCA tool. The quantities of materials are calculated based on values given in DANBRO. The cost of the repair is also based on values provided by DANBRO in 2012.

Included in the "DANBRO price" for each type of repair is an amount for administration, and an amount for the construction site is included in addition to the cost of materials and labour. This means that administration and amount for running the construction site are included twice, if two types of repairs are carried out at the same time. Therefore the total price of repair is subject to some level of uncertainty.

The amount and frequency of repairs are based on engineering judgements and experience. The O&M plan for this project is attached in Appendix D.

6.3 Traffic

The impact of traffic is taken into account in different ways in the LCC and LCA tools. The basis of those calculations is given in the following sub-sections. Moreover, a description of the traffic models used by VD is given along with a brief discussion of the differences between those models and the models forming the basis of the LCC and LCA tools.

6.3.1 Traffic models for LCC tool

In the LCC tool, the influence of traffic on the total cost during the service life of the bridge corresponds to the delay of the users and/or goods on the affected road section. A rather simplified model for this delay is proposed in the LCC tool assuming that the delay is due to a speed reduction on the affected road section. It is assumed that the road section has sufficient capacity, i.e. there is no tail back due to the road works. Finally, it is assumed in the tool that the traffic and number of cars and trucks are constant throughout the service life of the bridge. The LCC corresponding to the delay of the users is calculated from Eq. (1).

$$LCC_{user,delay} = \sum_{t=0}^{T} \left(\frac{S}{v_r} - \frac{S}{v_n}\right) ADT_t \cdot N_t (p_L w_L + (1 - p_L) w_D) \frac{1}{(1+r)^t} \tag{1}$$

where

S is the length of affected roadway on which cars drive,

v_r is the traffic speed during bridge work activity,

v_n is the normal traffic speed,

ADT_t is the average daily traffic, measured in numbers of cars per day at time t,

N_t is the number of days of road works at time t,

p_L is the amount of commercial traffic,

w_L is the hourly time value for commercial traffic,
w_D is the hourly time value for drivers and
r is the real interest rate.

The annual daily traffic on the road section is provided by the road-owner. In specific cases where operation, maintenance and repair works affect other roads, e.g. roads below the bridge, the owner of that road should provide information about ADT as well. The LCC calculations presented in this report are based on the average daily traffic, ADT_d and N_t is changed to N_d which is the number of days of road work.

Relevant values for the input parameters given above are presented in Table 1.

Table 2 Parameters for LCC calculations

ADT_d (Vindingevej)	9,554 vehicles/day
ADT_d (M11)	40,400 vehicles/day
v_n (Vindingevej)	50 km/h
v_r (Vindingevej)	30 km/h
v_n (M11)	110 km/h
v_r (M11)	70 km/h
w_D	105.25 DKR/h *
w_L	344.87 DKR/h *
p_L	0.15
R	5 %

* 2010 values provided by VD

Numbers concerning ADT_d for Vindingevej and M11 were provided by Roskilde Kommune and VD, respectively. The amount of trucks, p_L, is assumed based on experience from similar calculations. The value for the annual real interest rate, r, is the value used by VD.

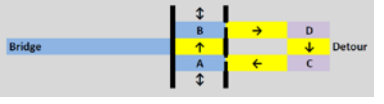
The LCC concerning the impact of traffic are calculated for the bridge (Vindingevej) and the highway (M11) in separate simulations.

6.3.2 Traffic models for LCA tool

The traffic model for the LCA tool is capable of simulating three different scenarios:

1 Two way traffic across the bridge during O&M:

2 One way traffic across the bridge and diversion of traffic in the other direction:



3 Diversion of the traffic in both directions:

The illustrations below each scenario are screen dumps from the LCA tool.

For each scenario the total emission, measured in CO_2, CO, HC and NO is calculated taking into account the following parameters:

- Length of detour (if there is a detour)
- Duration of the road works (in days)
- Average vehicle speed
- Average daily traffic
- Traffic load
- Amount of passenger cars (petrol and diesel), buses (diesel) and trucks (diesel).

The traffic load is used to describe the Rotation per Minute (RPM) of the engine, which in this case is directly linked to the fuel consumption. The fuel consumption for cars, buses and trucks is based on a weighted average of the fuel consumption of the most common vehicles.

At present, the LCA tool calculates the total emission during the road works, not only the extra emission due to the road works i.e. subtracting the average daily emission from the total emission.

The impact of the traffic in the LCA is calculated for the bridge (Vindingevej) and the motorway (M11) in separate simulations. The results of the LCA calculations cover the impact of the traffic on both roads.

In the present Vindingevej case the LCA calculations are based on two way traffic on and under the bridge. The distance travelled by the cars is calculated as a weighted average of the distance corresponding to each road work.

6.3.3 Traffic models used by VD

Three models are used by VD to estimate the expenses related to disturbances in the traffic caused by road works.

- Maintain the traffic on affected road by reducing the speed
- Diversion of the traffic
- Maintain the traffic on affected road by regulating the traffic with traffic lights.

All the models are based on simplified formulations and assuming that the capacity of the roads used for diversion is sufficient and that there is no creation of queues, etc. All the models are capable of extrapolating the amount of traffic.

The model used for calculating the costs associated with a reduction of the speed is similar to the model used within the LCC calculations in this project, Eq. (1), and for that reason the model is not further discussed in this section.

The cost due to a diversion of the traffic via an alternative route is calculated as the sum of the cost due to the increased travel time and the cost related to extra wear of vehicles. Costs due to the increased travel time are calculated by the use of Eq. (2).

$$LCC_{traffic\ time} = \sum_{t=0}^{T} \left(\frac{l_r}{v_r} - \frac{l_n}{v_n}\right) ADT_t \cdot N_t (p_L w_L + (1 - p_L) w_D) \frac{1}{(1+r)^t} \qquad (2)$$

where

l_r is the distance of the alternative route (diversion)[km],
l_n is the distance of the original route [km],
v_r is the speed on the alternative route [km/h]
v_n is the speed on the original route [km/h],
ADT
q_L is the cost for commercial traffic [DKK/km], and
q_D is the cost for cars [DKK/km].

The cost associated with increased wear of the vehicles due to extra distance via the alternative route is calculated by the use of Eq. (3).

$$LCC_{traffic,distance} = \sum_{t=0}^{T} \Delta l \cdot ADT_t \cdot N_t (p_L q_L + (1 - p_L) q_D) \frac{1}{(1+r)^t} \qquad (3)$$

where

Δl is the difference between the original distance and the alternative route [km],
q_L is the cost for commercial traffic [DKK/km], and

q_D is the cost for cars [DKK/km].

The final model concerns the increased costs due to regulation of traffic by the use of traffic lights. The model is based on the assumption that there is no tailback due to the regulation, and the difference between travel-time on the distance with/without the traffic light is calculated.

The average delay per vehicle due to the regulation is calculated by the use of Eq. (4).

$$F_{avg} = \frac{r^2}{[2 \cdot C \cdot (1 - b \cdot I)]} \tag{4}$$

where

r is the time which the traffic light is red
C is the sum of the time for one red and one green light in one direction.
b is the average time for finishing one vehicle (usually 2 s/vehicle-unit) and
I is the traffic intensity per direction.

Further information about the calculations of the time of green light, the average delay per vehicle, etc. is given in Ref. [1].

Based on the average delay of the vehicles the total costs related to traffic regulation is calculated for cars and trucks from Eq. (5) and (6), respectively.

$$LCC_{light,car} = \sum_{t=0}^{T} F_{avg} \cdot ADT_t \cdot N_t \cdot (1 - p_L) w_D \cdot \frac{1}{(1+r)^t} \tag{5}$$

$$LCC_{light,lorry} = \sum_{t=0}^{T} F_{avg} \cdot ADT_t \cdot N_t \cdot p_L \cdot w_L \cdot \frac{1}{(1+r)^t} \tag{6}$$

6.3.4 Discussion of traffic models

A short discussion of the traffic models incorporated in the LCC and LCA tools is provided in the following, along with a discussion of the traffic models used by VD. Moreover, the possibility of implementing the VD-models into the existing LCC and LCA tools is discussed.

Accounting for the cost related to the traffic in the LCC program is very user-friendly. The simple formulation considering a general reduction of the speed over a specified distance is transparent. However, the traffic model used in the LCC tool does not provide a possibility of taking delays due to traffic-light regulation into account, which is often used during maintenance and repair of a bridge.

Associated cost due to diversions of the traffic during the construction phase is not an option within the LCC model. Such cost can be, as will be seen in a separate section of this report, substantial. Finally the existing LCC tool is not capable of accounting for cost associated with traffic **on** the bridge and **under** the bridge at the same time.

The traffic model used within the LCA tool accounts for the emission due to a diversion of the traffic. It is easy to use and the formulation is rather detailed since it accounts for the emission as a function of the speed, the type of cars (petrol or diesel), etc. However, as for the model used in the LCC tool, it is not possible to account for traffic lights. In addition it is not possible to include emission associated with idle running of the cars and a general reduction of the speed cannot be considered. Moreover, it is not possible to account for traffic **on** and **under** the bridge.

The costs related to three typical scenarios can be calculated by the (simple) models used by VD, which makes the tool very useful. At present there is no link between the VD tool and the LCC tool, which can however be implemented.

The VD model does not calculate the emission from traffic.

7 Description of LCC tool

LCC is defined as the whole cost during the entire life cycle of a structure, in this case a bridge. The LCC tool developed as part of the ETSI project is described in this section. The description concerns the existing LCC tool, i.e. the calculation methods, the required input, and the output from the calculations.

LCC is an important input for infrastructure managers when considering the bridge management system. In this context LCC is defined as the actual whole cost of the bridge during its life span, including construction of the bridge, operation and maintenance, repair, traffic delays and demolition of the bridge.

In the design phase of a bridge such calculations are highly relevant when optimising the design of the structure and assisting in finding the optimal solution considering investment and maintenance. As the cost during the life span of the bridge is included in those calculations it is necessary to implement a plan for operation and maintenance of the bridge in such calculations. Calculating whole LCC of a bridge is very complex since a number of factors have to be considered, e.g. the service life of structural components, the cost of those components, the amount of traffic affected by interruptions due to maintenance and/or repair, etc. Moreover, it seems natural to divide the LCC into (at least) three parts, since different parties within the society are responsible for the costs. This is shown in Figure 5-1.

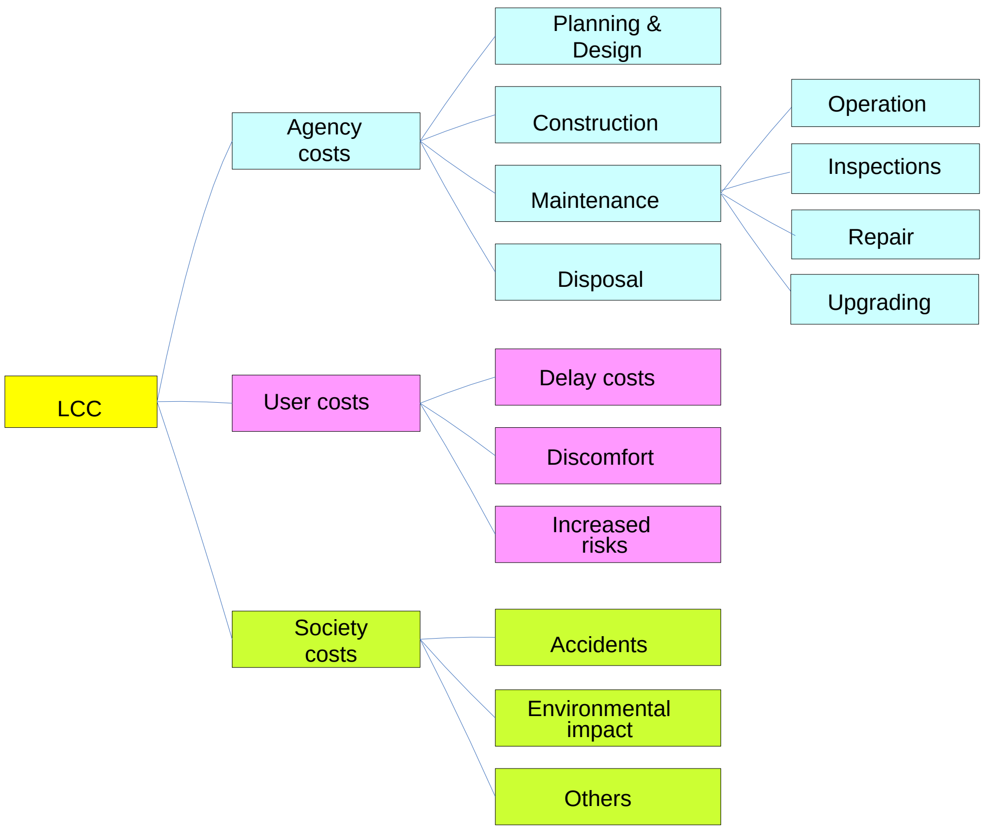


Figure 5-1 Schematic of whole LCC divided into affected bodies within the society.[ETSI-manual].

The LCC tool used for the calculations presented here covers the agency costs and the user costs (excluding discomfort and increased risk), described in the following.

7.1.1 Agency costs and user costs

The agency costs refer to the expenses encumbered by the bridge-owner. These costs cover planning, design, construction of the bridge, maintenance of the bridge, and disposal of the bridge as seen in Figure 1. The agency costs during the life span of the bridge are illustrated in Figure 5-2.

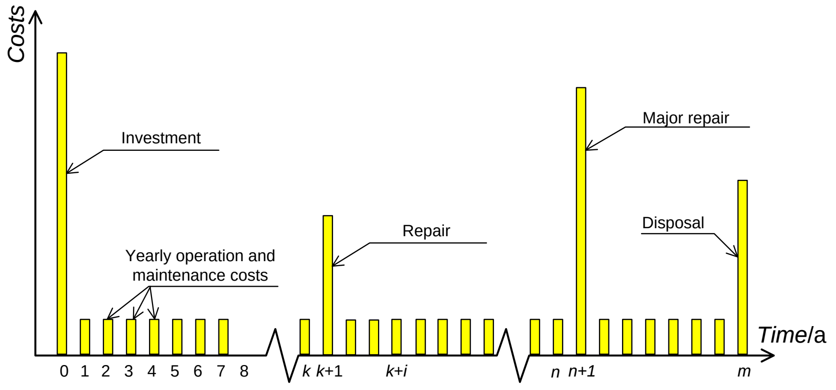


Figure 5-2 Schematic illustration of the agency costs for a bridge during its life span. Note that costs in the figure are not calculated according to net present value. [ETSI-manual]

Costs at various points in time, e.g. costs for investment, repair, etc. cf. Figure 5-2, are recalculated to a pre-defined point in time. In the LCC tool presented herein, this time is defined as the time of inauguration of the bridge, and all future costs are discounted to present value. Thus the total agency costs during the whole life span of the bridge, LCC_{Agency}, can be calculated from Eq. (7).

$$LCC_{Agency} = \sum_{t=0}^{T} \frac{C_t}{(1+r)^t} \qquad (7)$$

where

C_t is the sum of all costs at time t,
r is the real interest rate or a rate accounting for changes in the benefit of the structure, and
T is the time period studied, typically the life span.

The frequency/time intervals and extent of the O&M work is described in the O&M plan. The O&M plan is based on the degradation rate of the various structural elements. The degradation rate of structural elements can be estimated either by the use of theoretical degradation models (e.g. Fick's 2nd law) or from historical data from similar existing bridges. The use of such theoretical models requires substantial knowledge about the exposure conditions, material composition, etc. and the complexity of that approach is significant. Hence, estimates by experts on the expected service life of the structural components are often forming the basis of O&M plans. This is also the case in this study. The challenge herein lies in setting the correct service life given the knowledge based on past experience and the future expectations where improved technologies have been implemented.

Further descriptions of the O&M plan used for the calculations presented in this report are given in Section 4.2. The LCC tool developed as part of the ETSI project is capable of taking deterioration of the different structural components into account by the use of a so-called weight-factor. However, that system is based on Swedish conditions and is not fully understood by the authors. Thus the weight-factors have been omitted in this project.

According to Figure 5-1, the user costs cover the costs related to delays, discomfort and increased risk. In the LCC tool from the ETSI project only the user costs related to delays of the traffic are considered, i.e. delay of persons and goods. The model for calculating the user costs is given in Eq. (1).

In summary, the inclusion of LCC in the design phase allows for a better basis for choosing between different alternatives as seen from Figure 5-3.

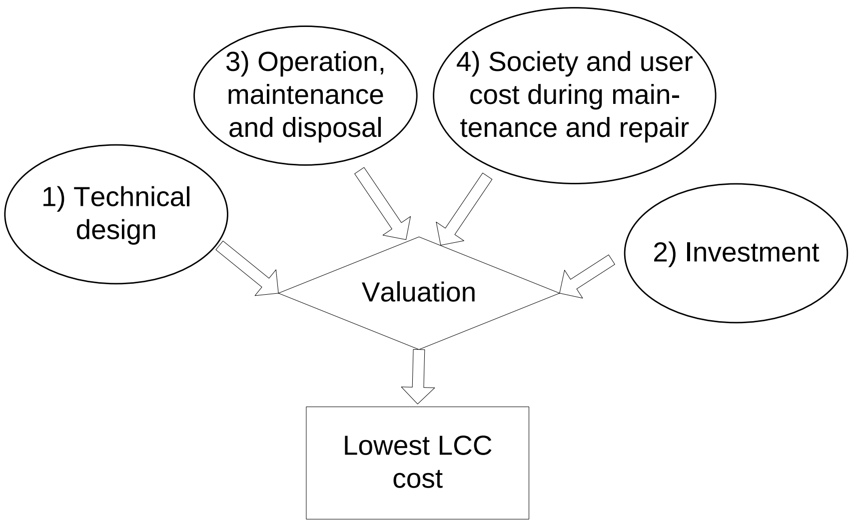


Figure 5-3 Illustration of the parameters accounted for in the decision-taking process between various alternatives. [ETSI-manual].

As seen in Figure 5-3 the aim of the valuation of different alternatives is to ensure the lowest possible LCC by balancing the different costs and the technical design without compromising the technical requirements (e.g. capacity) for the bridge.

8 Description of LCA model

8.1 Structure of the Bridge LCA

The structure of Bridge LCA is described in the user manual.

The LCA model is developed according to ISO 14041 and does thus include all potential environmental impacts during the full life cycle of bridges:

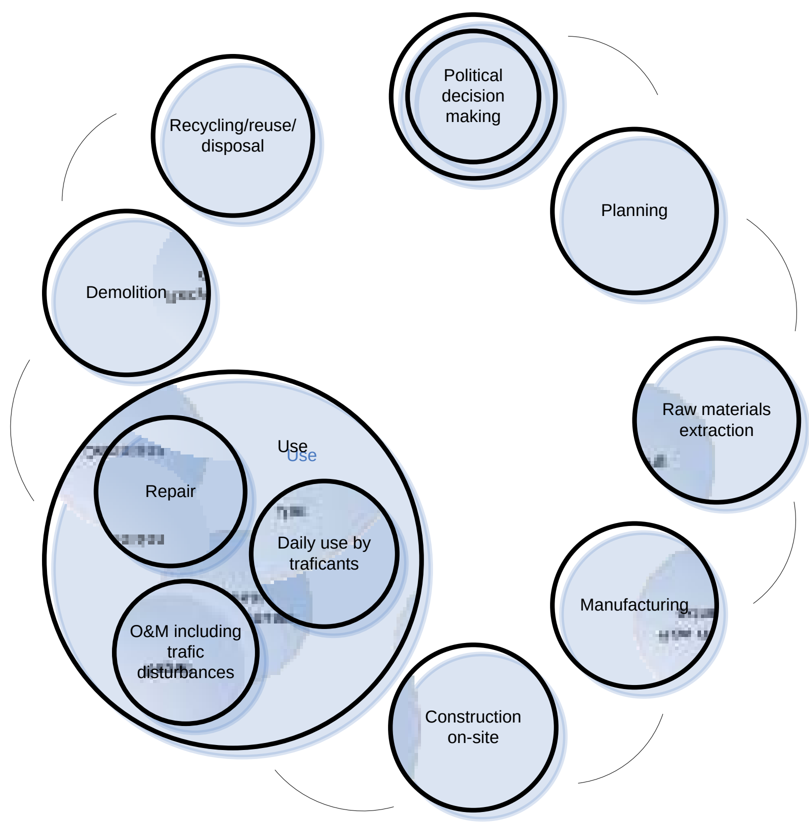


Figure 6-1: The phases of a bridge project

Bridge LCA enables the user to calculate and show results from every phase of the project: material production, construction, O&M, repair and EOL (End-Of-Life).

This structure diverges from the structure of Bridge LCC where O&M and Repair are split in two separate phases.

The materials for the bridge are divided into Major and Minor LCA impacts. This enables the user to focus on the materials which entails the largest potential environmental impacts. From experience it has been found that this split it useful in the early stages of projects - either in the tender phase or the feasibility phase.

8.2 Functional unit

As a general rule for LCA, a functional unit must be defined to enable the reader and user to make comparisons and evaluate the results of the LCA.

The functional unit is defined as a measure of the function of the studied system (in this case a bridge). It provides a reference to which inputs and outputs can be related.

Definition of the functional unit is vital in LCA as it enables the user to compare different solutions to a problem or challenge.

The functional unit for the given project can be:

a. Transportation of 9,554 transportation units (cars, trucks, buses etc.) during 100 years from A to B.

b. Transportation facilities for enabling 9,554 transportation units (cars, trucks, buses etc.) during 100 years to drive from A to B. This functional unit excludes potential environmental impacts from the transportation units during the full life time of 100 years.

In addition to the actual length of the bridge a 75% costs of the ramps leading to the bridge have been included in the LCC analysis. The A and B are hence defined as the bridge starting point (A) and end point (B) with an additional corresponding length.

In chapter 7 the results from both LCA calculations with the two functional units are discussed.

8.3 Goal and scope

The goal of the LCA on Vindingevej is to test the LCA tool, Bridge LCA which has been developed in the ETSI project.

Especially, the following topics have been evaluated:

› The environmental impact of end of life

› Relating national emission factors to the general Ecoinvent data incorporated in Bridge LCA

› Identification of potential modifications to meet Danish applications

› Evaluation of tests results

The scope is reflected in the functional unit described in section 6.2. The quantities inserted into the LCA are described in Chapter 4.

There are a few aspects which are not included in the present LCA version:

› Demolition of existing structure

› Energy for construction of the bridge

› Soil works

› Bituminous joints

› Anti grafitti coating

› Sand, stone and gravel

› Transport of construction materials to the construction site (except for sand, stone and gravel)

› Transport of materials after demolition of the bridge

8.4 Embedded data

Data derives from the well established database, Ecoinvent. The data in the database has been updated in 2011 where a new Ecoinvent database has been released. These updated data have not been included in the LCA tool at present. The data are generic and does not contain any country- or company specific conditions which are reflected in the emission factors.

Data for all types of cement and concrete are the same in the Ecoinvent database. It is possible to insert country- or company specific data e.g. for cement production at Aalborg Portland. For steel, only two emission vectors can be chosen. The emission factors from steel suppliers can deviate significantly from one supplier to another and due to the large influence on the total potential environmental impact it is important that these emission factors are correct. Therefore it is recommended to obtain emission factors from the 2-3 most used suppliers of steel/reinforcement in Denmark.

This is relevant in projects where the producers of materials are known.

If country- or company specific emission factors are inserted in Bridge LCA it must be realised that these data may be outdated after a few years and must thus be revised. So, the consequence of using process specific data entails a responsibility to update and revise data frequently.

Bridge LCA is intended for use in all phases of a bridge project.

The Ecoinvent data included in Bridge LCA forms a good basis for estimating the potential environmental impact in the early phase/planning stage of a project, where the overall strategy and possible alignment are outlined.

Bridge LCA can also be applied in later stages of a project where optimizations must be obtained. In this situation Bridge LCA can be applied - supplemented with emission factors and transport distances from the specific suppliers of materials.

When the potential environmental impacts from a constructed bridge is to be documented/declared data from the specific suppliers of materials etc. must be used. In the LCA calculations for Vindingevej we have used specific emission data from two different types of cement, and steel data from Celsa in Norway. The rest of the applied emission factors are from Ecoinvent.

8.5 End of life

End of life is included in Bridge LCA where the used materials are modelled with negative or positive environmental impacts occurring during incineration, reuse, demolition or land filling.

At the moment, the user chooses the actual end of life scenario for the single construction materials. When e.g. steel is reused, the total amount must be credited to the system.

Typically, end of life is a significant phase in many life cycle assessments. However for bridges, re-use will not typically go into a new bridge, but rather into road works etc. Therefore this will not be reflected in a reduction in the potential environmental impacts from bridges. Furthermore it must be acknowledged that the method for handling construction waste can be quite different at the time of bridge demolition (up to 100 years).

8.6 Materials

The materials in the LCA are divided into major LCA impacts, minor LCA impacts and other input factors.

The major LCA impacts are concrete, steel, timber and asphalt. This structure is quite useful for the users to provide a first impression on environmental impact for instance in relation with a feasibility study.

8.7 Impact assessment

The methodology applied for the impact assessment is described in the Bridge LCA user manual.

Normalisation is applied using the normalisation factors applied in the CML 2001 method according to the Bridge LCA user manual. This step of the LCA enables the user to assess the calculated potential environmental impact to the average load from one person during one year.

Weighting is the final step in an LCA where the potential environmental impacts are weighted according to Nordic, national or specific priorities and values. This means that e.g. global warming can be prioritised by setting a high weighting factor, The background for determining weighting factors are typically political targets, specific considerations in the organisation or it can be local environmental concerns - e.g. to areas sensitive to nutrient enrichment or toxicity.

At the moment, the weighting factors are set to the default value: 1. It is recommended that the Danish Road Directorate develops specific weighting factors based on values in the Danish Road Directorate or national targets.

9 Results - LCC & LCA

9.1 Results from LCC calculations

Prior to presenting the results from the LCC analysis the basis of those calculations is described.

At a relatively early stage in this project it was clear that some limitations of the LCC tool existed, e.g. traffic diversion during the construction phase is not considered, and the model accounting for the traffic-costs only considers a general reduction of speed, etc. However, taking into account that the aim of this project was to show how the existing tool for LCC can be implemented it was decided not to make any major changes to the tool, as the relevance of changes to a large extend would be country dependent. The only thing that has been implemented into the LCC tool is the possibility of taking into account traffic below the bridge, and the possibility of calculating costs for O&M and repair based on an O&M plan.

The bridge-project used for the demonstration of the LCC and LCA tools described in this report concerns the demolition of an existing bridge and the subsequent construction of a new bridge at the same location. Diversion of the existing traffic via an alternative route and the associated costs while the new bridge is constructed is not considered in the results shown in Figure 4 - Figure 9. The reason for this is that the existing LCC tool does not allow for such calculations.

Calculations of the costs associated to a diversion of the traffic were calculated by the authors using the models and corresponding unit-costs provided by VD. The difference between the alternative route and the actual route was approx. 1 km. Taking into account the cost due to increased wear of the vehicles and the delay of the users the cost associated to that diversion of the traffic was more than 40.000 DKK per day, resulting in more than 13 mio. DKK over the construction period for the bridge. In this context it is of relevance to mention that this diversion of the traffic is the best alternative. Thus the cost related to diversion of existing traffic is substantial, and the LCC tool could benefit from implementing methods for calculation of diversion.

Though the O&M plan prescribes that the regulation of traffic during parts of the road works should be done by the use of traffic-lights this has not been done in the calculations since the LCC tool does not allow for this. Consequently the associated cost due to those delays is solely based on a general speed reduction from 50 km/h to 30 km/h without accounting for the time that drivers have to wait for green light.

The LCC tool summarizes the results in one table and six graphs. Each of the graphs and the results table are presented and discussed separately in the following. Results presented in the following are calculated for 100 years life span of the bridge assuming an annual real interest rate, *r = 5%*.

Bridge Stand alone LCC **Optimal new bridges - Life cycle analysis**	
Life cycle cost Bridge at Vindingevej, across M11	
INVESTMENT COST	11,411,987
REPAIR COSTS	1,104,784
OPERATION AND MAINTENANCE	263,324
USER COSTS	207,429
DEMOLITION COST	8,678
SUM NET PRESENT VALUE	**12,996,202**
SUM NET PRESENT VALUE / BRIDGE AREA [CUR/m^2]	**15,751**

Figure 7-1 Output from LCC tool - summary of costs in net present value.

As seen from Figure 7-1 the total cost is divided into five sub-categories, of which the investment cost in this case is the major cost-driver (88 % of the total sum in net present value). In case diversion of the traffic was included this would even comprise an ever higher percentage.

The sum of repairs, operation and maintenance correspond to approx. 1.4 million DKK in net present value.

The user costs, i.e. the costs associated with delays of the road users, are at the same level as the costs for operation and maintenance. In this case operation and maintenance only cover the costs for inspection (general and special inspections) and minor cleaning. All other costs during the life span of the bridge, e.g. replacement of bearings, wearing course and waterproofing membrane, are considered as part of the repair costs. The cost for demolition of the bridge is calculated by the LCC tool as a predefined percentage (10%) of the total investment cost. However, this cost is not verified at present stage of the project.

A more detailed illustration of the total cost during the service life of the bridge is presented in Figure 7-2, showing the accumulated cost (in net present value) as a function of the service life.

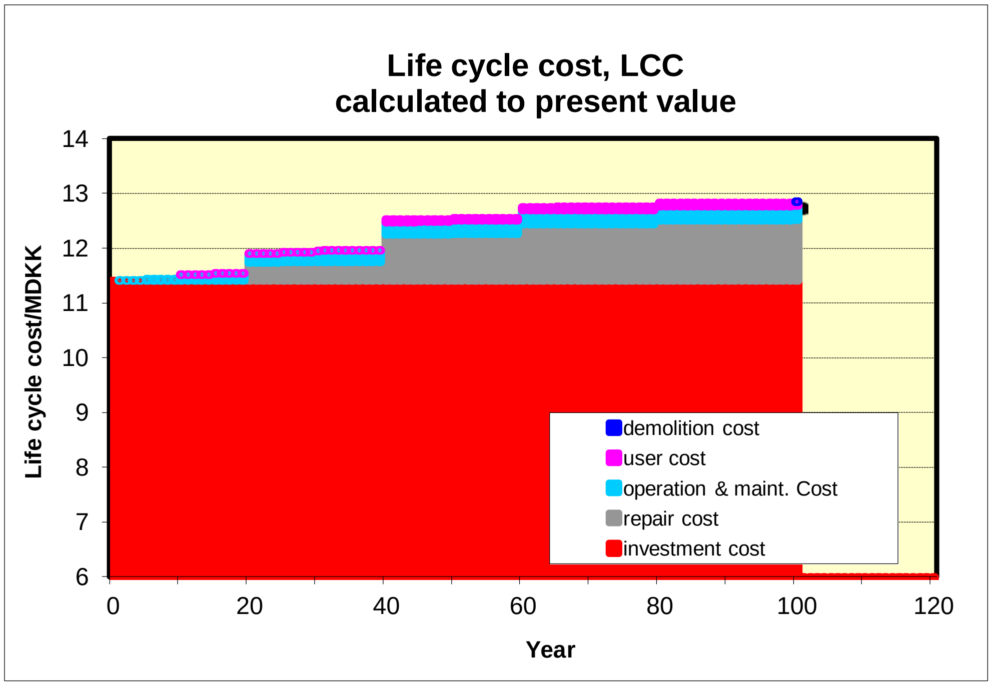


Figure 7-2 Whole life cycle cost for Vindingevej bridge. Calculated to present value.

The accumulated cost (net present value) for repair during the entire service life of the bridge is shown in Figure 7-3 along with the repair cost (not calculated to net present value) at different intervals (in accordance with the O&M plan) along the service life.

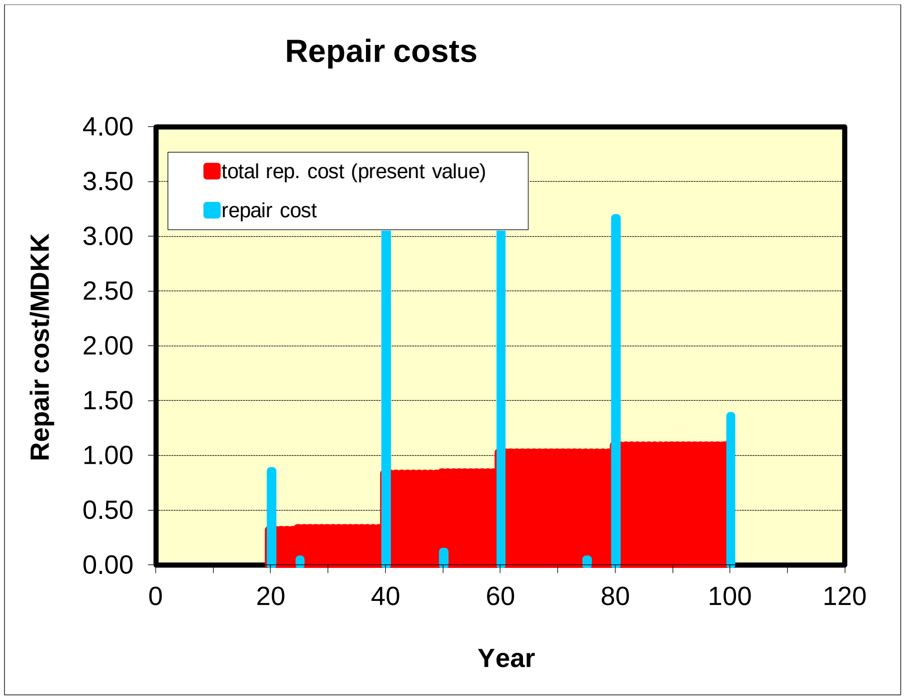


Figure 7-3 Accumulated repair cost (net present value) and repair cost (not calculated to net present value).

The repair costs presented in Figure 7-3 do not consider the associated user costs. Results showing the repair costs and the related costs due to traffic delays, i.e. user costs, are illustrated in Figure 7-4. Those costs are not converted to net present value.

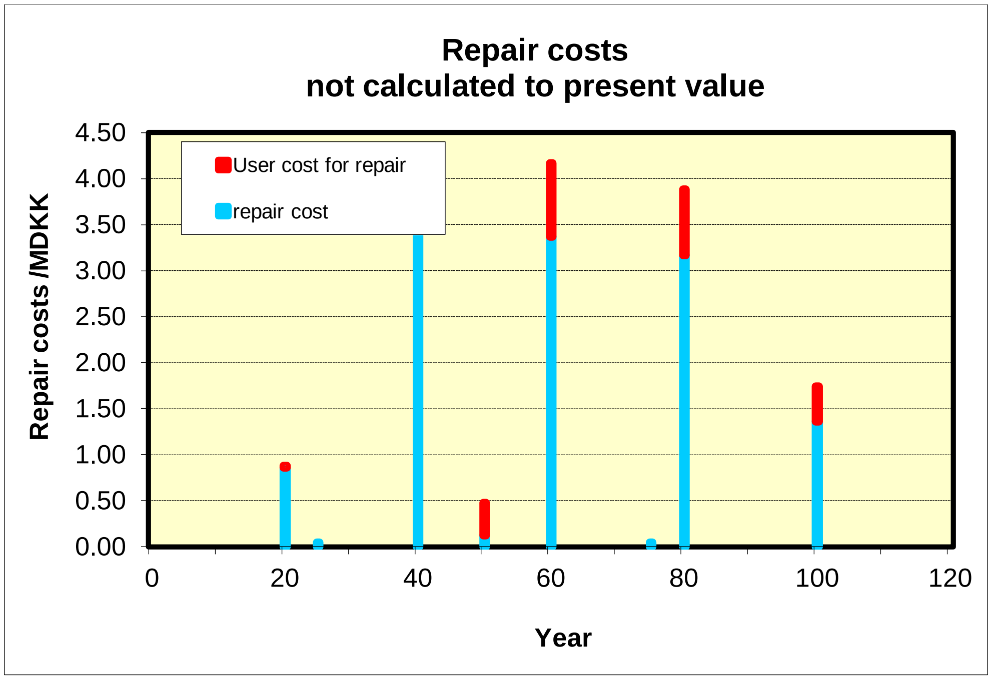


Figure 2-4 Repair costs and associated user costs. Not converted to net present value.

The accumulated cost for operation and maintenance (calculated to net present value) is presented in Figure 7-5 along with the cost for operation and maintenance (not converted to net present value) in accordance with the O&M plan.

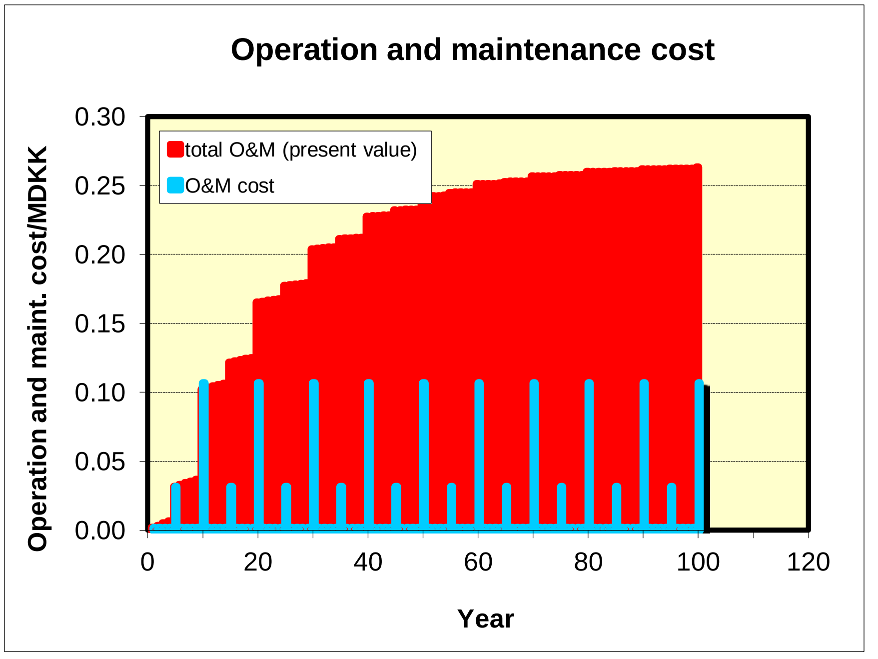


Figure 7-5 Accumulated cost for operation and maintenance (converted to net present value) and cost for operation and maintenance in accordance with O&M plan (not calculated to net present value).

Apart from costs to maintenance of road lights every year, the total cost for operation and maintenance consists of costs for general inspection (every 5th year) and costs for special inspections (every 10th year). Special inspections are usually not planned in advance, but have been inserted in this way due to limitations of the LCC tool. The related user costs are not presented in Figure 7-5. It is assumed in the O&M plan that most operation and maintenance work is carried out without interruptions of the traffic. Thus the user costs in this context are negligible, and therefore not included. This is seen from Figure 7-6, illustrating the user costs converted to net present value associated with repair and operation and maintenance, respectively.

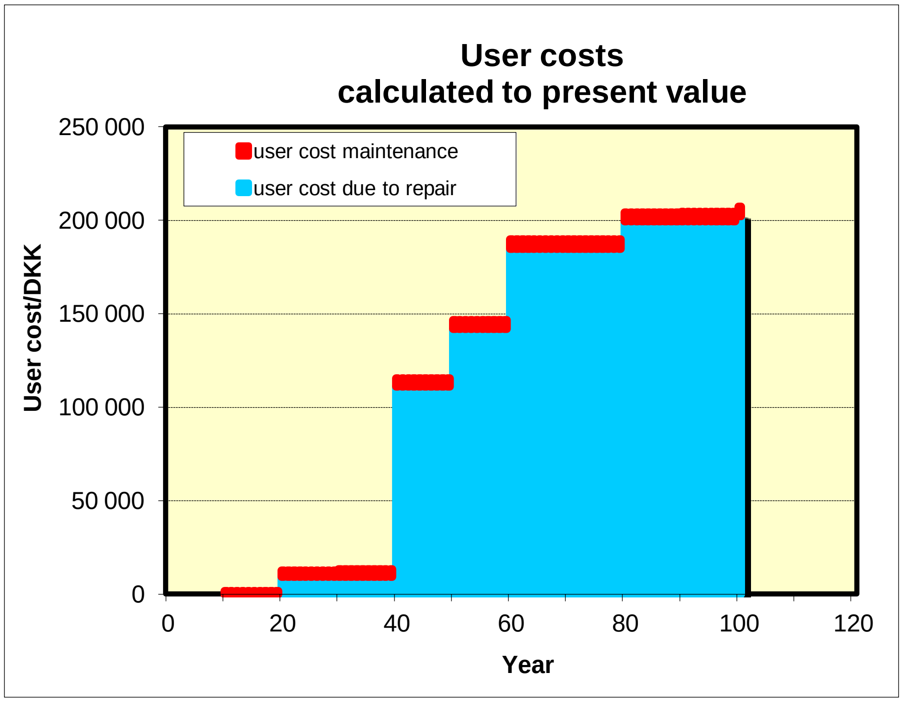


Figure 7-6 User costs related to repair and operation and maintenance, respectively (converted to net present value).

The illustrations of the results from the LCC calculations presented in Figure 4 - Figure 9 provide a general overview of the costs related to the project. However, it is not possible to identify the cost-drivers within a sub-category, e.g. repair. In order to evaluate the cost-drivers it is necessary to analyse the calculations forming the basis of the *results*-sheet, i.e. comparing the costs for different work.

9.2 Results from LCA calculations

Based on the quantities derived from the bill of quantities and the quantities from the operation, maintenance and repair, LCA results have been calculated.

The results from assessing the Vindingevej bridge by using Bridge LCA is depicted in the following figures.

In the first figure, the relative midpoint LCIA results are presented.

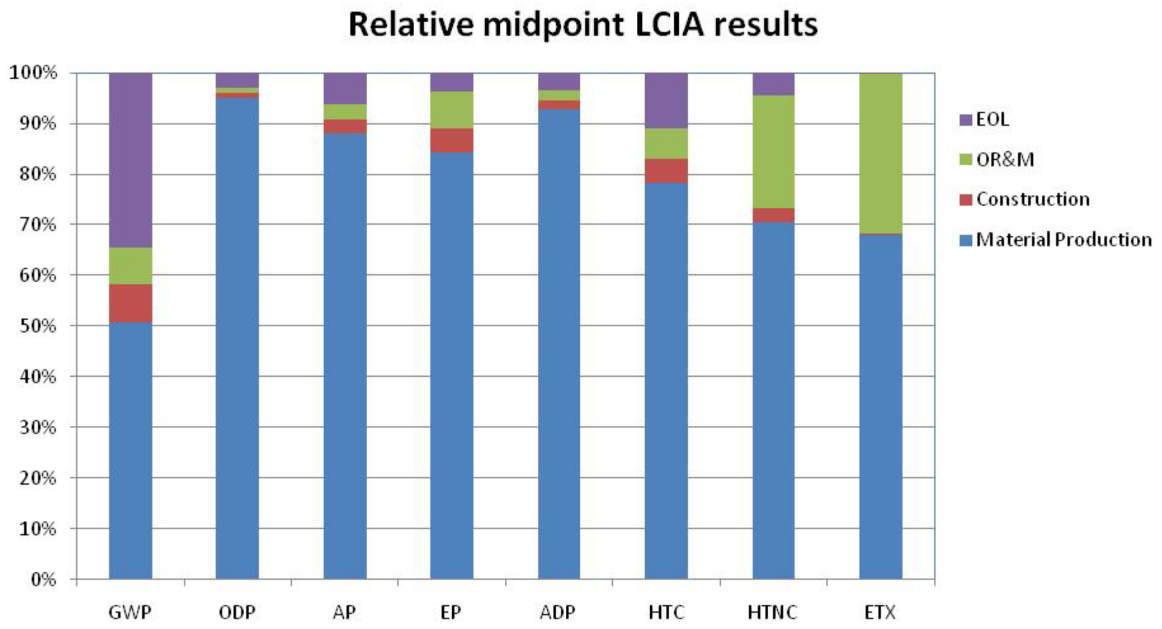


Figure 7-3: Relative midpoint LCIA results from assessing the Vindingevej bridge

This figure shows that the material production is contributing the most to the total potential environmental impact.

O&M shows significance for the potential impacts from toxicity.

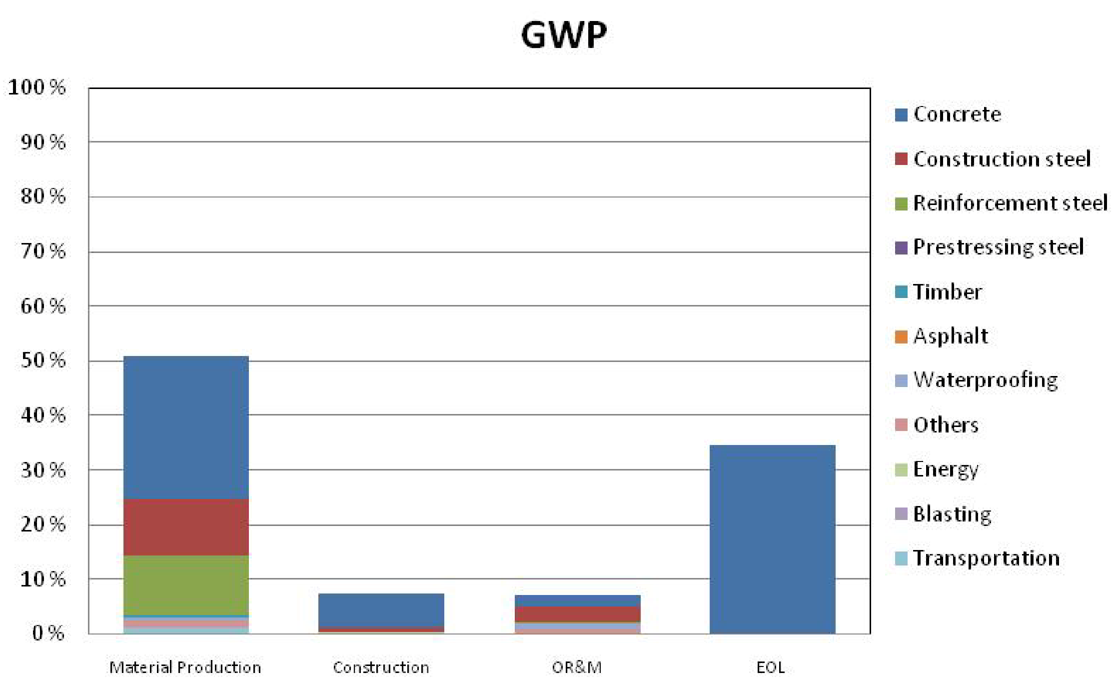


Figure 7-4: An example of the results from the LCA calculation in Bridge LCA. The figure shows normalised and weighted potential impacts on global warming.

From Figure 7-8 it can be concluded that steel causes the largest potential environmental impacts. The emission factors for steel must however be assessed further to be able to make a final conclusion.

It can also be concluded that the materials phase has the highest potential environmental impact. This is the case when the daily use of the bridge is not incorporated into the calculations. It is possible to insert data for the diesel consumption (in litres) but Bridge LCA has not been designed to incorporate this impact specifically.

The normalised figures show the same as the weighted figures due to the current incorporated weighting factors of 1.

The normalised impacts are divided into impact categories for the entire life cycle of the bridge:

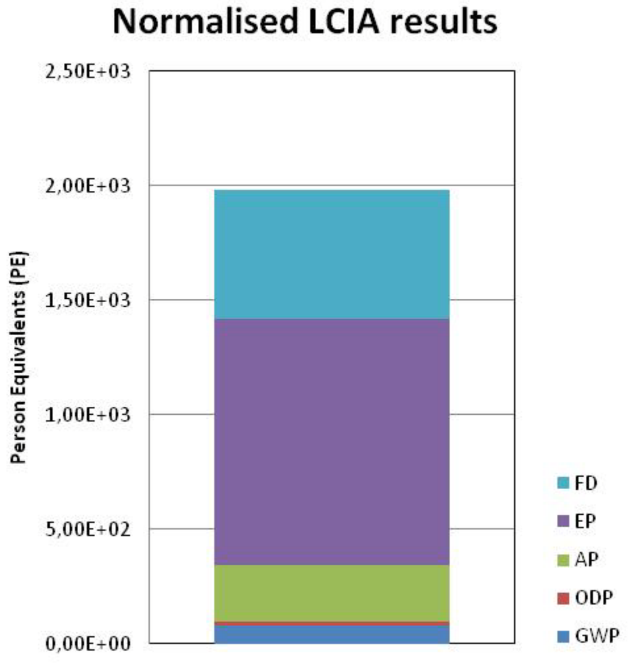


Figure 7-5: Normalised potential environmental impacts during the full life time of the bridge.

From this figure it is clear that the largest potential environmental impact is eutrophication. This impact primarily derives from the steel and zinc coating.

The importance of these potential environmental impacts is related to the average contribution from one average person per year.

FD expresses the fossil depletion and is the second largest potential environmental impact and related to the energy consumption during the life time of the bridge.

Energy

It is possible to assess the energy consumption via the following figures:

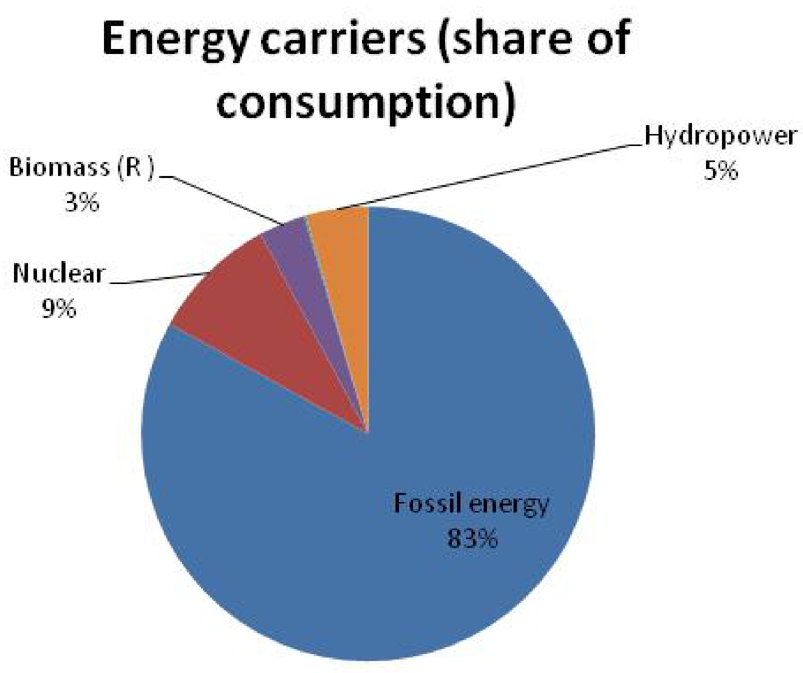


Figure 7-6: Energy consumption split into energy carriers

As the data primarily derives from the Swiss database Ecoinvent, the energy carriers are primarily fossil fuels and nuclear power.

This picture will change when figures for Danish conditions are inserted.

The result can also be shown in another way where the user can see the large consumers of energy in the materials phase:

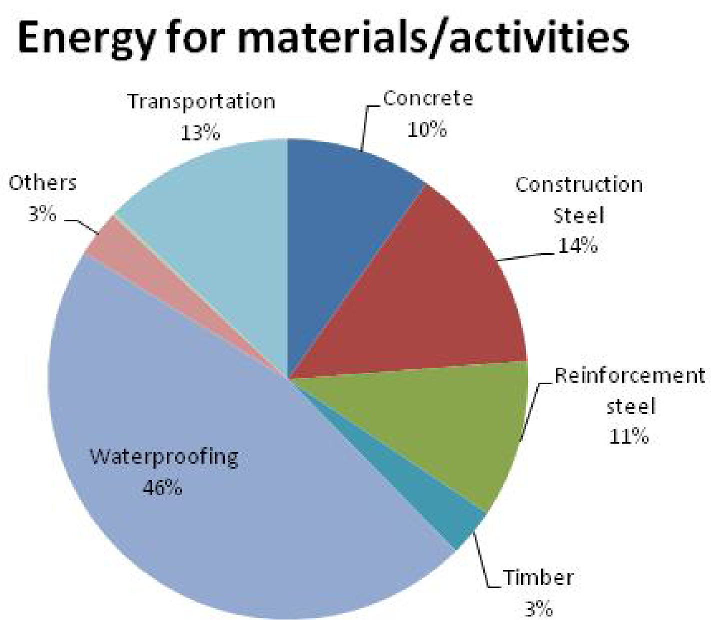


Figure 7-7: Energy for materials

As can be seen, the waterproofing membrane uses the highest amount of energy, using data from Bridge LCA. The second largest consumer is steel. Data for the specific waterproofing membrane need a further evaluation as the result is higher than expected.

Traffic

In Bridge LCA it is possible to insert traffic during road works. On the other side, it is not possible to insert the daily traffic from normal use of the bridge.

First of all, the importance of modelling and including potential environmental impacts from traffic during road works has been evaluated. It can be concluded that the traffic during road works has little potential impact compared to the daily traffic; 6% during the full lifetime of the bridge.

The daily traffic during the full life time of the project has great significance to the LCA result (the traffic during use stage has by far larger potential impacts than the other phases of the project (materials phase, OR&M and end-of-life)).

9.2.1 Areas for optimization

During the test of Bridge LCA it can be concluded that some parts of Bridge LCA can be optimised for he specific use in Denmark.

The possible areas for optimization are:

- Modelling of end-of-life
- Incorporation of Danish values for cement/concrete

- Incorporation of values for steel which are relevant for Danish bridge projects
- Possibilities to incorporate daily traffic of the bridge
- Expansion of the bridge to include roads, tunnels etc.
- Development of weighting factors
- Development of a roadmap to maintain the tool including updating emission factors
- Analyse the data to assess the significance of using generic data from Ecoinvent especially in relation to the use of energy (amount and type of fuel/energy carrier)

9.3 Concrete data, service life and optimisation

In the Nordic countries different approaches and requirements to concrete mixtures applied for various bridge parts exist, depending on national Annexes to EN standards as EN 206-1, and local regulations from national authorities.

Such local regulations are typically based on long term experience with specific locally produced cement types which may differ substantially between countries. Therefore, environmental impacts from different concrete types may vary from country to country, and it is recommended that country specific values are applied in the Bridge LCA-tool. The same applies for steel, with concrete and steel being the largest single contributors to environmental impacts from bridges.

For Danish conditions not many degrees of freedom are left for the specification of concrete mixtures, following EN standards with national annexes and the Road Directorate's general specifications for concrete works (AAB). Moreover, ready mix concrete suppliers deliver standardized concrete mixtures which are certified meaning that any alternative concrete mix will have to undergo a new and extensive pre-testing programme before acceptance. This will not be feasible for smaller bridge projects.

For the actual bridge at Vindingevej CO_2 contributions from cement have been calculated as an example only for CO_2, based on m^3 of concrete delivered for the construction of the bridge, see Table 7-1. The concrete mixtures typically include about 15-20% of added fly ash which does not add much to the CO_2 emission.

Table 7-1: Data for concrete used at Vindingevej based on CO_2 emission from cement.

Bridge part	Concrete, m^3	Cement content, kg/m^3	CO_2 emission* cement, kg/ton	CO_2 emission, total, ton
Foundation	54	285	926	14.3
Columns, walls	206	341	926	65.0
Bridge deck, edge beams	551	341	926	174.0
∑				253.3

**Data from cement supplier*

It is worth to remark that only 2-3 years ago the single Danish cement type allowed for aggressive (A) and extra aggressive (E) exposure conditions following AAB had a CO_2 emission of 1,240 kg CO_2 per ton, e.g. the emission for the Vindingevej bridge would have been 25 % higher. At the same time a requirement of maximum allowable CO_2 emission per m^3 of concrete was specified for the new Metrocityring in Copenhagen, making it difficult to fulfil the requirement with the specific Danish cement type.

The 25 % reduction has been caused by altered and more energy effective production methods from the cement factory which in this case has demonstrated responsibility in reducing CO_2 emissions and continued efforts for further reductions for all cement products are on-going

For maintenance activities during the estimated 100 years of service life about 40 m^3 of concrete needs to be replaced, following the O&M plan. This will imply an additional CO_2 contribution of 12.6 ton CO_2 which is ~5 % of CO_2 emission from concrete in the construction phase.

9.3.1 Service life

An overview of service life evaluations for concrete based on standards and guidelines and actual exposure conditions are attached in Appendix, in a Technical Note prepared earlier in the ETSI project on Methodology for LCC and LCA tools. Concrete durability and a long service lifetime are essential for large infrastructure investments involving concrete.

Service life estimations are a critical element in the development of LCC/LCA systems, to obtain accurate life cycle assessments and to compare different options.

9.3.2 Future optimisation

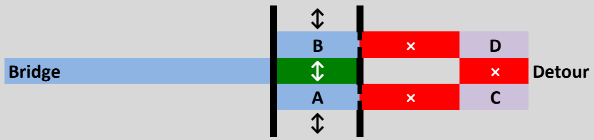
For optimising and obtaining greener concretes for future bridge structures a number of recommendations already exists, using larger mineral additions of e.g. fly ash and blastfurnace slag cements, thereby reducing the content of Portland cement.

Inside existing standards and requirements some CO_2 reductions can be obtained, especially by use of blastfurnace slag cements (reduction up to about 50 %) or high contents of fly ash, however resources of blastfurnace slag and fly ash are not large compared with the size of cement production.

Outside existing standards reduction possibilities are larger, also without compromising service life time, and test and trial bridges with innovative materials should be supported from relevant authorities to gain necessary experience.

Also, universities and the cement industry are involved in research introducing new low-energy cement types with similar properties as today. However, it will take decades before such new products are accepted and included into standards.

Fuel Consumption Impacts of Traffic Congestion during maintenance and detour



This is a simplified calculator for vehicle fuel consumption for three possible bridge scenarios.
The calculator consists of 4 waypoints and 4 possible paths. A and B are on each end of the bridge. C and D are access points to the detour as there might be situations where smaller roads need to be used to access the actual detour road. When the bridge is open two ways, there is no detour. If the bridge is open only one way or closed, the detour is accessed through waypoints C and D.

Bridge is open	2	**ways**
Duriation	0	**days**

				Distance [km]	Average Vehicle Speed [km/h]	Average Daily Traffic [Vehicles]	Vehicle Travel Time [minutes]	Traffic Load	Total Petrol Consumed [kg]	Total Diesel Consumed [kg]
Bridge	A	↕	B	0,25	50	1000	0,3	Congested	0	0
Detour access A	A	×	C	0,80	60	0	∞	Free Flowing	0	0
Detour	C	×	D	1,00	60	0	∞	Free Flowing	0	0
Detour access B	B	×	D	1,20	50	0	∞	Free Flowing	0	0

Average l/100km petrol	Average l/100km diesel
32,4	54,8
0,0	0,0
0,0	0,0
0,0	0,0

				Total Distance [km]	Average Speed [km/h]
Total Route	A	→	B	0,25	50
Total Route	B	→	A	0,25	50

Vehicle	Fuel	Mix
Passenger Car	Petrol	46%
Passenger Car	Diesel	39%
Bus	Diesel	0%
Lorry	Diesel	15%

Emissions	Petrol	Diesel
kg CO2	0	0
g CO	0	0
g HC	0	0
g NO	0	0

kg CO2-eq	477569	1328469
kg SO2-eq	514	4734

INPUT TABLE FOR BRIDGE LCA

Project:	Vindingevej	Analyst:	Linda Heibye, LAN	Date:	25.4.2012	RUN:	

Bridge situation	Denmark
Emission data	Denmark

Life cycle stages: Material production / Construction / OR&M / End of Life

Material production

Group	Material	Quality	Specific codes	Unit	1.1 Foundation slab	1.4 Piles	1.5 Erosion protection	3.1 Abutments	3.2 Piers	3.3 Covering of bridge support structure	4.1 Slab/deck	4.2 Beam, girder	4.3 Truss	4.4 Arch, vault	4.5 Cable System	4.6 Pipe, culvert	5.1 Cross beam	5.2 Wind bracing Truss	6.1 Bearing and hinge	6.2 Edge beam	6.3 Insulation and water proofing	6.4 Surfacing	6.5 Parapet, railing	6.6 Expansion joint	6.7 Drainage system
Major LCA impact	1. Concrete	1.1 C25/30	XC2; CEM II/A-M(S-LL) 4	m3				7,5														46,0			39,0
		1.2 C30/37	XC3, XC4, XF2, XD1; CEM	m3	54,0																				
		1.3 C45/55	XC3, XC4, XF4; CEM II/A	m3		59,1					551,0														
		1.4 C55/67	XC4, XS3, XF4; CEM II/A	m3																					
		1.5 C55/67 "Element Concrete"	XC3, XC4, XF4; CEM II/A	m3																					
		1.6 Self Compacting Concrete SCC C55/67	XC4, XS3, XF4; CEM II/A	m3																					
		1.7 Reinforced concrete pile C40/50	XC2; CEM II/A-LL 42,5 R	m3																					
	2. Construction Steel	2.1 S355NL		ton			79,6				30,0														
		2.3 1.4404		ton																					
		2.4 1.4301		ton																					
		2.5 S355K2W (weathering steel)		ton																			31,3		
	3. Reinforcement steel	3.1 A500HW		ton	6,0	3,1			5,0		53,0														
		3.2 B600KX (1.4301) Cold-rolled		ton																					
		3.3 B600KX (1.4301) Hot-rolled		ton																					
	4. Prestressing steel	4.1 St 1640/1860		ton																					
		4.2 Cables (Cable stayed and Suspension bridges)		ton																					
	5. Timber	5.1 Sawn timber		m3	0,9				2,7		25,3												14,0		
		5.2 Glue laminated timber		m3																					
	6. Asphalt	6.1 Asphalt concrete [AC 16/120]		m3																					
		6.2 Stone Mastic Asphalt [SMA 16/20]		m3																					
		6.3 Polymer Modified Mastic Asphalt [PMMA 16/80]		m3																					
Minor LCA impact	7. Waterproofing	7.1Asphalt membrane (double) (thickness 20 mm)		m2																	722,0				
		7.2 Epoxy (thickness 6 mm)		m2																	963,0				
		7.3 Rubberized bitumen lotion (0,2 kg/m2)		m2																					
		7.4 Asphalt Mastic (thickness 20 mm)		m2																		4589,0			
		7.5 Polyurethane (thickness 8 mm)		m2																					
	8. Others	8.1 Zinc coating (100 µm)		m2																			1197,0		
		8.2 Paint EPZn(R)EPPUR320/5-FeSa 2½ (thickness 320 µm)		m2																					
		8.3 Glass		kg																					
		8.4 Creosite impregnation (60 kg/m3)		m3																					
		8.5 Salt impregnation (10kg/m3)		m3																					
		8.6 Acryl (Plexiglass)		m3																					
		8.7 Polycarbonate (Plexiglass)		m3																					
		8.8 Plastic (PEH)		kg											1680										818
		8.X ...		xx																					
Other input factors	9. Energy	9.1 Diesel		l																					
		9.2 Electricity		kwh																					
		9.x																							
	10. Blasting	10.1 Blasting		kg																					
	11 Transportation	11.1 Material transportation ship		tkm	0			0			0						0		0						
		11.2 Material transportation truck		tkm	12179376			0			0						0		0						
		11.3 Material transportation train		tkm	0			0			0						0		0						
		11.4 Transportation workers (car)		pkm																					
		11.5 Petrol fuel consumption, Passenger vehicle mixed fleet		kg																					
		11.6 Diesel fuel consumption, vehicle mixed fleet		kg																					

Construction, OR&M, End of Life

Quality	Construction work	1.2 Excavation soil	1.3 Excavation rock	2.1 Embankment, embankment end, back fill	2.2 Soil reinforcement and slope protection	OR&M	Input to demolition	Materials to Landfill	Materials to material recovery	Materials to energy recovery	Total material amounts
1.1 C25/30						35,4	127,9				127,9
1.2 C30/37							54,0				54,0
1.3 C45/55				177,0		18,4	805,5				805,5
1.4 C55/67						1,2	1,2				1,2
1.5 C55/67 "Element Concrete"							0,0				0,0
1.6 Self Compacting Concrete SCC C55/67						13,8	13,8				13,8
1.7 Reinforced concrete pile C40/50							0,0				0,0
2.1 S355NL				16,0		2,6			128,2		128,2
2.3 1.4404									0,0		0,0
2.4 1.4301									0,0		0,0
2.5 S355K2W (weathering steel)						15,0			46,3		46,3
3.1 A500HW						1,0			68,1		68,1
3.2 B600KX (1.4301) Cold-rolled									0,0		0,0
3.3 B600KX (1.4301) Hot-rolled									0,0		0,0
4.1 St 1640/1860									0,0		0,0
4.2 Cables (Cable stayed and Suspension bridges)									0,0		0,0
5.1 Sawn timber						1,8				44,7	44,7
5.2 Glue laminated timber											0,0
6.1 Asphalt concrete [AC 16/120]									0,0		0,0
6.2 Stone Mastic Asphalt [SMA 16/20]									0,0		0,0
6.3 Polymer Modified Mastic Asphalt [PMMA 16/80]									0,0		0,0
7.1Asphalt membrane (double) (thickness 20 mm)						914,8				1636,8	1636,8
7.2 Epoxy (thickness 6 mm)						1694,0				2657,0	2657,0
7.3 Rubberized bitumen lotion (0,2 kg/m2)										0,0	0,0
7.4 Asphalt Mastic (thickness 20 mm)						174,2				4763,2	4763,2
7.5 Polyurethane (thickness 8 mm)						474,5				474,5	474,5
8.1 Zinc coating (100 µm)						1423,0					2620,0
8.2 Paint EPZn(R)EPPUR320/5-FeSa 2½ (thickness 320 µm)											0,0
8.3 Glass										0,0	0,0
8.4 Creosite impregnation (60 kg/m3)											0,0
8.5 Salt impregnation (10kg/m3)											0,0
8.6 Acryl (Plexiglass)										0,0	0,0
8.7 Polycarbonate (Plexiglass)										0,0	0,0
8.8 Plastic (PEH)										2497,5	2497,5
8.X ...										0,0	0,0
9.1 Diesel		43216,0									43216,0
9.2 Electricity											0,0
9.x											0,0
10.1 Blasting											
11.1 Material transportation ship	0					0		0			0
11.2 Material transportation truck	0					0		0			12179376
11.3 Material transportation train	0					0		0			0
11.4 Transportation workers (car)											0
11.5 Petrol fuel consumption, Passenger vehicle mixed fleet						0					0
11.6 Diesel fuel consumption, vehicle mixed fleet						0					0
											0

Transportation gate to site / Transportation O&M / Transportation EOL / Calculation factors

Quality	Gate to site: Transportation Ship (km)	Gate to site: Transportation lorry (km)	Gate to site: Transportation train (km)	O&M: Transportation Ship (km)	O&M: Transportation lorry (km)	O&M: Transportation train (km)	EOL: Transportation Ship (km)	EOL: Transportation lorry (km)	EOL: Transportation train (km)	Material density	Material density, default values	Unit	Material/ Layer thicknesses	Material/ Layer thicknesses default values	Unit
1.1 C25/30										2,38	2,38	ton/m3			
1.2 C30/37										2,38	2,38	ton/m3			
1.3 C45/55										2,38	2,38	ton/m3			
1.4 C55/67										2,38	2,38	ton/m3			
1.5 C55/67 "Element Concrete"										2,38	2,38	ton/m3			
1.6 Self Compacting Concrete SCC C55/67										2,38	2,38	ton/m3			
1.7 Reinforced concrete pile C40/50										2,38	2,38	ton/m3			
2.1 S355NL															
2.3 1.4404															
2.4 1.4301															
2.5 S355K2W (weathering steel)															
3.1 A500HW															
3.2 B600KX (1.4301) Cold-rolled															
3.3 B600KX (1.4301) Hot-rolled															
4.1 St 1640/1860															
4.2 Cables (Cable stayed and Suspension bridges)															
5.1 Sawn timber										0,50	0,50	ton/m3			
5.2 Glue laminated timber										0,55	0,55	ton/m3			
6.1 Asphalt concrete [AC 16/120]										2,40	2,40	ton/m3	0,05	0,05	m
6.2 Stone Mastic Asphalt [SMA 16/20]										2,40		ton/m3	0,05		m
6.3 Polymer Modified Mastic Asphalt [PMMA 16/80]										2,40		ton/m3	0,05		m
7.1Asphalt membrane (double) (thickness 20 mm)										2,17	2,17	ton/m3	0,00	0,02	m
7.2 Epoxy (thickness 6 mm)										2400,00	2400,00	kg/m3	0,01	0,01	m
7.3 Rubberized bitumen lotion (0,2 kg/m2)										0,20	0,20	kg/m2			
7.4 Asphalt Mastic (thickness 20 mm)										0,00	0,00	ton/m3	0,02	0,02	m
7.5 Polyurethane (thickness 8 mm)										2400,00	2400,00	kg/m3	0,01	0,01	m
8.1 Zinc coating (100 µm)															
8.2 Paint EPZn(R)EPPUR320/5-FeSa 2½ (thickness 320 µm)														320,00	um
8.3 Glass										0,00	0,00	ton/kg			
8.4 Creosite impregnation (60 kg/m3)															
8.5 Salt impregnation (10kg/m3)															
8.6 Acryl (Plexiglass)															
8.7 Polycarbonate (Plexiglass)															
8.8 Plastic (PEH)										0,00	0,00	ton/kg			
8.X ...										1,00					

Transportation ship (tkm) / Transportation truck (tkm) / Transportation train (tkm)

Quality	Ship: Foundation	Ship: Abutments and piers	Ship: Main load bearing structure	Ship: Secondary Load bearing system	Ship: Equipment	Ship: Construction	Ship: Operation and maintenance	Ship: End of Life	SUM Ship transportation (tkm)	Truck: Foundation	Truck: Abutments and piers	Truck: Main load bearing structure	Truck: Secondary Load bearing system	Truck: Equipment	Truck: Construction	Truck: Operation and maintenance	Truck: End of Life	SUM Lorry transportation (tkm)	Train: Foundation	Train: Abutments and piers	Train: Main load bearing structure	Train: Secondary Load bearing system	Train: Equipment	Train: Construction	Train: Operation and maintenance	Train: End of Life	SUM Train transportation (tkm)
1.1 C25/30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.2 C30/37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.3 C45/55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.4 C55/67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 C55/67 "Element Concrete"	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.6 Self Compacting Concrete SCC C55/67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.7 Reinforced concrete pile C40/50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.1 S355NL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.3 1.4404	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.4 1.4301	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.5 S355K2W (weathering steel)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.1 A500HW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.2 B600KX (1.4301) Cold-rolled	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.3 B600KX (1.4301) Hot-rolled	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.1 St 1640/1860	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.2 Cables (Cable stayed and Suspension bridges)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.1 Sawn timber	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.2 Glue laminated timber	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.1 Asphalt concrete [AC 16/120]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.2 Stone Mastic Asphalt [SMA 16/20]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.3 Polymer Modified Mastic Asphalt [PMMA 16/80]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.1Asphalt membrane (double) (thickness 20 mm)									0									0									0
7.2 Epoxy (thickness 6 mm)									0									0									0
7.3 Rubberized bitumen lotion (0,2 kg/m2)									0									0									0
7.4 Asphalt Mastic (thickness 20 mm)									0									0									0
7.5 Polyurethane (thickness 8 mm)									0									0									0
8.1 Zinc coating (100 µm)									0									0									0
8.2 Paint EPZn(R)EPPUR320/5-FeSa 2½ (thickness 320 µm)									0									0									0
8.3 Glass									0									0									0
8.4 Creosite impregnation (60 kg/m3)									0									0									0
8.5 Salt impregnation (10kg/m3)									0									0									0
8.6 Acryl (Plexiglass)									0									0									0
8.7 Polycarbonate (Plexiglass)									0									0									0
8.8 Plastic (PEH)									0									0									0
8.X ...									0									0									0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

General conditions

Name of bridge:	Bridge at Vindingevej, across M11
Project number:	Bridge no 72.10
Administrator:	BBU, JTL, AHPE & ADSO
Date:	2012-04-24

Climate zone:		South Sweden
Road salting		Normal salt spreadin
Investment cost according to tender	CUR	11.400.000
Demolition cost in % of investment cost	%	10,0
Calculus period	years	100
Yearly real interest rent	%	5,0
Traffic **on** bridge		
Average daily traffic, ADT		9.554
Percentage of trucks	%	15,0
Allowed speed on the bridge	km/h	50
Reduced speed due to repair actions	km/h	30
Hourly cost, car	CUR/h	105
Hourly cost, truck	CUR/h	345
Traffic **below** bridge		
Average daily traffic, ADT		40.400
Percentage of trucks	%	15,0
Allowed speed below the bridge	km/h	110
Reduced speed due to repair actions	km/h	70
Hourly cost, car	CUR/h	105
Hourly cost, truck	CUR/h	345
Bridge length (total)	m	51,6
Lengths of edge beams	m	103
Effective bridge width	m	14,0
Total bridge width	m	16,0
Bridge area	m^2	825
Area of surfacing	m^2	722
Painted area (steel beams etc)	m^2	0
Number of railings (parapets)	st	2
Total length of railings(parapets)	m	103

	Weighting inputted default intervals factor	own factor
Climate zone	1,0	1,0
Average daily traffic, ADT	1,0	1,0
Saltning	1,0	1,0
Construction part subjected to salt action	1,0	1,0
Concrete quality > C30/C37	1,0	1,0
Concrete cover > Standard	1,0	1,0

Investment cost

	New construction costs	
	Unit price	
formwork	1.274	CUR/m^2
concrete	1.395	CUR/m^3
steel (sheet piles)	8.588	CUR/ton
reinforcement	10.910	CUR/ton
cables	585	CUR/m
rammed piles	516	CUR/m
parapet	1.970	CUR/m
insulation	654	CUR/m^2
surfacing	988	CUR/m^2

Dotted fields contain the default values evaluated with the help of previously entered data. You have the possibility to input your own values in the fields.

	Quantities for calculation of investment cost							
	formwork [m^2]	concrete[m^3]	reinf. [ton]	steel [ton]	cables [m]	piles [m]	others, total cost	cost
SUBSTRUCTURE								
foundation slab	31	54	6			294		331.994
pier & column	101	29	5					223.628
abutment + wing wall	589	177	17					1.182.476
sheet piles				78,3				672.300
ground anchors							873.500	873.500
Interim wall							92.000	92.000
backfill							162.065	162.065
SUPERSTRUCTURE								
cables					801			468.375
bridge deck + edge beams	993	553	52					2.603.202
superstructure others							53.720	53.720
BRIDGE DETAILS								
bearing							27.600	27.600
insulation							472.087	472.087
surfacing							713.660	713.660
railing or parapet							250.200	250.200
drainage system							81.040	81.040
bridge details others							85.528	85.528
OTHERS								
demolition of old bridge							306.112	306.112
ROAD PROJECT								
ground works							558.750	558.750
drainage system							194.250	194.250
gravel							148.500	148.500
surfacing							1.617.000	1.617.000
equipment							294.000	294.000
							Σ Investment cost/CUR	11.411.987

Operation and Maintenance cost

dotted fields contain the default values evaluated with the help of previously entered data. You have the possibility to input your own values in the fields.

	MR&R unit cost & quantities			MR&R interval alt. Single year				Traffic disturbance		MR&R cost		User cost	
	unit costs		quantities	interval, year	action year	action year	action year	days	length	cost each time	tot cost	cost each time	tot cost
Maintenance of road lighting	625	CUR		1	0	0	0			625	12.405	0	0
Superficial inspection	30.000	CUR		5	0	0	0			30.000	107.759	0	0
Main inspection	75.000	CUR		10	0	0	0	1,0	0,1	75.000	118.350	1.796	2.834
Cleaning	0,76	CUR/m²	825	1	0	0	0			625	12.405	0	0
Cleaning of drainage system	625	CUR		1	0	0	0			625	12.405	0	0
										Σ present cost	263.324 kr	Σ present cost	2.834 kr

Operation and Maintenance cost

dotted fields contain the default values evaluated with the help of previously entered data. You have the possibility to input your own values in the fields.

	MR&R unit cost & quantities			MR&R interval alt. Single year				Traffic disturbance		MR&R cost		User cost	
	unit costs		quantities	interval, year	action year	action year	action year	days	length	cost each time	tot cost	cost each time	tot cost
Maintenance of road lighting	625	CUR		1	0	0	0			625	12.405	0	0
Superficial inspection	30.000	CUR		5	0	0	0			30.000	107.759	0	0
Main inspection	75.000	CUR		10	0	0	0	1,0	0,1	75.000	118.350	1.480	2.335
Cleaning	0,76	CUR/m^2	825	1	0	0	0			625	12.405	0	0
Cleaning of drainage system	625	CUR		1	0	0	0			625	12.405	0	0
										Σ present cost	263.324 kr	Σ present cost	2.335 kr

Repair cost

<Repair alt new part>

Dotted fields contain the default values evaluated with the help of previously entered data. You have the possibility to input your own values in the fields.

	Repair quantities and unit costs			MR&R interval alt. Single year				Traffic disturbance		Input for weighting of time interval			Repair cost		User cost	
	unit cost		quantities	interval, year	action year	action year	action year	days	length	salt exposure	Concrete quality CX/37	cover qoutient	cost each time	tot cost	cost each time	tot cost
SUBSTRUCTURE																
Abutment, shotcrete repair, no rebar	5.500	CUR/m²	24		60								132.000	7.067	0	0
Abutment, shotcrete repair, with rebar	8.600	CUR/m²	6		60								51.600	2.762	0	0
Piers, shotcrete repair, no rebar	5.500	CUR/m²	17		60								90.750	4.858	0	0
Piers, shotcrete repair, with rebar	8.600	CUR/m²	6		60								47.300	2.532	0	0
SUPERSTRUCTURE																
Shotcrete repair of superstructure	7.300	CUR/m²	80		40	60	80						584.000	126.003	0	0
Replacement of edge beams	12.200	CUR/m	100	60				70,0	0,2				1.220.000	65.313	188.596	10.097
Shotcrete repair of edge beams	12.100	CUR/m²	32		60	100							384.780	23.525	0	0
BRIDGE DETAILS																
Replacement of bearings	24.000	CUR/item	3	50									72.000	6.826	0	0
Replacement of waterproofing system and surfacing	3.500	CUR/m²	722	40				112,0	0,2				2.526.930	409.925	301.754	48.951
Replacement of wearing course	600	CUR/m²	779		20	60	100	14,0	0,1				467.400	204.735	25.146	11.015
Replacement of bituminous sealing joint	2.100	CUR/m	28	20									58.800	35.295	0	0
Replacement of parapets (no strengthning of edge beams)	2.800	CUR/m	127		40								355.600	50.511	0	0
Regalvanizing of parapets	2.600	CUR/m	127		20	60	100						330.200	144.637	0	0
Replacement of lighting	50.000	CUR/item	1	25									50.000	20.793	0	0
													Σ present value	1.104.784 kr	Σ present value	70.063 kr

Repair cost

<Repair alt new part>

Dotted fields contain the default values evaluated with the help of previously entered data. You have the possibility to input your own values in the fields.

	Repair quantities and unit costs			MR&R interval alt. Single year				Traffic disturbance		Input for weighting of time interval			Repair cost		User cost	
	unit cost		quantities	interval, year	action year	action year	action year	days	length	salt exposure	Concrete quality CX/37	cover qoutient	cost each time	tot cost	cost each time	tot cost
SUBSTRUCTURE																
Abutment, shotcrete repair, no rebar	5.500	CUR/m^2	24		60								132.000	7.067	0	0
Abutment, shotcrete repair, with rebar	8.600	CUR/m^2	6		60								51.600	2.762	0	0
Piers, shotcrete repair, no rebar	5.500	CUR/m^2	17		60			7,0	0,9				90.750	4.858	176.071	9.426
Piers, shotcrete repair, with rebar	8.600	CUR/m^2	6		60								47.300	2.532	0	0
SUPERSTRUCTURE																
Shotcrete repair of superstructure	7.300	CUR/m^2	80		40	60	80	14,0	1,0				584.000	126.003	414.284	89.385
Replacement of edge beams	12.200	CUR/m	100	60									1.220.000	65.313	0	0
Shotcrete repair of edge beams	12.100	CUR/m^2	32		60	100							384.780	23.525	0	0
BRIDGE DETAILS																
Replacement of bearings	24.000	CUR/item	3	50				14,0	0,9				72.000	6.826	352.141	33.386
Replacement of waterproofing system and surfacing	3.500	CUR/m^2	722	40									2.526.930	409.925	0	0
Replacement of wearing course	600	CUR/m^2	779		20	60	100						467.400	204.735	0	0
Replacement of bituminous sealing joint	2.100	CUR/m	28	20									58.800	35.295	0	0
Replacement of parapets (no strengthning of edge beams)	2.800	CUR/m	127		40	80							355.600	50.511	0	0
Regalvanizing of parapets	2.600	CUR/m	127		20	60	100						330.200	144.637	0	0
Replacement of lighting	50.000	CUR/item	1	25									50.000	20.793	0	0
													Σ present value	1.104.784 kr	Σ present value	132.197 kr

	Operation, repair and maintenance plan	Unit	Quantities	Percent	Unit cost DKK	Cost pr year, DKK	Interval, year	Starting year	Nos/lifetime	Total cost DKK	Traffic disturbance [days/each time]	Traffic disturbance [m]
	Cleaning	nos	1	100%	625	625	1	1	100	62.500	0,5	50
	Cleaning of drainage system	nos	1	100%	625	625	1	1	100	62.500	0	0
	Maintenance of road lighting	nos	1	100%	625	625	1	1	100	62.500	0	0
	Superficial inspection	nos	1	100%	30.000	30.000	5	5	20	600.000	0	0
	Main inspection	nos	1	100%	75.000	75.000	10		10	750.000	1	50
DANBRO	**Repair**											
4 B	Abutment, shotcrete repair, no rebar	m^2	300	8%	5.500	132.000	50	60	1	132.000	14	800
4 C	Abutment, shotcrete repair, with rebar	m^2	300	2%	8.600	51.600	50	60	1	51.600	14	800
5 B	Piers, shotcrete repair, no rebar	m^2	110	15%	5.500	90.750	50	60	1	90.750	7	850
5 C	Piers, shotcrete repair, with rebar	m^2	110	5%	8.600	47.300	50	60	1	47.300	7	850
6 A	Replacement of bearings	nos	3	100%	24.000	72.000	50	50	2	144.000	14	850
7 A	Shotcrete repair of superstructure	m^2	800	10%	7.300	584.000	20	40	4	2.336.000	14	1000
8 A	Replacement of waterproofing system and surfacing	m^2	722	100%	3.500	2.527.000	40	40	2	5.054.000	112	150
9 A	Replacement of edge beams	m	100	100%	12.200	1.220.000	60	60	1	1.220.000	70	150
9 C	Shotcrete repair of edge beams	m^2	212	15%	12.100	384.780	60	40	2	769.560	0	0
10 A	Replacement of parapets (no strengthning of edge beams)	m	127	100%	2.800	355.600	40	40	1	355.600	0	0
10 D	Regalvanizing of parapets	m	127	100%	2.600	330.200	40	20	3	990.600	14	100
11 C	Replacement of wearing course	m^2	779	100%	600	467.400	40	20	3	1.402.200	14	100
12 B	Replacement of bituminous sealing joint	m	28	100%	2.100	58.800	20	20	5	294.000	0	0
	Replacement of lighting	unit	1	100%	50.000	50.000	25	25	4	200.000	2	25
	Total cost	unit								**14.625.110**		

Lifetime **100** **years**

Example of calculation of material quantities, used as input values for LCA-tool

	Operation, repair and maintenance plan	Unit	Unit/ mainunit	Total quantity in lifetime
DANBRO	**Repair**			
4 C	**Abutment, shotcrete repair, with rebar**	**m^2 ***		**6**
13.11.34	*Partial removal of concrete, sub-structure, thickness = 40-70 mm, 75%*	m^3	0,04125	0,248
13.11.35	*Partial removal of concrete, sub-structure, thickness = 70-100 mm, 25%*	m^3	0,02125	0,128
13.7.63	*Sandblasting, sub-structure*	m^2	1	6
6.2.4	*Reinforcement mesh Ø 3 mm, 50 x 50 mm*	kg	2,2	13,2
8.8.1	*Shotcrete, set up*	stk	0,2	1,2
8.8.320	*Shotcrete application, sub-structure, thickness = 40-70 mm, 75%*	m^3	0,04125	0,248
8.8.330	*Shotcrete application, sub-structure, thickness = 70-100 mm, 25%*	m^3	0,02125	0,128

* Mainunit in bold

ELEMENT		ARBEJDE	ENHED	ENHEDSPRIS
10. AUTOVÆRN / RÆKVÆRK				
	A	Udskiftning (uden forstærkning af kantbjælker)	m	2,800
	B	Udskiftning (med forstærkning af kantbjælker)	m	15,400
	C	Hævning af B-profil	m	1,600
	D	Omforzinkning	m	2,600
	E	Udskiftning af autoværn og rækværk (ikke standard)	m	2,900
	F	Maling af rækværker og autoværn	m	1,300
	K	Vejautoværn (B-profil)	m	470
	L	Pletmaling	m	1,100
	M	Maling af let rækværk	m	370
	N	Udskiftning af let rækværk	m	1,700
	Z	Ikke standard reparationsarbejde	1	
ELEMENT		ARBEJDE	ENHED	ENHEDSPRIS
11. BROBELÆGNING				
	A	Udskiftning, tæt belægning excl. fugtisolering	m2	1,700
	B	Udskiftning af åbne belægninger	m2	1,200
	C	Udskiftning af slidlag	m2	600
	D	Overfladebehandling (OB)	m2	600
	K	Lappe huller/lunker	m2	780
	L	Tætning af belægningsrevner	m	190
	M	Opretning af grusvej	m2	160
	N	Blødfuge, type GUMA	m	500
	O	Etablering af nedløbsbrønd med rist og 10 m afløb	stk.	17,100
	P	Retablering af drænasfalt i vandrender	m	1,700
	Q	Etablering af kontrabanket langs kantbjælker	m	780
	Z	Ikke standard reparationsarbejde	1	
ELEMENT		ARBEJDE	ENHED	ENHEDSPRIS
12. DILATATIONSFUGER				
	A	Udskiftning	m	34,000
	B	Stenfyldt fugemasse (50 x 10 cm)	m	2,100
	Z	Ikke standard reparationsarbejde	1	

ELEMENT		ARBEJDE	ENHED	ENHEDSPRIS
13. AFLØBSKONSTRUKTIONER				
	Z	Ikke standard reparationsarbejde	1	
ELEMENT		ARBEJDE	ENHED	ENHEDSPRIS
14. UNDERFØRT PASSAGE				
14	Z	Ikke standard reparationsarbejde	1	
ELEMENT		ARBEJDE	ENHED	ENHEDSPRIS
15. ANDRE ELEMENTER				
	A	Skærver/Ballastskærm	m	1,800
15	Z	Ikke standard reparationsarbejde	1	

Vejdirektoratet

DANBRO
Standardreparationspriser
Rev. Februar 2011
Inkl. tillæg for arbejdsplads 25%
Ekskl. tillæg for administration

1. **BRONUMMER**
2. **DATO**
3. **VEJR**
4. **FACADEFOTO**
5. **BETYDENDE SKADER**
   Foto, antal
   Tilstandskarakter
   Vedligeholdskarakter
   Påkrævet særeftersyn
   Reparationstype
   Reparationsmængde
   Reparationsår
   Reparationsudgift
   Trafikal Restriktion

Nævnes for elementerne 2 - 15

2 Fløje
3 Skråninger
4 Endeunderstøtninger
5 Mellemunderstøtninger
6 Lejer
7 Bærende overbygning
8 Fugtisolering
9 Kantbjælker
10 Autoværn / rækværk
11 Brobelægning
12 Dilatationsfuger
13 Afløbskonstruktioner
14 Underført passage
15 Andre elementer

6. **GENEREL BEMÆRKNING**
   Øvrige bemærkninger
   Foto, antal
   Tilstandskarakter
   Vedligeholdskarakter
   Påkrævet særeftersyn
   Reparationstype
   Reparationsmængde
   Reparationsår
   Reparationsudgift
   Trafikal Restriktion ⟷ Trafikal restriktion kode nævnes - hvis nødvendig ⟷

Trafikal Restriktion

Kode/tekst:
1 Sporspærring
2 Vagtpost
3 Kørestrømsafbrydelse
4 Sporspærring og vagtpost
5 Sporspærring og kørestrøm
6 Vagtpost og kørestrøm
7 Hastighedsnedsættelse
8 Hastighedsnedsættelse og vagtpost
9 Hastighedsneds., sporsp. og vagtp
11 Motorvej, langsomme spor
12 Motorvej, hurtige spor
13 Øvrige veje, kørebane

7. **Foto af overført passage**
8. **Næste generaleftersyn**

DANBRO GENERALEFTERSYN - STANDARDREPARATIONER 2011

LEMENT		ARBEJDE	ENHED	ENHEDSPRIS
HELE BYGVÆRKET	ART			
	A	Udskiftning af bro for OF vej	m2	19,800
	B	Udskiftning af bro for UF vej	m2	31,000
	C	Udskiftning af bro for OF i øvrigt	m2	21,000
	D	Udskiftning af bro for UF i øvrigt	m2	35,000
	E	Udskiftning af overbygning for vej	m2	14,300
	F	Udskiftning til ståltunnel spv. 2,5	m2	16,500
	G	Udskiftning til betontunnel spv. 2,5	m2	19,500
	K	Udskiftning til Ø 1,0 m beton- el. stålrør	m	19,000
	L	Udskiftning af bro til Perstrup tunnel spv.4,5	m2	22,000
	Z	Ikke standard reparationsarbejde	1	

LEMENT		ARBEJDE	ENHED	ENHEDSPRIS
FLØJE				
	B	Sprøjtebetonreparationer uden armering	m2	5,500
	C	Sprøjtebetonreparationer med armering	m2	8,600
	D	Påstøbning af kappe	m2	5,800
	E	Hævning	m	3,500
	F	Udskiftning	m2	8,800
	K	Understøbning	m	5,500
	L	Lokalreparation afsk./revne	stk.	1,800
	M	Afrensning	m2	100
	N	Algebehandling, incl. afrensning	m2	310
	O	Revneinjicering	m	3,900
	P	Overfladebehandling, tynd film	m2	390
	Q	Overfladebehandling, tyk film	m2	800
	R	Isætning af dræn	stk.	930
	S	Reparation af hårdfuger	m	300
	T	Retablering af blødfuger	m	280
	U	Etablering af ny 30 cm tyk arm. fløj	m2	8,600
	Z	Ikke standard reparationsarbejde	1	

LEMENT		ARBEJDE	ENHED	ENHEDSPRIS
SKRÅNINGER				
	C	Skråningsbeklædning	m2	780
	K	Retablering, fyld	m3	660
	L	Fjerne bevoksning	m2	90
	N	Faskinesikring	m	1,900
	O	Retablering af grøftrør	m	1,500
	P	Træspuns	m	6,800
	Q	Stålspuns	m	8,500
	Z	Ikke standard reparationsarbejde	1	

ELEMENT		ARBEJDE	ENHED	ENHEDSPRIS
4. ENDEUNDERSTØTNINGER				
	B	Sprøjtebetonreparation uden armering	m2	5,500
	C	Sprøjtebetonreparation med armering	m2	8,600
	D	Påstøbning af kappe	m2	5,800
	K	Understøbning	m	5,200
	L	Lokalreparation afsk./revne	stk.	1,700
	M	Afrensning	m2	100
	N	Algebehandling, incl. afrensning	m2	310
	O	Revneinjicering	m	3,900
	P	Overfladebehandling, tynd film	m2	420
	Q	Overfladebehandling, tyk film	m2	800
	R	Isætning af dræn	stk.	940
	S	Reparation af hårdfuger	m	310
	T	Retablering af blødfuger	m	280
	Z	Ikke standard reparationsarbejde	1	

ELEMENT		ARBEJDE	ENHED	ENHEDSPRIS
5. MELLEMUNDERSTØTNINGER				
	B	Sprøjtebetonreparation uden armering	m2	5,500
	C	Sprøjtebetonreparation med armering	m2	8,600
	K	Understøbning	m	5,500
	L	Lokalreparation afsk./revne	stk.	1,700
	M	Afrensning	m2	100
	N	Algebehandling, incl. afrensning	m2	310
	O	Revneinjicering	m	3,900
	P	Overfladebehandling, tynd film	m2	420
	Q	Overfladebehandling, tyk film	m2	800
	R	Isætning af dræn	stk.	940
	S	Reparation af hårdfuger	m	310
	T	Retablering af blødfuger	m	280
	Z	Ikke standard reparationsarbejde	1	

ELEMENT		ARBEJDE	ENHED	ENHEDSPRIS
6. LEJER				
	A	Udskiftning	stk	24,000
	B	Renovering af stållejer	stk	13,000
	K	Sandblæsning, maling, små	stk.	3,200
	L	Udskiftning af små lejer	stk.	12,500
	Z	Ikke standard reparationsarbejde	1	

ELEMENT		ARBEJDE	ENHED	ENHEDSPRIS
7. BÆRENDE OVERBYGNING				
	A	Sprøjtebetonreparation på underside	m2	7,300
	B	Delvis udskiftning	m2	6,500
	C	Forstærkning med overbeton	m2	7,800
	L	Lokalreparation afsk./revne	stk.	1,700
	M	Afrensning	m2	100
	N	Algebehandling, incl. afrensning	m2	310
	O	Revneinjicering	m	3,900
	P	Overfladebehandling, tynd film	m2	420
	Q	Overfladebehandling, tyk film	m2	800
	S	Reparation af hårdfuger	m	310
	T	Retablering af blødfuger	m	280
	U	Overfladebeskyttelse af ståldele	m2	2,500
	Z	Ikke standard reparationsarbejde	1	

ELEMENT		ARBEJDE	ENHED	ENHEDSPRIS
8. FUGTISOLERING				
	A	Udskiftning (incl.brobelægning)	m2	3,500
	B	Isolering (Type 1) med sporafstivning	m2	40,700
	K	Udskiftning, tynd isolering incl.brobelægning	m2	4,800
	Z	Ikke standard reparationsarbejde	1	

ELEMENT		ARBEJDE	ENHED	ENHEDSPRIS
9. KANTBJÆLKER				
	A	Udskiftning	m	12,200
	B	Hævning	m	10,800
	C	Sprøjtebetonreparation	m2	12,100
	D	Udskiftning af kantbjælkeelementer	m	7,500
	E	Overfladebehandling, tyk film	m2	850
	K	Lokalreparation afsk./revne	stk.	1,700
	L	Afrensning	m2	100
	M	Algebehandling, incl. afrensning	m2	310
	N	Revneinjicering	m	3,900
	O	Overfladebehandling, tynd film	m2	420
	Q	Reparation af hårdfuger	m	310
	R	Retablering af blødfuger	m	280
	Z	Ikke standard reparationsarbejde	1	

MHop

Bilag G11 - Levetider for konstruktionselementer

Nedenfor er angivet gennemsnitlige, normale levetider for konstruktionselementer under forudsætning af normalt ren- og vedligehold. Listen er opdelt efter de overordnede konstruktionselementer på standardlisten, jf. afsnit 5.2.2.

		Levetid - år
1. Hele bygværket	– Hovedkonstruktionsdele	50 - 100
2. Fløje	– Støttevægge	50 - 100
	– Spunsvægge	50 - 100
	– Fundamentsdele	50 - 100
	– Overfladebeskyttelse	10 - 15
3. Skråninger	– Jord/grustilfyldning	25 - 50
	– Beklædningssten	25 - 50
	– Faskine	20 - 30
	– Spuns	20 - 30
4. Ende- og	– Vægge	50 - 100
5. mellemunderstøt-	– Søjler, inkl. evt. søjleåg	50 - 100
ninger	– Fundamentsdele	50 - 100
	– Lejehylder	50 - 100
	– Parament	25 - 50
	– Overfladebeskyttelse	10 - 15
6. Lejer	– Lejekonstruktionsdele	25 - 50
	– Lejeplint/understopning	25 - 50
7. Bærende over-	– Broplade/dækplade	50 - 100
bygning	– Kassedrager	50 - 100
	– Længde- og tværbjælker	50 - 100
	– Gitterdragere	50 - 100
	– Afstivninger	50 - 100
	– Overfladebeskyttelse	10 - 15
8. Fugtisolering	– Fugtisoleringslag	20 - 40
	– Beskyttelseslag	20 - 40
	– Kant- og endeinddækninger	20 - 40
	– Drænrender og dryprør	20 - 40
9. Kantbjælker	– In-situ støbte kantbjælker	30 - 50
	– Præfabrikerede kantelementer	20 - 40
	– Fuger i kantbjælker	5 - 10
10. Autoværn/-	– Ståldele	30 - 50
rækværk	– Varmforzinkning	15 - 25
	– Overfladebeskyttelse, maling	5 - 10

		Levetid - år
11. Belægninger/-banelegeme	– Asfaltbelægninger, bærelag	20 - 40
	– Asfaltbelægninger, slidlag	10 - 15
	– Kunststofbelægninger	10 - 15
	– Fliser, kantsten m.v.	20 - 30
	– Afløb, brønde m.v.	20 - 30
	– Bitumenfuger	5 - 10
	– Skinner og sveller	20 - 30
	– Ballastskærver	20 - 30
12. Dilatationsfuger	– Fugekonstruktioner inkl. evt. fugebånd	20 - 30
	– Fuger med stenfyldt fugemasse	10 - 15
13. Andre elementer	– Specielle signaler, belysning m.v.	20 - 30
	– Trapper	25 - 50
	– Støttemure	25 - 50
	– Pumpebrønde	25 - 50
	– Sluseelementer	25 - 50
	– Nedgangsskakte til ledningstunneler	25 - 50
	– Ledningstunnelelementer	25 - 50

HP	PO	UP	Betegnelse	Enhed	Antal enheder	Enheds-pris Kr.	Ialt Kr.
2			**JORDARBEJDER**				
	11		**RYDNING**				-
		11	Rydning	sum	1	66.830,00	66.830,00
		12	Rydning og bortskaffelse af beplantning	m²	7.500	10,00	75.000,00
			Post 11 Total			==>	141.830,00
	13		**OPBRYDNING M.V.**				
		12	Opbrydning og bortskaffelse af stabilt grus og bundsikringsgrus i interimsvej	m³	900	40,00	36.000,00
		15	Asfalt, opbrydning og bortskaffelse t <= 0,1 m	t	530	55,00	29.150,00
		16	Asfalt, opbrydning og bortskaffelse t > 0,1 m	t	900	58,00	52.200,00
		21	Asfaltfræsning, t = 0,0-0,1 m	m²	125	70,00	8.750,00
		22	Asfaltfræsning, t = 0,1-0,2 m	m²	125	140,00	17.500,00
		31	Asfaltskæring, t = 0,0-0,1 m	m	600	20,00	12.000,00
		32	Asfaltskæring, t = 0,1-0,2 m	m	600	32,00	19.200,00
		41	Kantsten, optage og fjerne	m	250	54,00	13.500,00
		51	Chaussesten, optage og fjerne	m²	125	72,00	9.000,00
		61	Autoværn at optage og bortskaffe	m	475	38,00	18.050,00
		91	Nedtagning og bortskaffelse af vejvisningstavler	stk	1	4.820,00	4.820,00
		92	Nedtagning og bortskaffelse af færdselstavler	stk	1	800,00	800,00
			Post 13 Total			==>	220.970,00
	14		**AFRØMNING AF MULDJORD M.V.**				
		1	Rabatjord til depot, t=0,3m	m³	300	47,00	14.100,00
		11	Muldjord til depot t <= 0,8m	m³	650	25,00	16.250,00
		21	Overjord til depot	m³	260	50,00	13.000,00
			Post 14 Total			==>	43.350,00
	31		**JORD AFGRAVNING OG INDBYGNING**				
		13	Flytteafstand 0 - 260 m	m³	1.100	58,00	63.800,00
		86	Indbygning fra depot	m³	170	95,00	16.150,00
			Post 31 Total			==>	79.950,00
	32		**JORD AFGRAVNING OG UDSÆTNING**				
		41	Afgravning til depot	m³	3.570	45,00	160.650,00
			Flytteafstand 4000 - 5000 m				
			Post 34 Total			==>	160.650,00
	41		**UDLÆGNING AF MULDJORD**				
		13	På sidetags- og dyrkningsområder m.v. t=0,30 m	m²	2.100	20,00	42.000,00
		32	Overjord på andre arealer. t = 0,30 m	m²	850	20,00	17.000,00
		40	Rabatjord t=0,30 m	m²	1.000	20,00	20.000,00
			Post 41 Total			==>	79.000,00
	42		**GRÆSSÅNING**				
		11	På skråninger og grøfter	m²	1.750	5,00	8.750,00
		12	På rabatter og trug	m²	2.100	5,00	10.500,00
			Post 42 Total			==>	19.250,00
			Samlet tilbudssum Hovedpost 2 Jordarbejder at overføre til samleside motorvej			==>	**745.000,00**

HP	PO	UP	Betegnelse	Enhed	Antal enheder	Enheds-pris Kr.	Ialt Kr.
3			**AFVANDINGSARBEJDER**				
	16		**DRÆN AF DOBBELTVÆGGEDE FULDSLIDSEDE PLASTRØR I VEJAREAL**				
		13	D 100 mm dybde 1,0-1,5 m	m	14	255,00	3.570,00
			Post 16 Total			==>	3.570,00
	17		**DRÆN AF DOBBELTVÆGGEDE TOPSLIDSEDE PLASTRØR I VEJAREAL**				
		21	KL 150 mm dybde 0,0-0,6 m	m	58	160,00	9.280,00
		23	KL 150 mm dybde 1,0-1,5 m	m	48	265,00	12.720,00
		32	KL 200 mm dybde 0,6-1,0 m	m	87	240,00	20.880,00
			Post 17 Total			==>	42.880,00
	22		**PLASTRØR KLASSE SN 8**				
		31	PL 250 mm dybde 0,0-1,0 m	m	21	420,00	8.820,00
			Post 22 Total			==>	8.820,00
	52		**ANNULLERING AF LEDNINGER**				
		10	Injicering af ledninger med beton	m	20	175,00	3.500,00
		11	Vandtæt afpropning, alle dimensioner	stk	4	1.420,00	5.680,00
		21	Opgravning, fjernelse og tilfyldning dybde 0-3 m dim <= 500 mm	m	214	110,00	23.540,00
			Post 52 Total			==>	32.720,00
	53		**ANNULLERING AF BRØNDE OG BYGVÆRKER**				
		11	Diameter <= 400 mm	stk	6	825,00	4.950,00
		21	400 < Diameter <= 1000 mm	stk	4	1.240,00	4.960,00
			Post 53 Total			==>	9.910,00
	55		**SÆRLIGE ARBEJDER**				
		99	Faunapassage	m	31	4.250,00	131.750,00
		130	Højderegulering af nedløbsbrønde	stk	4	1.240,00	4.960,00
			Post 55 Total			==>	136.710,00
	67		**NEDLØBSBRØNDE**				
		2	ø 450/400 mm plastbrønd med plastkegle, karm og rist. 310 x 310 mm rist. Typetegning nr. 26261	stk	6	4.065,00	24.390,00
			Post 67 Total			==>	24.390,00
			Samlet tilbudssum Hovedpost 3 Afvandingsarbejder at overføre til samleside motorvej			==>	**259.000,00**
5			**BUNDSIKRINGSARBEJDER**				
	1		**BUNDSIKRING, LEVERE OG INDBYGGE**				
		2	I varierende tykkelse i omlagte veje	m³	700	145,00	101.500,00
		15	Rekomprimering af eksisterende bundsikring	m²	3.500	7,00	24.500,00
			Post 1 Total			==>	126.000,00
	2		**BUNDSIKRING, UDGRAVE I SIDETAG ELLER VEJLINIE OG INDBYGGE**				
		2	I varierende tykkelse i veje	m³	400	90,00	36.000,00
		11	I rabatter og nødspor på motorvej og ramper	m³	400	90,00	36.000,00
			Post 2 Total			==>	72.000,00
			Samlet tilbudssum Hovedpost 5 Bundsikringsarbejder at overføre til samleside motorvej			==>	**198.000,00**

HP	PO	UP	Betegnelse	Enhed	Antal enheder	Enheds-pris Kr.	Ialt Kr.
6			**BELÆGNINGSARBEJDER**				
	15		**STABILT GRUS, LEVERING OG INDBYGNING**				
		6	I veje, t=0,15 m	m²	2.300	28,00	64.400,00
		7	I veje, t=0,20 m	m²	1.250	36,00	45.000,00
		13	I cykelsti, t=0,15 m	m²	700	28,00	19.600,00
		19	I nødspor på motorvej og ramper, t=0,20 m	m²	1.250	36,00	45.000,00
		27	Interimsbelægning ifm. forlægning af rampe, t=0,2 m	m²	1.600	36,00	57.600,00
		32	I markoverkørsel, interimsvej, t=0,20m	m²	150	40,00	6.000,00
			Post 15 Total			==>	237.600,00
	21		**OPRETNING OG AFRETNING**				
		1	Maskinopretning inkl. klæbning	t	100	940,00	94.000,00
		11	Maskinafretning inkl. klæbning	t	25	1.500,00	37.500,00
			Post 21 Total			==>	131.500,00
	22		**PULVERASFALT (PA)**				
		36	Asfaltvulst på interimsvej	m	500	72,00	36.000,00
		40	50 kg/m² (t) på cykelstier	m²	700	82,00	57.400,00
		49	Reguleringspris (t)	kg	5.000	0,90	4.500,00
			Post 22 Total			==>	97.900,00
	23		**ASFALTBETON (AB)**				
		34	70 kg/m² (t) på veje	m²	1.250	71,00	88.750,00
		39	Reguleringspris (t)	kg	7.000	0,90	6.300,00
		44	Modificeret sinus bump	stk	2	26.775,00	53.550,00
			Post 23 Total			==>	148.600,00
	24		**SKÆRVEMASTIKS (SMA)**				
		4	70 kg/m² på ramper	m²	1.900	68,00	129.200,00
		99	Reguleringspris	kg	7.000	0,90	6.300,00
			Post 24 Total			==>	135.500,00
	27		**ASFALTBETONBINDELAG (ABB)**				
		27	135 kg/m² på ramper	m²	1.250	88,00	110.000,00
		98	Reguleringspris	kg	7.000	0,75	5.250,00
			Post 27 Total			==>	115.250,00
	28		**GRUSASFALTBETON 0 (GAB 0)**				
		17	225 kg/m² interimsbelægning ifm forlægning af rampe	m²	1.600	125,00	200.000,00
		34	115 kg/m² på cykelstier	m²	700	110,00	77.000,00
		36	135 kg/m² på veje	m²	3.550	95,00	337.250,00
		90	Kantfyldning i 15-20 cm's bredde langs kantbegrænsning	m	250	65,00	16.250,00
		99	Reguleringspris	kg	24.000	0,60	14.400,00
			Post 28 Total			==>	644.900,00
	29		**GRUSASFALTBETON I (GAB I)**				
		36	160 kg/m² på interimsvej	m²	2.300	90,00	207.000,00
		38	180 kg/m² på veje	m²	1.250	127,00	158.750,00
		99	Reguleringspris	kg	30.000	0,55	16.500,00
			Post 29 Total			==>	382.250,00
	30		**GRUSASFALTBETON II (GAB II)**				
		20	180 kg/m² på forstærkede nødspor	m²	1.250	110,00	137.500,00
		99	Reguleringspris	kg	10.000	0,50	5.000,00
			Post 30 Total			==>	142.500,00
	33		**OVERFLADEBEHANDLING (OB)**				
		21	På nødspor	m²	1.250	38,00	47.500,00
			Post 33 Total			==>	47.500,00
	62		**NYE GRANIT-/BETONSTEN, LEVERE OG INDBYGGE**				
		12	Rabatkantsten, lige	m	250	290,00	72.500,00
			Post 62 Total			==>	72.500,00
			Samlet tilbudssum Hovedpost 6 Belægningsarbejder at overføre til samleside motorvej			==>	**2.156.000,00**

HP	PO	UP	Betegnelse	Enhed	Antal enheder	Enheds-pris Kr.	Ialt Kr.
7			**UDSTYR**				
	1		**STÅLAUTOVÆRN**				
		3	SW 1.1 SIGMA 100.2 med trækbånd	m	400	375,00	150.000,00
		7	SW 3.1 IPE 140.3	m	110	840,00	92.400,00
		25	Endestykke	stk	1	780,00	780,00
			Post 1 Total			==>	243.180,00
	21		**HVID KØREBANEAFMÆRKNING, PLAN MED LANG HOLDBARHED**				
		1	0,10 m brede linier	m	4.050	15,00	60.750,00
		3	0,30 m brede linier	m	1.300	26,00	33.800,00
		15	Fladeafmærkning. Fodgængerfelter, spærreflader m.fl. (S17, Q45 m. fl.)	m²	70	195,00	13.650,00
		17	Vigelinie - hajtænder S11	stk	8	80,00	640,00
		21	Enkeltpile l=2.6 m, R 11.1-5 samt R 11.14-15	stk	4	365,00	1.460,00
			Post 21 Total			==>	110.300,00
	50		**KABELFORBEREDENDE ARBEJDER**				
		21	Kabelrørsgrav, 0,60 m jorddækning, max. 0,30 m bred, fri strækning (op til 2 stk. rør)	m	20	85,00	1.700,00
		22	Kabelrørsgrav, 0,60 m jorddækning, max. 0,60 m bred, fri strækning (op til 5 stk. kabelrør)	m	40	100,00	4.000,00
		23	Kabelrørsgrav, 0,60 m jorddækning, max. 0,30 m bred, i skråning (op til 2 stk. kabelrør)	m	60	100,00	6.000,00
		32	Jordlagte kabelrør Ø 110	m	180	30,00	5.400,00
		42	Kabelbrønd til 1,5 T, LxBxD=650x650x680 mm	stk	4	5.355,00	21.420,00
			Post 50 Total			==>	38.520,00
			Samlet tilbudssum Hovedpost 07 Udstyr at overføre til samleside motorvej			==>	**392.000,00**

SAB nr.	HP	PO	UP	Betegnelse	Enhed	Antal enheder	Enheds-pris Kr.	Underpost i alt Kr.	Post i alt Kr.
8	2			JORDARBEJDE					
		3		RÅJORDSARBEJDER					
			1010	Afgravning	m³	2.420	55,00	133.100,00	
			2010	Graderet sand-grusfyld at levere og indbygge	m³	166	165,00	27.390,00	
			4011	SG II, 200 mm	m²	35	45,00	1.575,00	
				Post 8-2.3 total			==>	162.065,00	
		11		NEDBRYDNINGS- OG NEDRIVNINGSARBEJDER					
			2011	Nedrivning af Bro 72 i 2 etaper, inkl. endevederlag, mellemunder-støtninger, lysmaster, brobelægning mv. ekskl. nordlig spuns	Sum	1	#########	295.112,00	
			3400	Nedbrydning og bortskaffelse af eksisterende støjskærm	m	20	550,00	11.000,00	
				Post 8-2.11 total			==>	306.112,00	
				Hovedpost 8-2 total				==>	468.177,00
	3			AFVANDINGSARBEJDER					
		6		BROAFLØB- OG AFVANDING					
			1010	Broafløbsskål med ramme og rist (som ACO-Passavant 4979.08)	stk.	4	4.800,00	19.200,00	
			2010	Indstøbte afvandingsledninger Ø160 mm (som Geberit)	m	56	225,00	12.600,00	
				Post 8-3.6 total			==>	31.800,00	
		16		DRÆN AF DOBBELTVÆGGEDE PLASTRØR					
			1010	D 100 mm i 400 x 400 mm specialfilter (BD)	m	104	185,00	19.240,00	
				Post 8-3.16 total			==>	19.240,00	
		67		NEDLØBSBRØNDE					
			1010	ø450/380 mm dobbeltvægget, udvendig korrugeret plastnedløbsbrønd m. sandfang, kegle samt 310 x 310 mm rist (NSF)	stk.	4	4.250,00	17.000,00	
			2010	315 mm spulebrønd	stk.	4	3.250,00	13.000,00	
				Post 8-3.67 total			==>	30.000,00	
				Hovedpost 8-3 total				==>	81.040,00
	4			FUNDERING					
		1		AFSTIVNING OG FORANKRING AF BYGGEGRUBE					
			2014	Interimsvæg ved midterfundament	m	23	4.000,00	92.000,00	
				Post 8-4.1 total			==>	92.000,00	
		3		DIREKTE FUNDERING					
			1010	Renselag	m²	144	165,00	23.760,00	
				Post 8-4.3 total			==>	23.760,00	
		4		JERNBETONPÆLE					
			2010	Prøveramning af 300 x 300 mm jernbetonpæle, længde 14,0 m	stk.	4	8.500,00	34.000,00	
			3011	Nedbringning af 300 x 300 mm jernbetonpæle, 8 m < længde < 15 m	m	238	425,00	101.150,00	
			4010	Forlængelse af 300 x 300 mm jernbetonpæle ved påstøbning	stk.	4	1.500,00	6.000,00	
			5010	Videreramning af 300 x 300 mm jernbetonpæle	stk.	4	100,00	400,00	
			6010	Forboring for 300 x 300 mm jernbetonpæle, 10 m < dybde < 15 m	m	136	75,00	10.200,00	
				Post 8-4.4 total			==>	151.750,00	
		6		NEDBRINGNING AF SPUNS					
			2010	Stålspuns, W ≥ 2750 cm³/m, S355, dybde ≤ 12 m	m²	498	1.350,00	672.300,00	
				Post 8-4.6 total			==>	672.300,00	
		7		KONTROLMÅLINGER					
				Udgår					
			3010	PDA-målinger og CAPWAP analyse	stk.	4	2.000,00	8.000,00	
				Post 8-4.7 total			==>	8.000,00	
		8		ANKRE OG STRÆK					
			1030	Jordanker i høj sikkerhedsklasse, regnm. horisontal kraft, 50 kN/m < P ≤ 200 kN/m, 6 m ≤ fri længde ≤ 8 m, forankret i moræneler / sand	stk.	2	13.000,00	26.000,00	
8		8	1032	Jordanker i høj sikkerhedsklasse, regnm. horisontal kraft, 300 kN/m < P ≤ 500 kN/m, 6 m ≤ fri længde ≤ 8 m, forankret i moræneler / sand	stk.	18	16.500,00	297.000,00	
			1033	Jordanker i høj sikkerhedsklasse, regnm. horisontal kraft, 50 kN/m < P ≤ 100 kN/m, 13 m ≤ fri længde ≤ 15 m, forankret i moræneler / sand	stk.	2	16.300,00	32.600,00	
			1034	Jordanker i høj sikkerhedsklasse, regnm. horisontal kraft, 100 kN/m < P ≤ 200 kN/m, 13 m ≤ fri længde ≤ 15 m, forankret i moræneler / sand	stk.	8	16.300,00	130.400,00	
			1035	Jordanker i høj sikkerhedsklasse, regnm. horisontal kraft, 200 kN/m < P ≤ 300 kN/m, 13 m ≤ fri længde ≤ 15 m, forankret i moræneler / sand	stk.	2	17.500,00	35.000,00	
			1036	Jordanker i høj sikkerhedsklasse, regnm. horisontal kraft, 300 kN/m < P ≤ 500 kN/m, 13 m ≤ fri længde ≤ 15 m, forankret i moræneler / sand	stk.	12	22.000,00	264.000,00	
			1037	Jordanker i høj sikkerhedsklasse, regnm. horisontal kraft, 50 kN/m < P ≤ 200 kN/m, 8 m ≤ fri længde ≤ 12 m, forankret i moræneler / sand	stk.	2	15.000,00	30.000,00	
			1039	Jordanker i høj sikkerhedsklasse, regnm. horisontal kraft, 300 kN/m < P ≤ 500 kN/m, 8 m ≤ fri længde ≤ 12 m, forankret i moræneler / sand	stk.	3	19.500,00	58.500,00	
				Post 8-4.8 total			==>	873.500,00	
				Hovedpost 8-4 total				==>	1.821.310,00
				Sum overføres til næste side					2.370.527,00

				Sum overført fra forrige side					2.370.527,00
8	5			STILLADS OG FORM					
		1		FORM TIL FUNDAMENTER					
			1010	Form til fundamenter	m²	31	395,00	12.245,00	
				Post 8-5.1 total			==>	12.245,00	
		2		FORM FOR SØJLER					
			2010	Form til søjler, synlig ru	m²	101	650,00	65.650,00	
				Post 8-5.2 total			==>	65.650,00	
		3		FORM FOR VÆGGE, FLØJE OG STØTTEMURE					
			3012	Overform til fløjvægge, synlig ru	m²	41	695,00	28.495,00	
			3013	Form til betonhammer, ikke synlig inkl. stillads	m²	28	875,00	24.500,00	
			3014	Overform til betonhammer, ikke synlig	m²	7	875,00	6.125,00	
			3015	Form til vægge og fløje synlig ru med profilering	m²	334	735,00	245.490,00	
			3016	Form til betonhammer, synlig ru med profilering inkl. stillads	m²	107	875,00	93.625,00	
				Post 8-5.3 total			==>	398.235,00	
		4		FORM FOR BRODÆK OG KANTBJÆLKER					
			4010	Form for brodæk inkl. stillads	m²	544	1.725,00	938.400,00	
			4011	Form for kantbjælke inkl. stillads	m²	392	1.725,00	676.200,00	
				Post 8-5.4 total			==>	1.614.600,00	
		6		FORM TIL IKKE SYNLIGE FLADER					
			6010	Form til støbeskel, brodæk	m²	36	675,00	24.300,00	
			6011	Form til broender	m²	21	925,00	19.425,00	
			6014	Form til støbeskel, vægge	m²	72	675,00	48.600,00	
				Post 8-5.6 total			==>	92.325,00	
		7		PLASTRØR FOR KABLER OG LEDNINGER					
			5011	Plastrør for kabler og ledninger (PE Ø75)	m	105	60,00	6.300,00	
			5012	Plastrør for kabler og ledninger (PE Ø110)	m	105	70,00	7.350,00	
8			5014	Plastrør for kabler og ledninger (PE Ø160) inkl. indvendige plastrør					
				Ø75 mm, Ø63 mm og 2 stk. Ø40 mm	m	210	100,00	21.000,00	
				Post 8-5.7 total			==>	34.650,00	
		8		FUGEBÅND					
			6010	Tætningsfugebånd, ekspanderende som Hydrotite eller Leakmaster	m	18	215,00	3.870,00	
				Post 8-5.8 total			==>	3.870,00	
		9		ØVRIGE INDSTØBNINGSDELE					
			7010	Polystyren, t = 10 mm ved knækpunkt i sætningsplade	m²	2	335,00	670,00	
			7011	Polystyren, t = 20 mm under sætningsplade	m²	10	355,00	3.550,00	
			7013	Polystyren, 200 x 200 x 600 mm ved betoncharnier	stk.	12	405,00	4.860,00	
			7020	Indstøbning af nivellementsbolte	stk.	4	380,00	1.520,00	
			7030	Prægning af årstal	stk.	2	2.300,00	4.600,00	
				Post 8-5.9 total			==>	15.200,00	
				Hovedpost 8-5 total				==>	2.236.775,00
	6			SLAP ARMERING					
		2		GLAT ARMERING					
			4010	Rundjern (R) i betonpåstøbning	tons	1	9.500,00	9.500,00	
				Post 8-6.2 total			==>	9.500,00	
		3		RIBBESTÅL					
			1010	Kamstål (Y) i fundamenter og sætningsplader	tons	6	10.900,00	65.400,00	
			1011	Kamstål (Y) i vægge, fløje, støttevægge, endevægge og vederlag	tons	16	10.900,00	174.400,00	
			1012	Kamstål (Y) i søjler	tons	5	10.900,00	54.500,00	
			1020	Kamstål (Y) i broplade, -dæk, og kantbjælker	tons	52	10.900,00	566.800,00	
				Post 8-6.3 total			==>	861.100,00	
		6		STØDKOBLINGER					
			3011	Stødkobling, M16, kamstål Y	stk.	16	135,00	2.160,00	
				Post 8-6.6 total			==>	2.160,00	
				Hovedpost 8-6 total				==>	872.760,00
	7			SPÆNDT ARMERING					
		2		EFTERSPÆNDT ARMERING					
			1020	Linekabler, som Freyssinet 19C15, inkl. kabelstole	m	801	375,00	300.375,00	
			1021	Forankringssæt, som 19C15 aktiv - aktiv(1 sæt = 2 forankringer)	stk.	16	10.500,00	168.000,00	
				Post 8-7.2 total			==>	468.375,00	
				Hovedpost 8-7 total				==>	468.375,00
				Sum overføres til næste side					5.948.437,00

				Sum overført fra forrige side					5.948.437,00
8	8			BETON					
		1		BETON I FUNDAMENTER OG SÆTNINGSPLADER					
			1010	Beton 35-A i sætningsplader, inkl. form	m³	14	1.550,00	21.700,00	
			1011	Beton 35-A i fundamenter	m³	40	1.350,00	54.000,00	
				Post 8-8.1 total			==>	75.700,00	
		2		BETON I SØJLER					
			2010	Beton 40-E i søjler	m³	29	1.600,00	46.400,00	
				Post 8-8.2 total			==>	46.400,00	
		3		BETON I VÆGGE, VEDERLAG, FLØJE OG STØTTEMURE					
			3010	Beton 40-E i vægge, fløje og støttemure	m³	133	1.450,00	192.850,00	
			3011	Beton 40-E-SCC i vægge, fløje og støttemure	m³	44	1.600,00	70.400,00	
				Post 8-8.3 total			==>	263.250,00	
		4		BETON I OVERBYGNING					
			3510	Beton 40-E (A) i brodæk og kantbjælker	m³	551	1.300,00	716.300,00	
				Post 8-8.4 total			==>	716.300,00	
		20		SPECIALBETON					
			5011	Specialbeton ved betoncharnier	m³	2	2.400,00	4.800,00	
				Post 8-8.20 total			==>	4.800,00	
		50		STØBESKEL					
			1010	Afrensning af støbeskel	m²	47	75,00	3.525,00	
				Post 8-8.50 total			==>	3.525,00	
				Hovedpost 8-8 total				==>	1.109.975,00
	9			AUTOVÆRN OG RÆKVÆRKER					
		1		BROAUTOVÆRN					
			1011	Levering og opsætning af broautoværn type S-100 inkl. B-profil, med rækværksfunktion og udfyldningsstænger	m	127	1.400,00	177.800,00	
				Post 8-9.1 total			==>	177.800,00	
		10		BOLTEGRUPPER OG BETONSOKLER					
			3010	Levering og montering af boltegruppe for S-100 broautoværn	stk.	36	1.300,00	46.800,00	
			3011	Levering og sætning af betonsokkel ved broender til S-100 broautoværn	stk.	8	3.200,00	25.600,00	
				Post 8-9.10 total			==>	72.400,00	
				Hovedpost 8-9 total				==>	250.200,00
	10			FUGTISOLERING					
		1		AFRENSNING OG FRÆSNING					
			3010	Slyngrensning af brodæk o.s. for ny fugtisolering	m²	717	50,00	35.850,00	
			3020	Sandblæsning af broender	m²	9	25,00	225,00	
				Post 8-10.1 total			==>	36.075,00	
		3		GRUNDING					
			1011	Epoxygrunder	m²	722	70,00	50.540,00	
				Post 8-10.3 total			==>	50.540,00	
		6		FUGTISOLERING MED POLYMERBITUMENPLADER					
			1012	Fugtisolering, type IVa	m²	722	415,00	299.630,00	
				Post 8-10.6 total			==>	299.630,00	
		7		FASTGØRELSE					
			2010	Klemskinne	m	104	505,00	52.520,00	
				Post 8-10.7 total			==>	52.520,00	
		10		TYND ISOLATION					
			1010	Tynd isolation	m²	113	295,00	33.335,00	
				Post 8-10.10 total			==>	33.335,00	
				Hovedpost 8-10 total				==>	472.100,00
				Sum overføres til næste side					7.780.712,00

				Sum overført fra forrige side					7.780.712,00
8	11			BROBELÆGNINGER					
		1		DRÆNLAG					
			1010	Drænlag ÅAB 8 B70/100, t = 20 mm	m²	779	120,00	93.480,00	
				Post 8-11.1 total			==>	93.480,00	
		3		BESKYTTELSESLAG					
			1010	Beskyttelseslag ABM B40/60, type c, t = 45 mm	m²	779	225,00	175.275,00	
				Post 8-11.3 total			==>	175.275,00	
		5		SLIDLAG					
			1011	Slidlag SMA B40/60 modificeret, type 11B, t = 40 mm	m²	401	250,00	100.250,00	
			1012	Slidlag AB B160/220, type 8t, t = 25 mm	m²	363	125,00	45.375,00	
				Post 8-11.5 total			==>	145.625,00	
		6		BÆRELAG					
			1010	Tilstødende vejbelægning GAB II	m²	120	430,00	51.600,00	
			1011	Udligning med GAB under fortov/cykelsti	m²	27	255,00	6.885,00	
			1020	Tilstødende vejbelægning ABB	m²	140	185,00	25.900,00	
			2010	Udligning med GAB/ABB på sætningsplader	m³	62	2.050,00	127.100,00	
				Post 8-11.6 total			==>	211.485,00	
		8		DRÆNKANAL AF ÅBEN KUNSTSTOFBETON					
			1010	Drænkanal af åben kunststofbeton, 30 x 100 mm	m	101	195,00	19.695,00	
				Post 8-11.8 total			==>	19.695,00	
		11		FUGER					
			1010	Fugemasse type A - 20 x 30 mm, med klæbebrydende bundlag	m	320	195,00	62.400,00	
			2010	Fugemasse type B	m	104	55,00	5.720,00	
				Post 8-11.11 total			==>	68.120,00	
				Hovedpost 8-11 total				==>	713.680,00
	13			ANDRE ARBEJDER					
		3		LEJER OG INDDÆKNING					
			1012	Neoprenleje, Type C, udskifteligt, lejelinie B	stk.	3	7.000,00	21.000,00	
			2010	Inddækning med neopren-folie mellem overbygning og underbygning	m	6	1.100,00	6.600,00	
				Post 8-13.3 total			==>	27.600,00	
		4		BROLÆGNINGSARBEJDER VED OG PÅ BROER					
			1010	Græsarmeringsten, 10 cm, grå	m²	25	495,00	12.375,00	
			1012	Fliser, 40 x 20 x 6 cm, grå	m²	19	375,00	7.125,00	
			1015	Betonkantsten	m	102	285,00	29.070,00	
			1016	Fliser, 80 x 62,5 x 7 cm, grå (sat i beton ved broender)	m	16	425,00	6.800,00	
				Post 8-13.4 total			==>	55.370,00	
		5		OVERFLADEBESKYTTELSE					
			7010	Antigraffitibehandling	m²	409	62,00	25.358,00	
				Post 8-13.5 total			==>	25.358,00	
		12		DRYPRØR					
			1010	Dryprør	stk.	4	1.200,00	4.800,00	
				Post 8-13.12 total			==>	4.800,00	
				Hovedpost 8-13 total				==>	113.128,00
				Samlet tilbudssum HP 8, Bro 72.10 i alt at overføre til Tilbudsliste samleside, side B				==>	**8.607.520,00**