

# Development of a sustainability assessment system for steel and composite bridges

**Tabea Beck\*, Matthias Fischer**

<sup>1</sup>University of Stuttgart, Chair for Building Physics, Department Life Cycle Engineering,  
70771 Leinfelden-Echterdingen, Germany

\*tabea.beck@lbp.uni-stuttgart.de

**Abstract** In bridge construction, despite a new regulation allowing for the consideration of sustainability related aspects, currently mainly cost aspects are taken into account in assignment practice. This is due to the fact that there is a lack of quantifiable sustainability criteria, which can be included into tendering procedures for bridges. To develop such quantitative criteria, regarding the aspects of ecological quality, economical quality and functional quality, an interdisciplinary project, including civil engineers, LCA specialists, economists, and specialists from the German Federal Highway Research Institute has been launched by the FOSTA, the German Research Foundation for Steel Applications. To develop reference values for economic and ecological criteria, the life cycles of three representative bridge types are analyzed and assessed using the methods of LCA (Life Cycle Assessment) and LCC (Life Cycle Costing) within the same system boundaries. Data acquisition for the use / maintenance phase of the bridges is supported by analyzing and interpreting data bases of the German Federal Highway Research Institute. External costs and ecological effects of bridge construction and maintenance, being used to take into consideration the functional quality of the bridges, are accounted for separately. Using the results of these studies, which are currently being conducted, an applicable sustainability index for bridges is developed. Methodological approaches for this are being generated.

## 1 Introduction

Within the construction sector, the topic of sustainability assessment rapidly gains importance. Starting from there, appropriate solutions are searched for also for infrastructure. Adaptations have to be made of course e.g. regarding the aspects addressed in the use phase, and regarding the lifetime: bridges are supposed to last for approximately twice as long as buildings. Therefore, durability of components is quite an important aspect. In today's ordering procedure in bridge construction,

however, mostly lowest initial costs offers are successful. Life cycle thinking and sustainability aspects are not considered due to a lack of respective guidelines. This is the starting point for the NaBrue project, aiming at the development of a sustainability assessment system for steel and composite bridges. Using this system, in addition to initial costs, life cycle costs, socio-cultural/functional and environmental aspects can be taken into consideration when contracting out, thus leading to a more sustainable allocation of public funding.

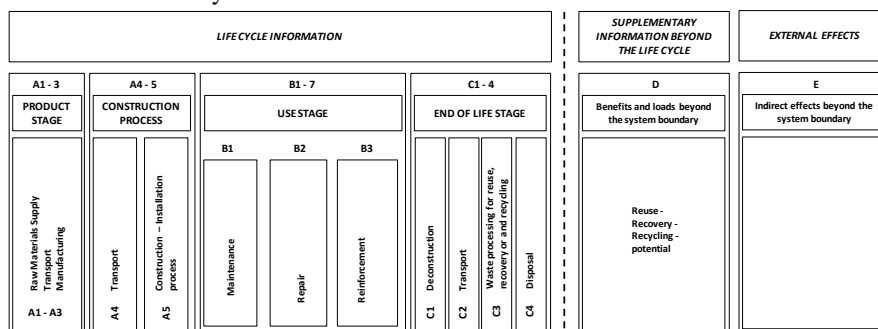
## **2 Qualities regarded and methods used**

Following the "three pillars of sustainability" concept, within the sustainability assessment system, the ecological quality, the economic quality and the social and functional quality of the bridges are assessed. The assessment of the ecological quality is based on Life Cycle Assessment. Criteria have been chosen in accordance with current standardization and LCA practice: Within the assessment system, the indicators addressing the ecological quality will be Global Warming Potential, Ozone Depletion Potential, Acidification Potential, Eutrophication Potential and Photochemical Ozone Creation Potential [2]. The economic quality will be addressed using a Life Cycle Costing (LCC) Analysis within the same system boundaries as the LCA. For social and functional quality, currently the main approach is to perform an assessment of external costs of the bridge life cycle, thus accounting for the costs the society has to pay for as the main social impacts of a bridge. In addition, "external" environmental impacts will be calculated in line with these external costs.

## **3 Choice of reference bridges, system boundaries, data availability and LCI modelling**

To develop the sustainability assessment system, a set of representative reference bridges, representing market relevant options for current steel construction has been chosen: Type A bridges pass over a motorway with a width of about 45 m, type B bridges are multiple span girder bridges of mean spans, that are investigated with regard to open and closed cross-sections and type C bridges are big viaducts; here, the use of high web plates is investigated. Data necessary for the LCA are derived from building documentations and bid documents. The system boundaries are set in line with FprEN15978, a European standard currently developed, which deals with the sustainability assessment of buildings [1].

According to this standard, the production stage of a building has to be included, considering Raw Material Supply (module A1), Transport of raw materials to manufacturing (module A2) and Manufacturing (module A3). For modules A1-A3, LCA data sets from the German ökobau.dat are used. Whereas in most other building LCAs, currently the modules A4 Transport to construction site and A5 Construction - Installation process are not regarded, it was decided to include them into the NaBrue analyses. One reason for this is that in bridge construction, the operation phase, playing an important part in building LCAs, is less important, and therefore the relative importance of the construction stage increases. Respective LCA data for the construction process are compiled in cooperation between LCA experts and bridge engineers. For the use stage (modules B1-B7), adaptations of FprEN 15978 had to be made, as for bridges, operational energy and water use do not matter. Furthermore, the modules Use, Maintenance, Repair, Replacement and Refurbishment (modules B1 and B5 in FprEN 15978) were converted to Maintenance (module B1), Repair (module B2) and Reinforcement (module B3). LCA data for the use stage is derived from a bridge management database hosted by the German Federal Highway Research Institute. For the end-of-life stage, same as for the construction process, LCA data for modules C1 to C4 is developed by LCA experts and bridge engineers. Following the requirements of FprEN 15978, the Benefits and loads beyond the system boundary, including the Reuse, Recovery and Recycling potential, is accounted for separately in module D, thus taking account of the fact that these benefits do not take place within the actual life cycle of the building. Within NaBrue, in addition to the modules mentioned, a further module (module E) was implemented including environmental impacts of indirect effects beyond the system boundary: Within this assessment, environmental impacts of the activities causing indirect costs, such as bridge construction and repair, are accounted for in line with the economic assessment, and reported separately. The LCI modelling and is conducted using the LCA software system GaBi 4.



**Fig.1: Aspects to be included into the sustainability assessment of bridges (based on FprEN15978)**

## 4 Summary and Conclusion

Regarding the Life Cycle Assessment, NaBrue has a pioneering role by developing data for transport and construction processes and by including them into the LCA. Results will show the bias of not regarding these life cycle stages, which is currently state-of-the art in LCAs of buildings, compared to the effort needed to compile this data. The NaBrue project as a whole clearly improves the situation for decision making in bridge construction by providing a first sustainability assessment system for bridges, thus contributing to more sustainable ordering procedure practices and management of public funds.

## 5 Project consortium and funding

The IGF-Proposal "AIF IGF 353ZN/3 NaBrue" of the "Forschungsvereinigung Stahlanwendung e.V. (FOSTA)" is a sub-project of the research cluster "Sustainability of steel in construction" (NASTA) and is funded via the AiF within the scope of the "Program for the promotion of industrial cooperational research" (IGF) by the German Federal Ministry of Economics and Technology according to a resolution of the German Bundestag.

Members of the consortium are Prof. Dr.-Ing. Dipl. Phys. Klaus Sedlbauer, Chair for Building Physics, Prof. Dr.-Ing. Ulrike Kuhlmann and Dipl.-Ing. Philippa Maier, Institute of Structural Design, University of Stuttgart; Univ.-Prof. Martin Mensinger and Dipl.-Ing. Marjolaine Pfaffinger, Chair for Metal Construction, Technical University of Munich; Prof. Dr.-Ing. Thomas Ummenhöfer and Dipl.-Ing. Dipl.-Wirtsch.-Ing. Tim Zinke, Steel & Lightweight Structures Research Center for Steel, Timber & Masonry, Karlsruhe Institute for Technology and Dr.-Ing Jürgen Krieger and Dipl.-Ing. H. Friedrich, German Federal Highway Research Institute, Bergisch-Gladbach.

## 6 References

- [1] FprEN 15978: 2011: Sustainability of construction works — Assessment of environmental performance of buildings — Calculation method. European Committee for Standardization CEN.
- [2] Guinée et al. (2001): Handbook on Life-Cycle Assessment - Operational Guide to the ISO standards. Centre of Environmental Science, Leiden University (CML), The Netherlands, 2001.