MANAGEMENT SUMMARY

Sustainability plays an increasingly important part in the purchasing decision. This applies to many sectors, but is especially valid for building and infrastructure. Rijkswaterstaat, ProRail, municipalities and provinces develop criteria for sustainable procurement and support innovative projects.
It is therefore not surprising that producers want to have a better sustainability performance than their competitors. This discussion came to a height following the publication in 2009 on an environmental analysis of bridges by Fiber Core, producer of composite bridges. Resulting from this discussion, the idea arose to do a new environmental study on bridges of various materials in cooperation with all relevant sectors. NL Agency supports this project from the Long-Term Agreements on Energy Efficiency (LTA3). Rijkswaterstaat has been invited as an important client in the civil engineering sector and developer of DuboCalc.

Project goals

The main goals of the project were:

- Establish the sustainability score of bridges of four different materials (steel, concrete, composite, wood) and in two different classes;
- Provide insight into the structure of the environmental impact and providing tools for improving the design of the bridges.

Bridges

The specifications of the bridges were established early 2012 and reflect the standards of that time. The main specifications are summarized below. In addition, agreements were made on the requirements for vibration, shock loads, fire load, fatigue and the choices for finishing surfaces, handrails, guide rail, glancing edge and foundation.

	Fietsbrug	Verkeersbrug
Length	Free span 14 meters	24 meters (heart heart imposition)
Width	(between rails) 3 meters	12 meters between handrails 12.6 meters total
Lifetim	50 years	100 years
Load	Load 5kN/m2 + service vehicle according to Eurocodes and Dutch attachments	Transport Category 2 - Load using Eurocodes - The correction factors: $\alpha q; 1 =$ 1.15 and (i> 1) is $\alpha q, i = 1.40$ - Consequence Class 2
Material norms	Design in accordance with applicable material standards	Design according ROK (version December 2011) of RWS

Methodology and data used

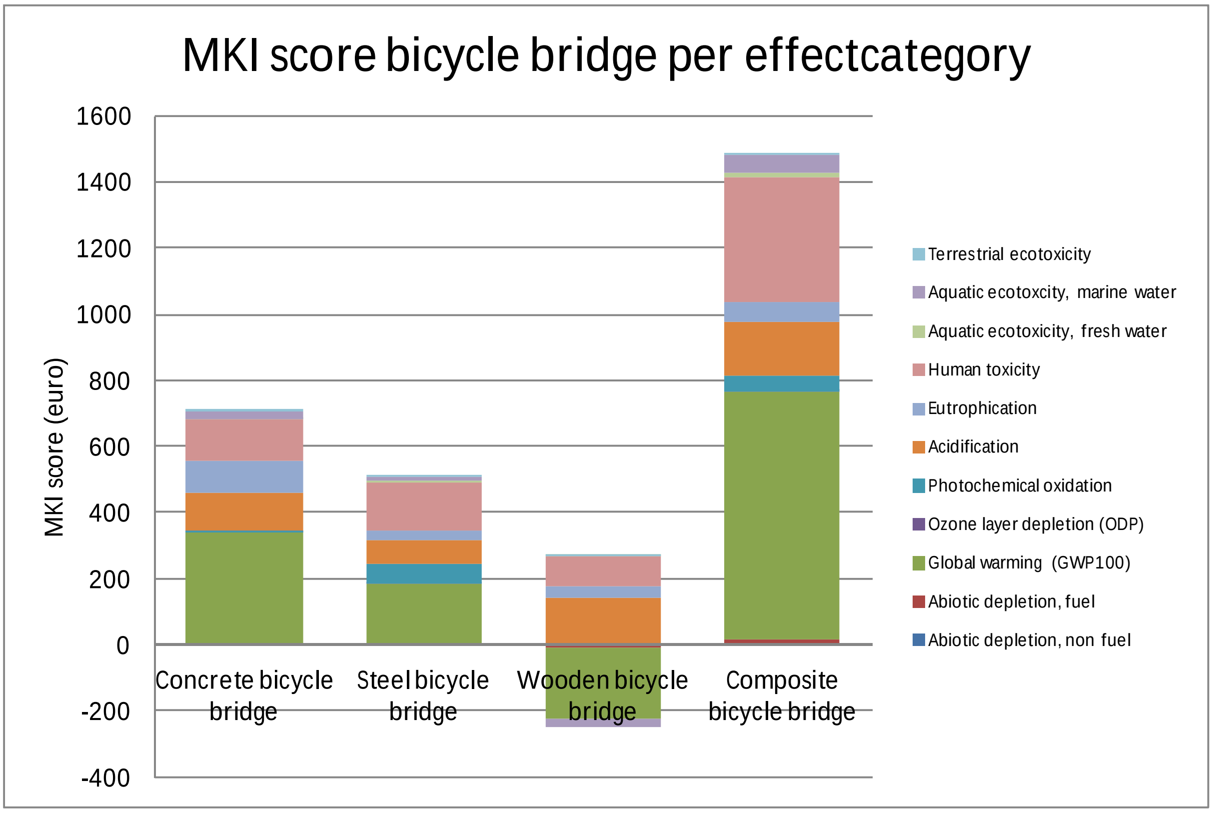
To determine the environmental impact the "*SBK-Bepalingsmethode Milieuprestatie Gebouwen en GWW-werken*" (in short *SBK-Bepalingsmethode*) was used. This stands for SBK-Determination Method Environmental Buildings and civil engineering works. The basis for this *SBK-Bepalingsmethode* is the Dutch norm NEN 8006 and ISO 14040/44. The NEN 8006 was developed at the product level, the *SBK-Bepalingsmethode* added additional agreements on building and building level. The results of the calculation is expressed as a onepointscore, the MilieuKostenIndicator (MKI, Environmental Costs Indicator). For this MKI score several environmental effects are weighted and added up using 'shadow

cost pricing'. The ISO 14044 protocol for LCA indicates than no weighting should be used in comparative LCA studies for external publication. Since the MKI score is so important and accepted in the construction / civil engineering industry it was still chosen to include in the results. At this point, however, the study therefore is not according ISO 14044.
Initially, the intention was to perform this analysis in the DuboCalc program, which is also based on the SBK-Bepalingsmethode and results in MKI scores. The data in the available DuboCalc program was however not sufficient to achieve the requested goals.
Wherever possible, data is used from the same source as DuboCalc: LCA data based on validated studies conducted according to the SBK-Bepalingsmetode and/or used in the Nationale Milieudatabase (Dutch National Environmental Database).

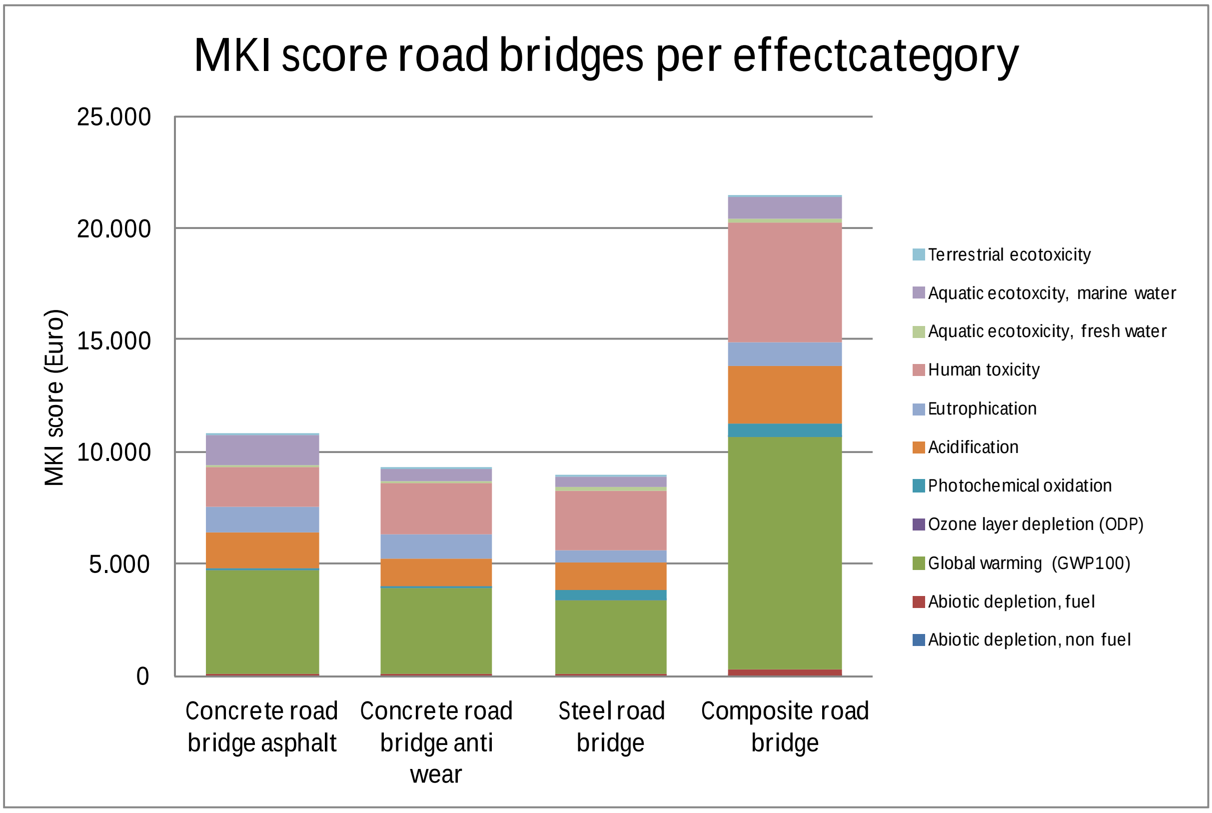
Parties involved
The cooperation of all the different sectors makes this a unique study. Of the steel, concrete and wood industry, representatives of industry associations were involved (Bouwen met Staal, BFBN, VVNH). Of the composite industry no representative from an industry association was involved. As an imporant player in this industry producer Fiber Core participated on behalf of the composite sector
For this project, an advisory committee was formed with representatives from NL Agency, Rijkswaterstaat, BAM Infra Consult and NIBE. The study was conducted by Beco. The LCA study was reviewed by IVAM.

Approach and development project
The project was launched in September 2011. An important first step in the project was to establish non-bound material specifications for the selected bridges. This was a source of much discussion and it was therefore up to May 2012 before there was definitive agreement between the parties. Subsequently, the various sectors were invited to deliver bridge designs and data. In the following months, the analyzes by sector were presented to the industry representatives for monitoring and response. In September 2012, the results were merged into a draft final report. Based on the results, the composite sector indicated that they want to make further analysis of the data. Also NIBE and other sectors came with comments to improve the report. Thus several sensitivity analyzes was added. In March 2013, an external review of the LCA study was made by IVAM concluding that the study was performed following the requirements of the *SBK Bepalingsmethode*. In May 2013 a number of concerns and questions emerged about meeting the specifications of, in particular, the composite bridges. After double-check the final judgment of Rijkswaterstaat was that although there are differences between the bridges, they all are sufficiently similar and meet the specifications. In September 2013 the final report was completed.

Environmental impact bridges
The graphs below show all the results of all bridges, expressed in MKI score. Regarding the results it should be noted that norms and standards reflect the situation in a specific moment in time, both in the construction and civil engineering sector in LCA methodology and LCA data. The results give an accurate image of the reality but developments in these areas can lead to considerable differences in environmental impact. It is for this reason important that sectors should directly orchestrate the values in databases of their materials and (semi-) finished products.



The environmental impact expressed in MKI score of the bicycle bridges varies greatly. The wooden bike bridge has a very low MKI score. The MKI scores of concrete bicycle bridge is slightly higher than that of the steel cycle bridge and about half of the MKI score of the composite bridge.



The results of the road bridges are largely similar to the bicycle bridges: The MKI score of the steel and concrete bridges are similar and the MKI score of the composite bridge is about double this score.
The conclusions are sensitive to a number of issues such as design specifications, materials (cement type used), frequency of maintenance, service life and disposal (in composite cement kiln). Together, these have a significant impact on the relationship in MKI score. The conclusions have not been found sensitive to the number of foundation piles.

Conclusions by bridge type
The production of the materials is the most dominant phases in the life cycle of concrete bridges. The use of cement with slag (CEMIII) which is included in this study, results in a 20% lower environmental impact than using 'new' cement (CEMI). The environmental impact of a bridge with an anti wear surface is slightly lower than a bridge with asphalt surface. The environmental impact per kg of the anti wear surface can be lowered through the use of other materials, lowering the total environmental impact of the concrete bridge.

The environmental impact of the steel cycle bridge is mainly caused by the coating. This is because it needs to be reapplied every 25 years. Also in the steel road bridge, the application of coating has a large impact as well the application and replacement of the anti wear layer. The reduction of the use of coating - without damaging the structure -seems to be the most important possibility to decrease the environmental impact.

The environmental impact of the wooden bicycle bridge is largely determined by the timber, in particular the transport from the forest and shipment to the Netherlands. The burning of the wood in an incinerator (AVI) at the end of life, provides energy and thus a significant positive environmental impact. This is not a recommendation to burn as much timber as possible The timber must be sustainably produced to prevent depletion and degradation of ecosystems

The biggest environmental impact of composite bridges comes from the production of materials: glass, resin and polyurethane foam. The relatively high MKI score of these materials per kg in this study is not offset by a much lower weight. A design according to 'material specific' specifications seems to lead to a reduction in the weight and thus the environmental impact by approximately 17%. Combustion in a cement kiln instead of in a waste incineration could reduce the environmental impact by 18-20%. The environmental impact per kg can be lowered through the use of other materials.

General conclusions
All parties have positively and constructively contributed to achieving the end result.The execution of this project, and in particular the formulation of functional and technical specifications of the bridges, took much more time than anticipated. It proved difficult to find common ground as almost every specification had a direct impact on the performance and thus the environmental impact. A 'normal' requirement for a bridge from one material means a 'heavy' requirement for a bridge from the other material and vice versa.
In general, therefore, it is recommended that when designing bridges one should look very critical at the specifications. Attention has to be paid to the difficulty of developing genuine 'material free' specifications. If bridges of different materials are compared for the same application, it is recommended that the technical team has sufficient knowledge to make an adequate comparison.

For execution of similar projects we recommend to strengthen the team of LCA experts with an independent team of experts in the technical field. This team is responsible for the preparation of (material free) specifications and testing the specifications of the submitted designs. Preferably this is done before the LCA study itself starts.
The analysis was not performed with the DuboCalc program because the program did not contain sufficient relevant data. This is then immediately the main suggestion for the improvement of this program.